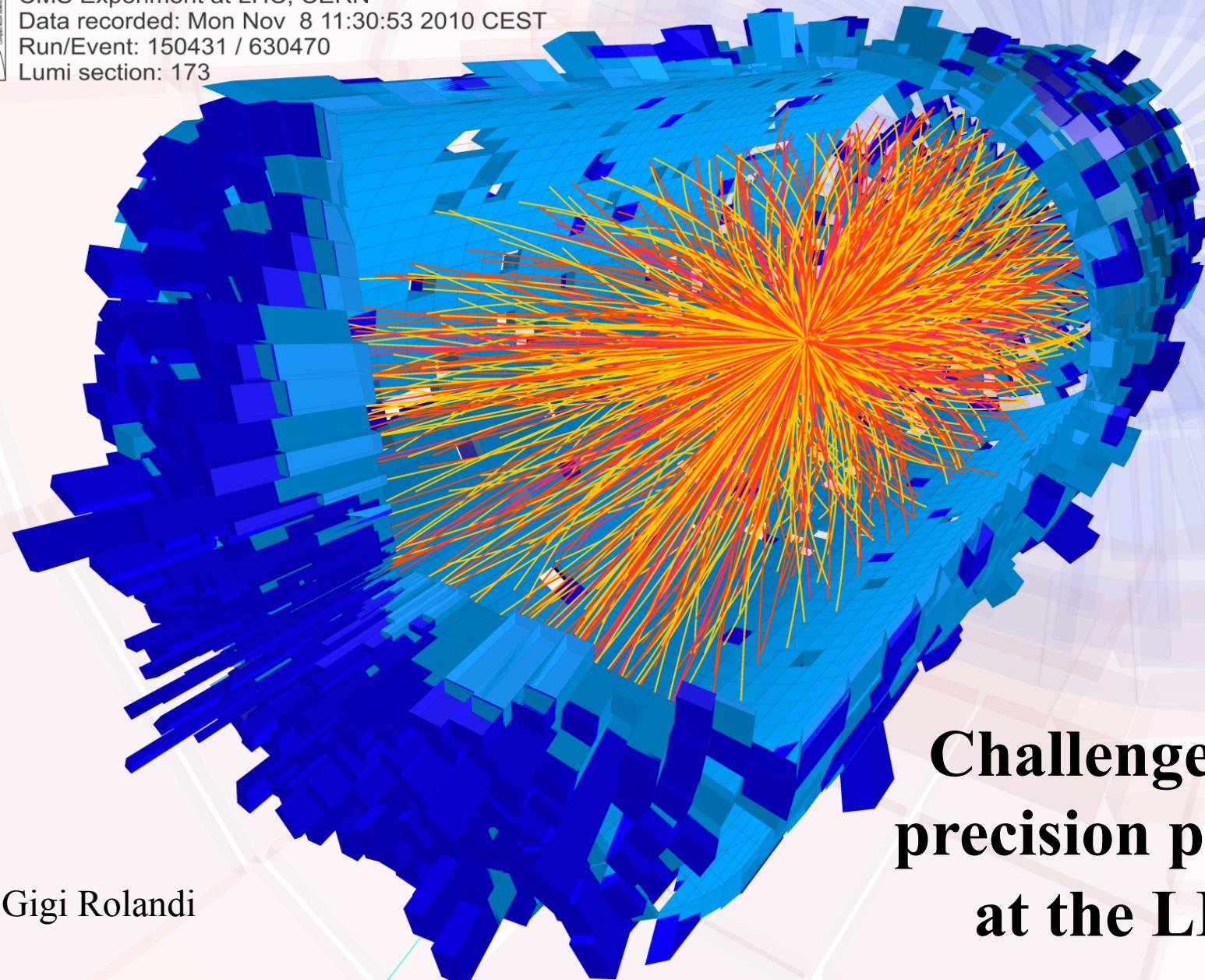


# STATUS AND PERSPECTIVES OF CMS



CMS Experiment at LHC, CERN  
Data recorded: Mon Nov 8 11:30:53 2010 CEST  
Run/Event: 150431 / 630470  
Lumi section: 173

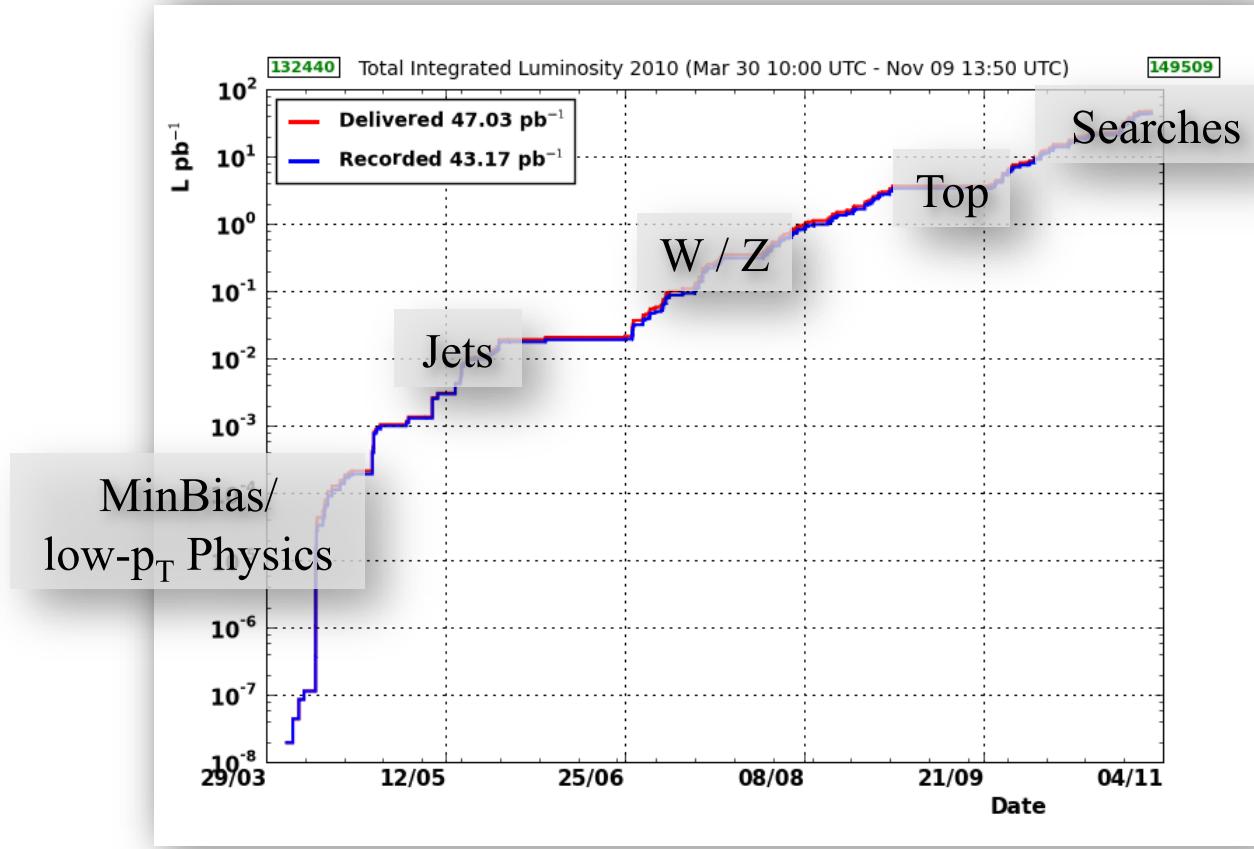


**Challenges for  
precision physics  
at the LHC**

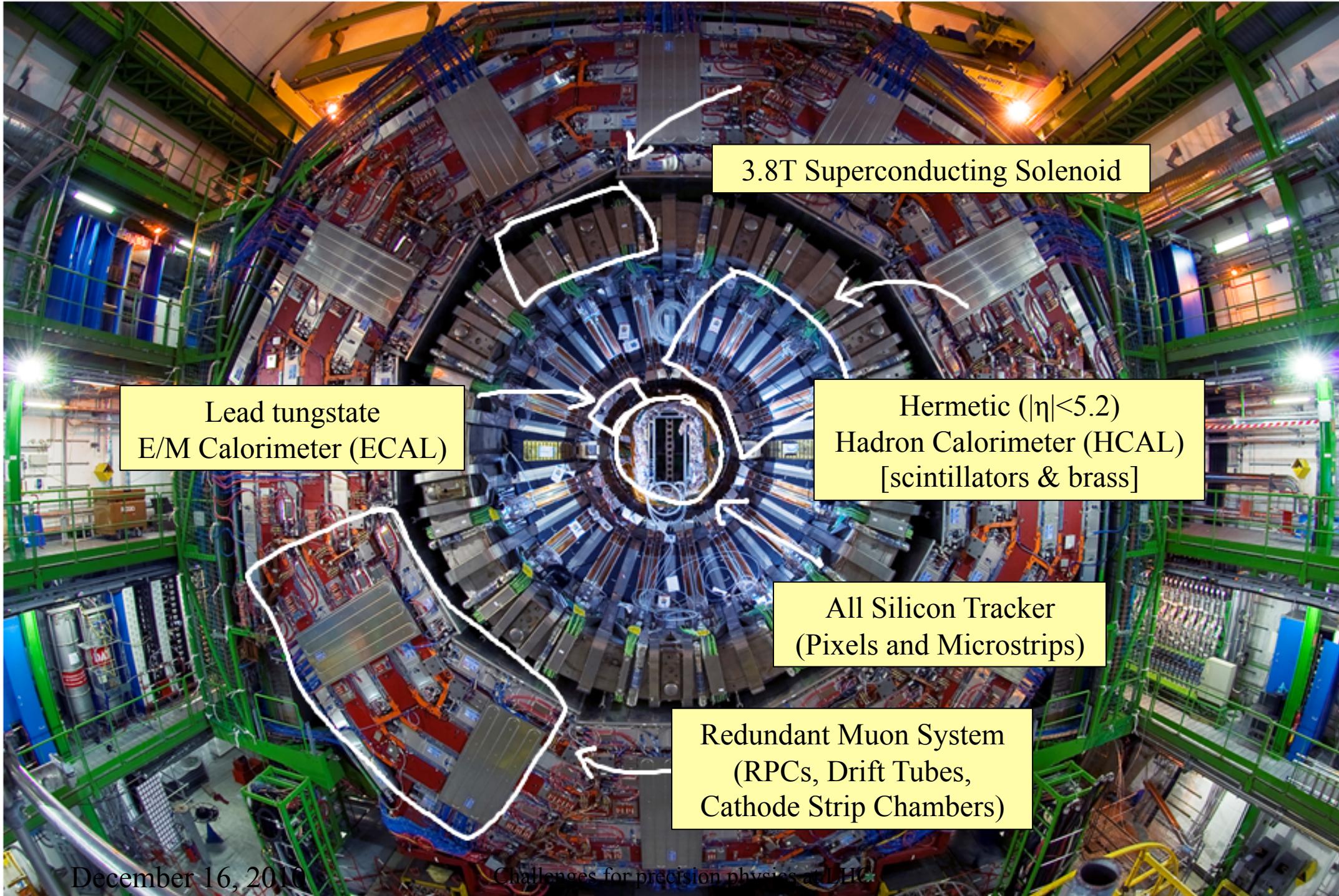
Gigi Rolandi



# Integrated Luminosity since 30 March 2010

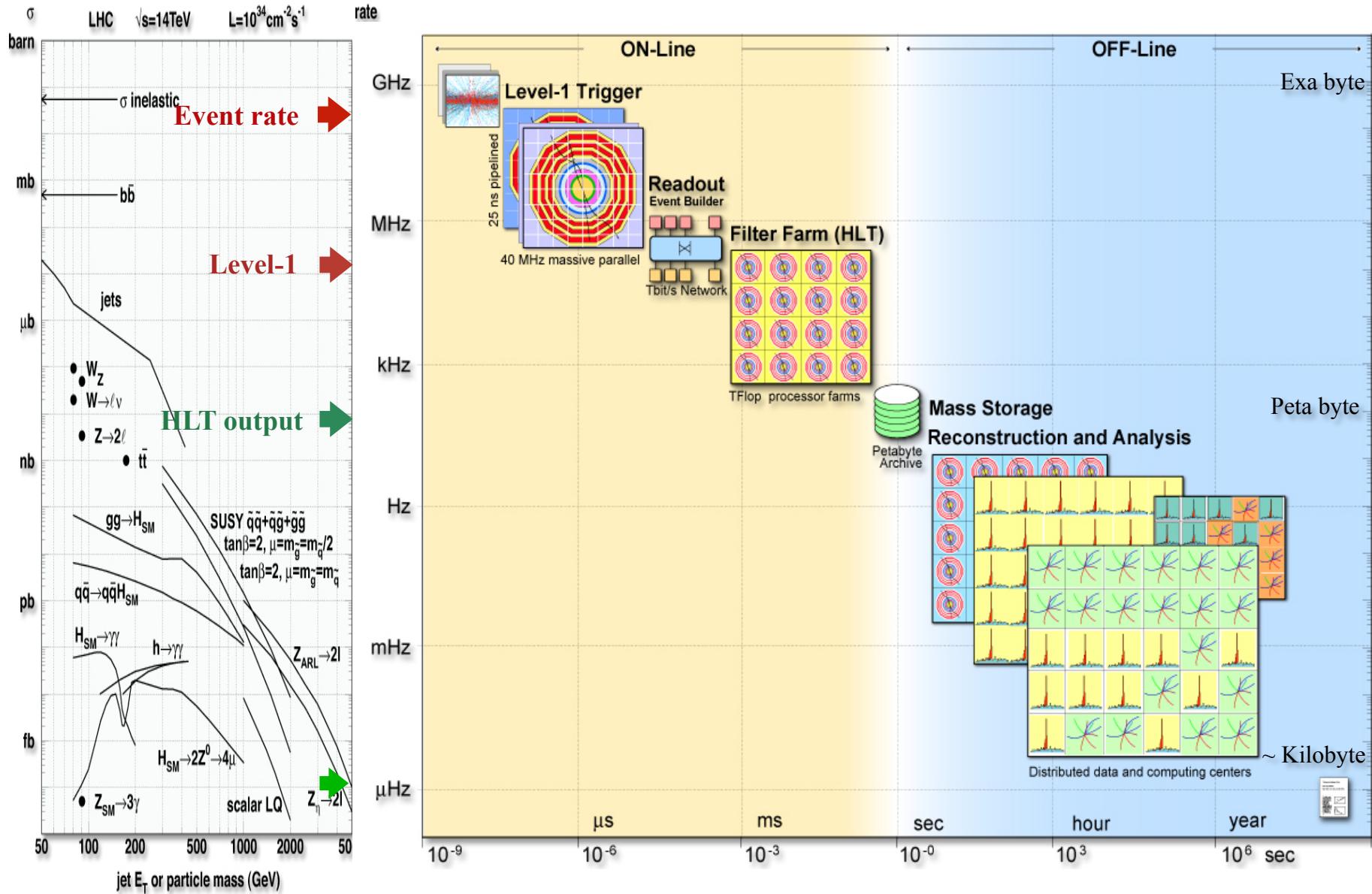


Reliable operations with  $47 \text{ pb}^{-1}$  delivered by LHC  
CMS recorded  $43 \text{ pb}^{-1}$ . Overall data taking efficiency **larger than 90%**  
Note: all subdetectors have **at least 98%** of all channels operational!





# DATA ACQUISITION

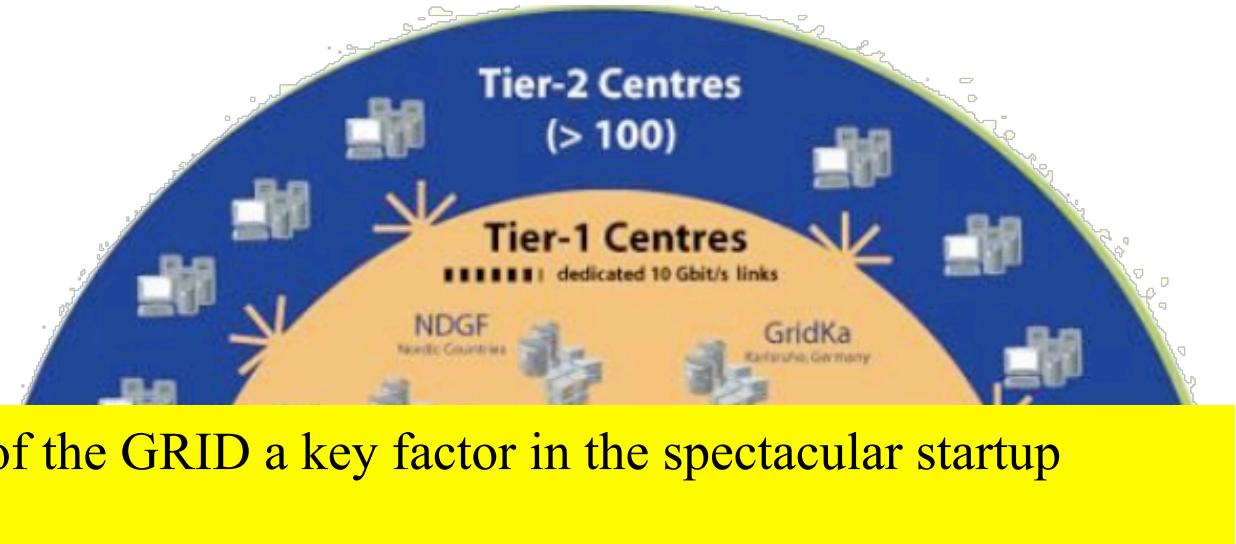




# Data Analysis all over the World

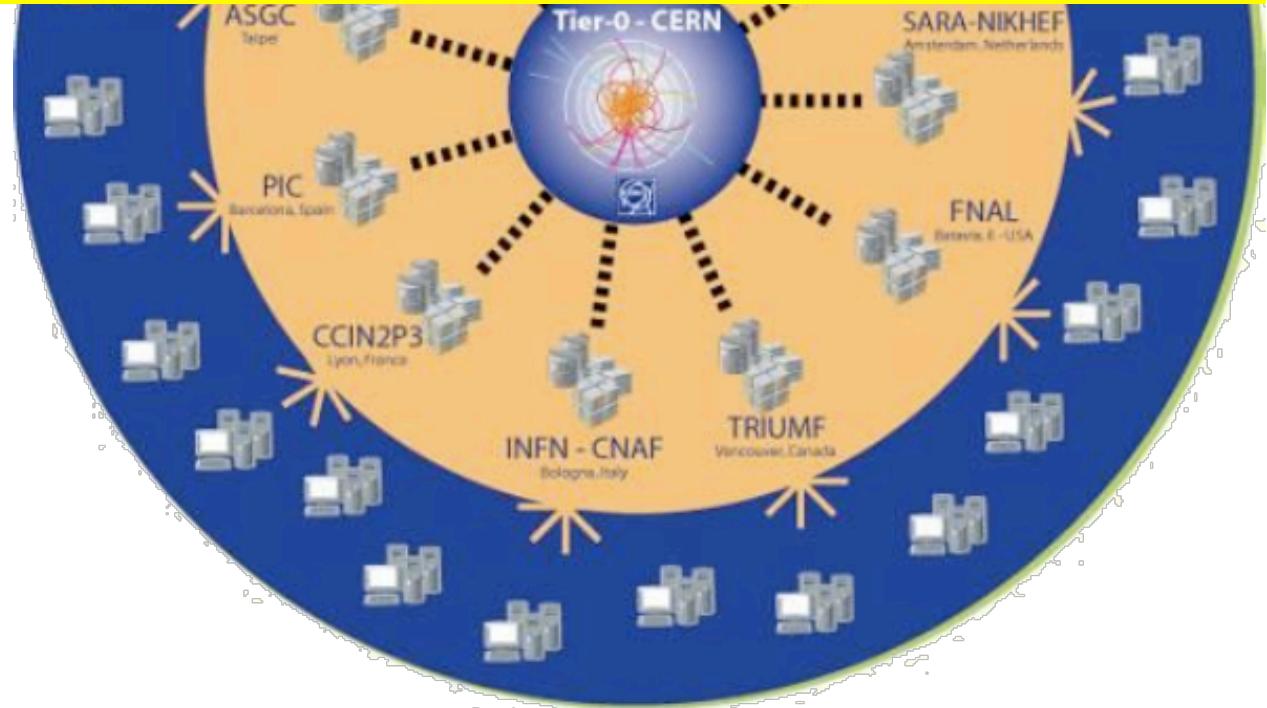
**T0 - T1:**

- dedicated 10 Gbit/s optical network



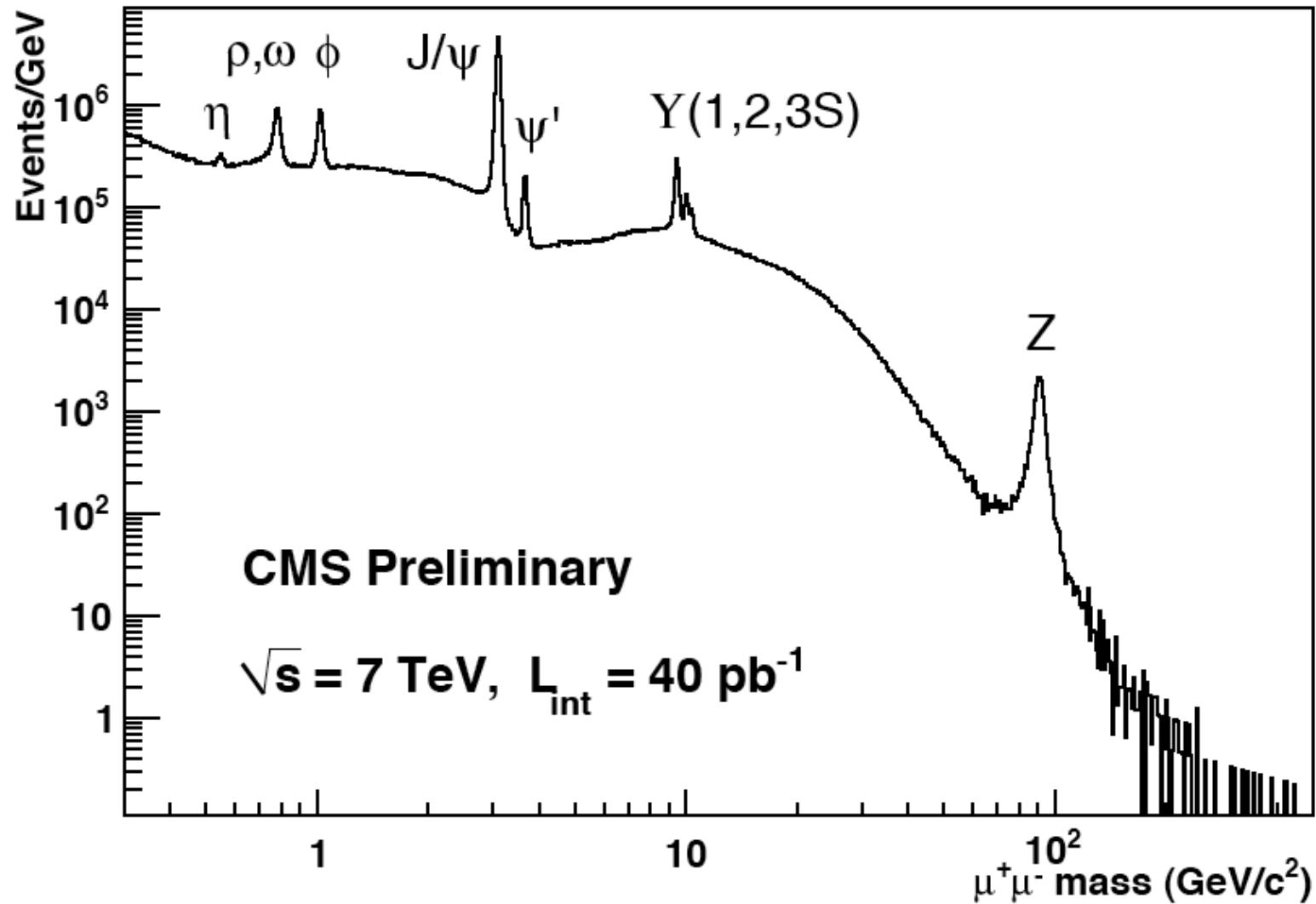
**Tier-2s and Tier-1s:**

- inter-connected by the general purpose research networks
- any Tier-2 center needs to access data at any Tier-1





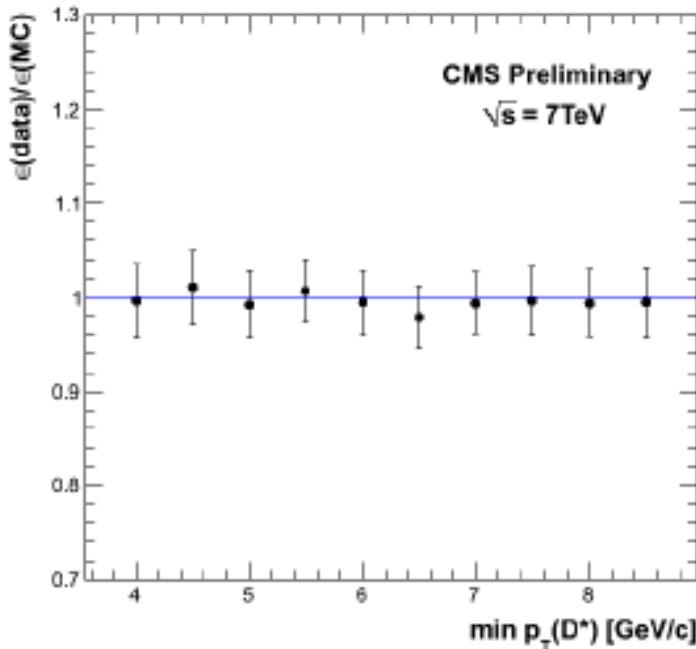
# Tracking and Muons



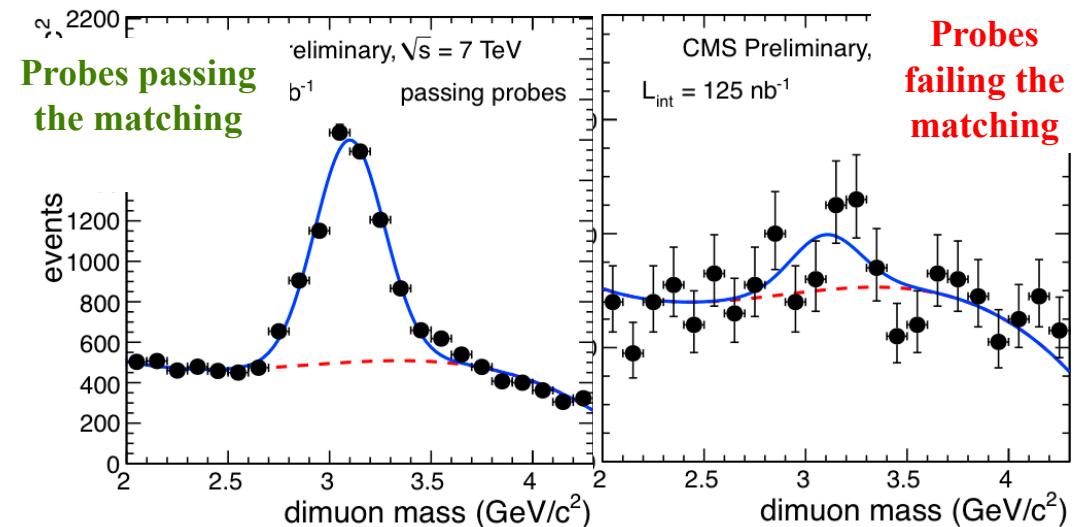


# Tracking Efficiency

$$\frac{D^0 \rightarrow K^- \pi^+ \pi^- \pi^+}{D^0 \rightarrow K^- \pi^+}$$



J/Psi Tag and probe



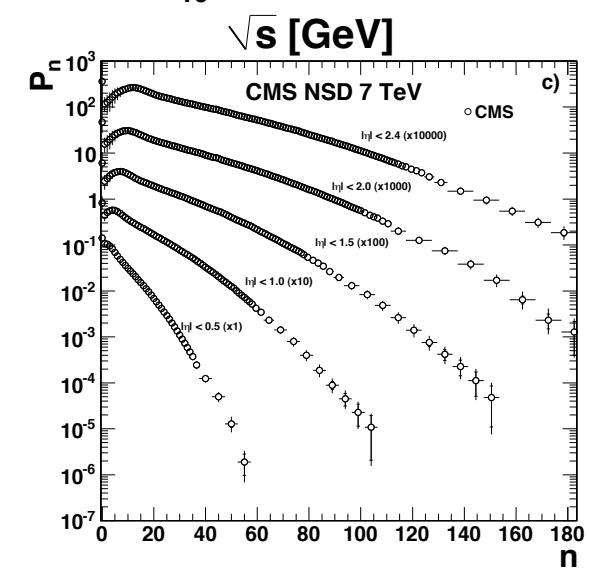
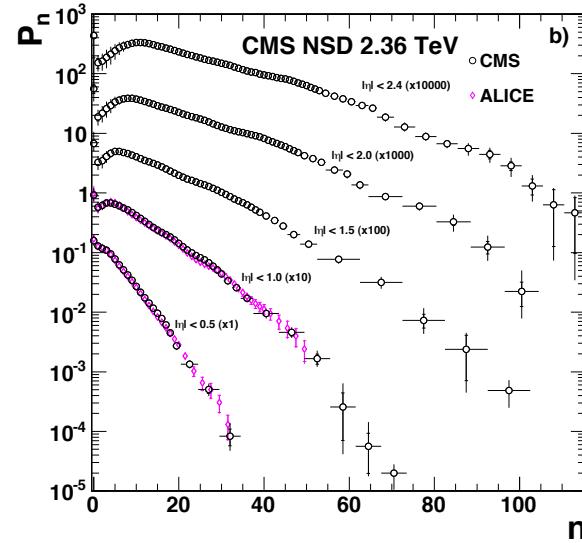
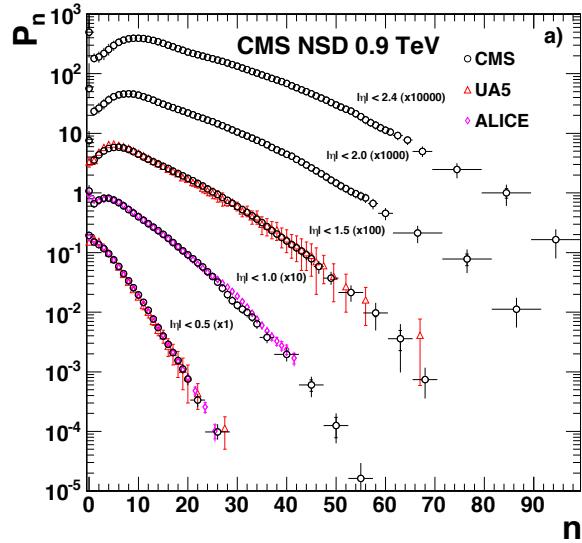
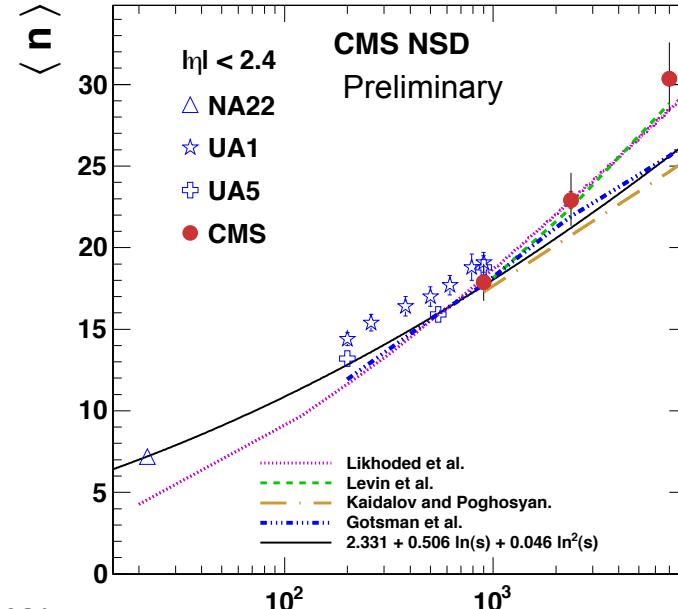
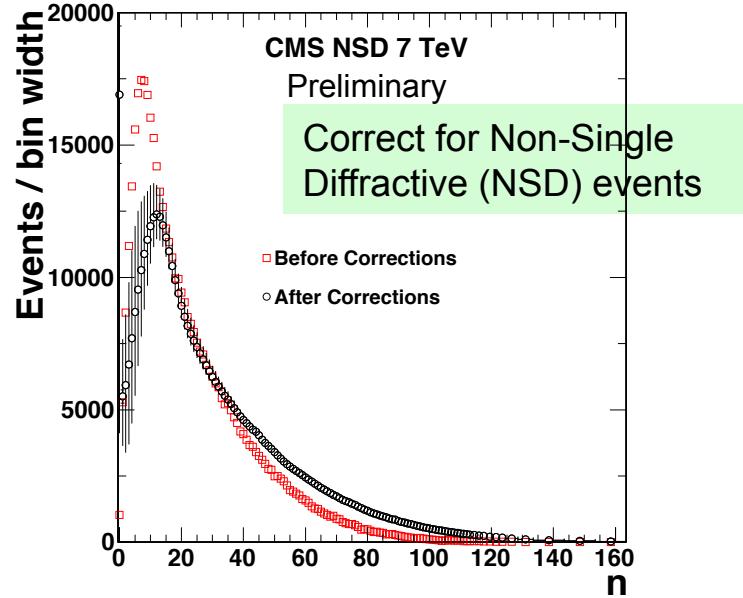
Probes failing the matching

Region	Data Eff. (%)	Sim Eff. (%)	Data/Sim
$0.0 \leq  \eta  < 1.1$	$100.0^{+0.0}_{-0.3}$	$100.0^{+0.0}_{-0.1}$	$1.000^{+0.001}_{-0.003}$
$1.1 \leq  \eta  < 1.6$	$99.2^{+0.8}_{-1.0}$	$99.8^{+0.1}_{-0.1}$	$0.994^{+0.009}_{-0.010}$
$1.6 \leq  \eta  < 2.1$	$97.6^{+0.9}_{-1.0}$	$99.3^{+0.1}_{-0.1}$	$0.983^{+0.009}_{-0.010}$
$2.1 \leq  \eta  < 2.4$	$98.5^{+1.5}_{-1.6}$	$97.6^{+0.2}_{-0.2}$	$1.010^{+0.015}_{-0.016}$
Combined	$98.8^{+0.5}_{-0.5}$	$99.2^{+0.1}_{-0.1}$	$0.996^{+0.005}_{-0.005}$



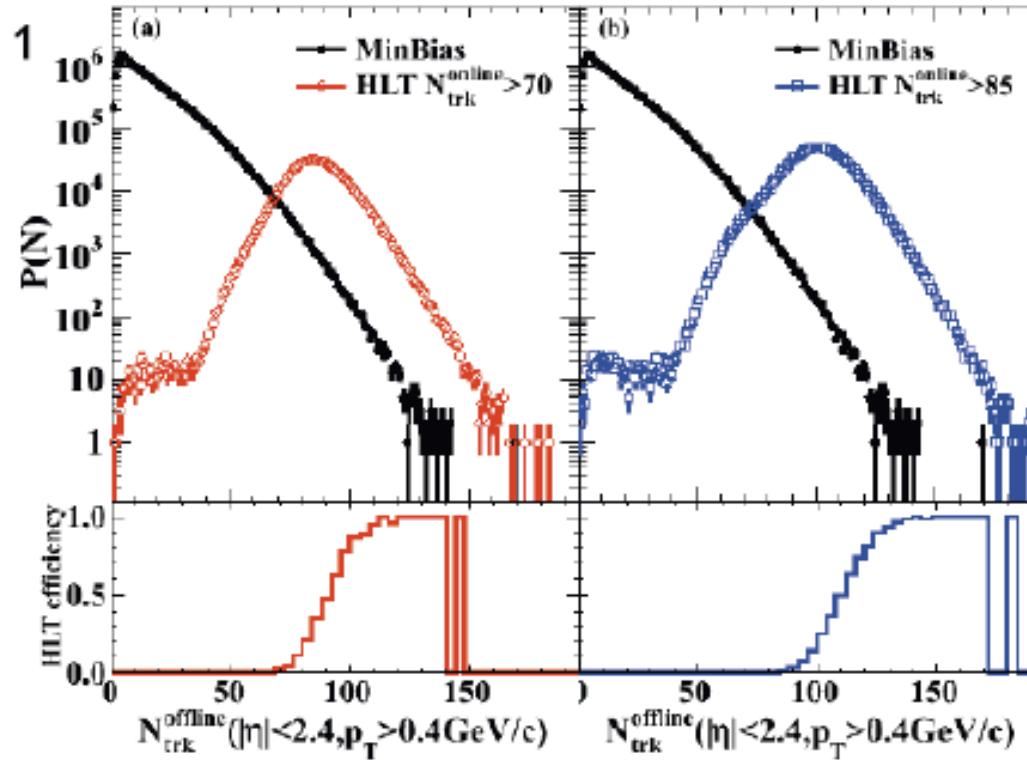
# Soft QCD: charged track multiplicities

arXiv 1011.5531





# Collecting High Multiplicity events



Multiplicity binning uses  
 $p_T > 0.4 \text{ GeV}/c$   
 $|\Delta\eta| < 2.4$

Two different HLT thresholds:  
 $N_{\text{online}} > 70$  and  $N_{\text{online}} > 85$

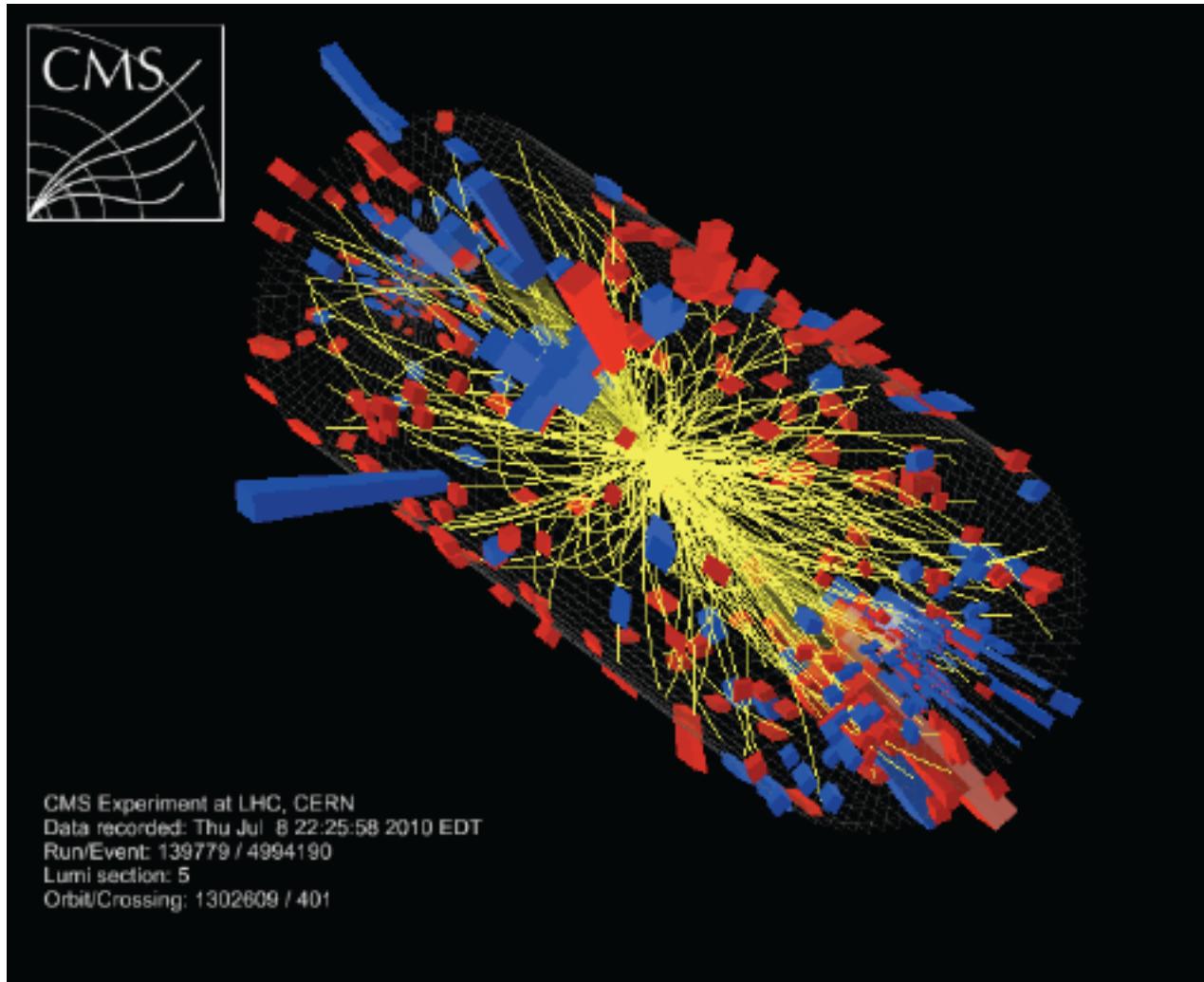
HLT85 trigger range un-prescaled  
for full  $980\text{nb}^{-1}$

Multiplicity bin ( $N_{\text{trk}}^{\text{offline}}$ )	Event Count	$\langle N_{\text{trk}}^{\text{offline}} \rangle$
MinBias	21.43M	15.9
$N_{\text{trk}}^{\text{offline}} < 35$	19.36M	13.0
$35 \leq N_{\text{trk}}^{\text{offline}} < 90$	2.02M	45.3
$90 \leq N_{\text{trk}}^{\text{offline}} < 110$	302.5k	96.6
$N_{\text{trk}}^{\text{offline}} \geq 110$	354.0k	117.8

out of  $5 \times 10^{10}$  collisions



# One High Multiplicity event



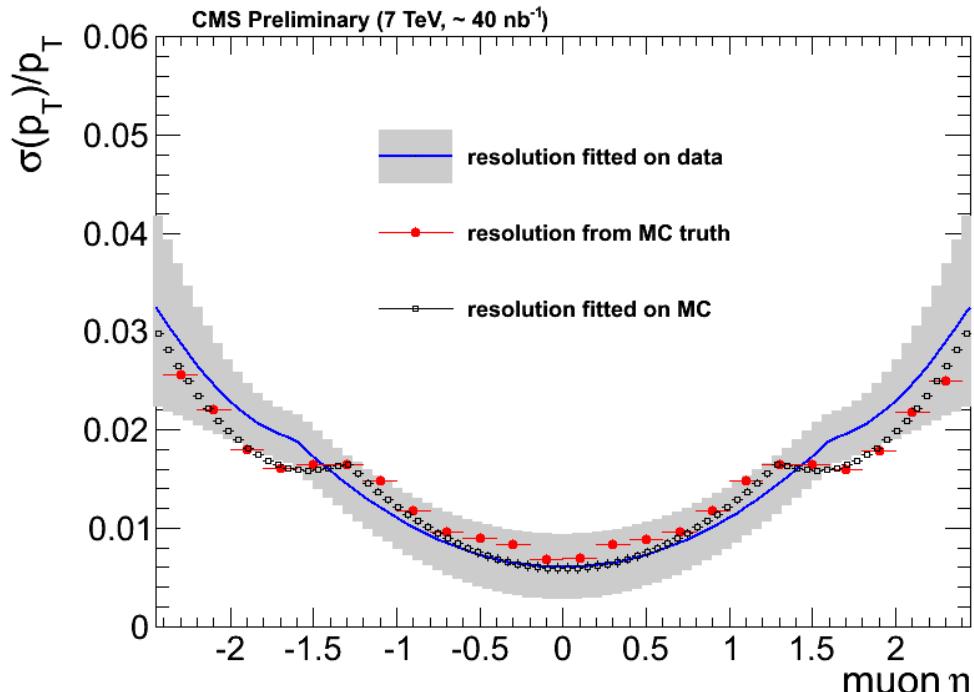
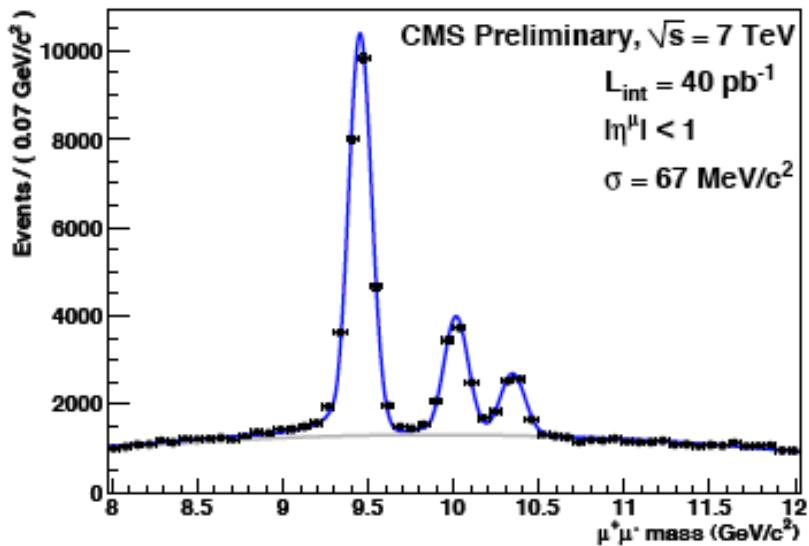
$N_{ch} \sim 260$



# Momentum Resolution

J/ $\Psi$  width expressed as a function of the kinematics of the 2 tracks.

The best estimate of the  $p_T$  resolution is then determined through an unbinned likelihood fit of data.

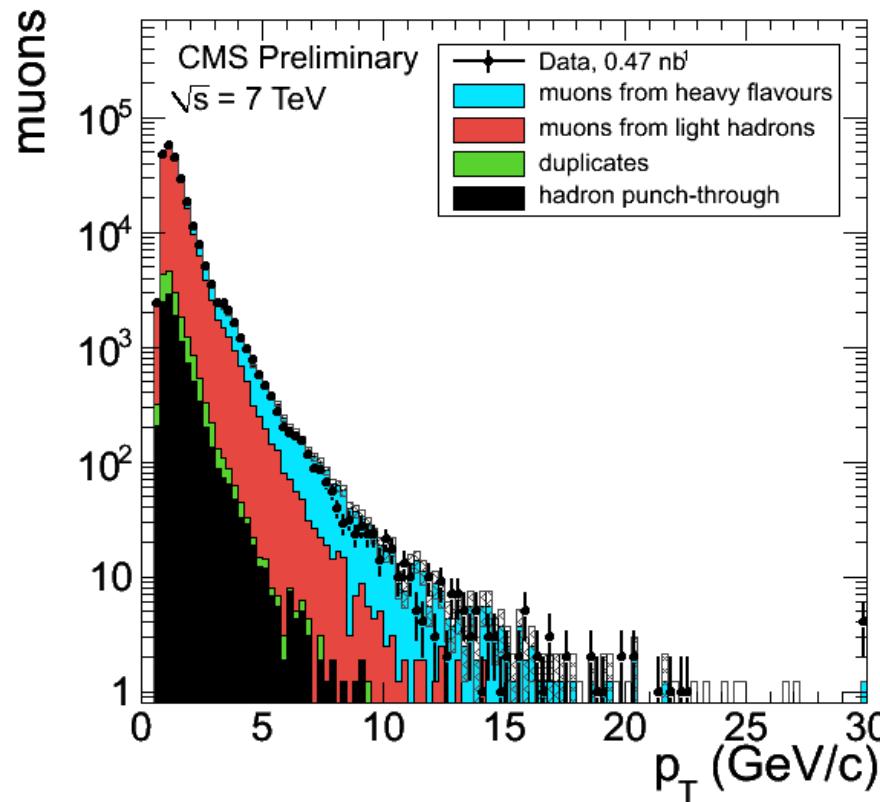


Alignment of the 15600 Silicon Modules

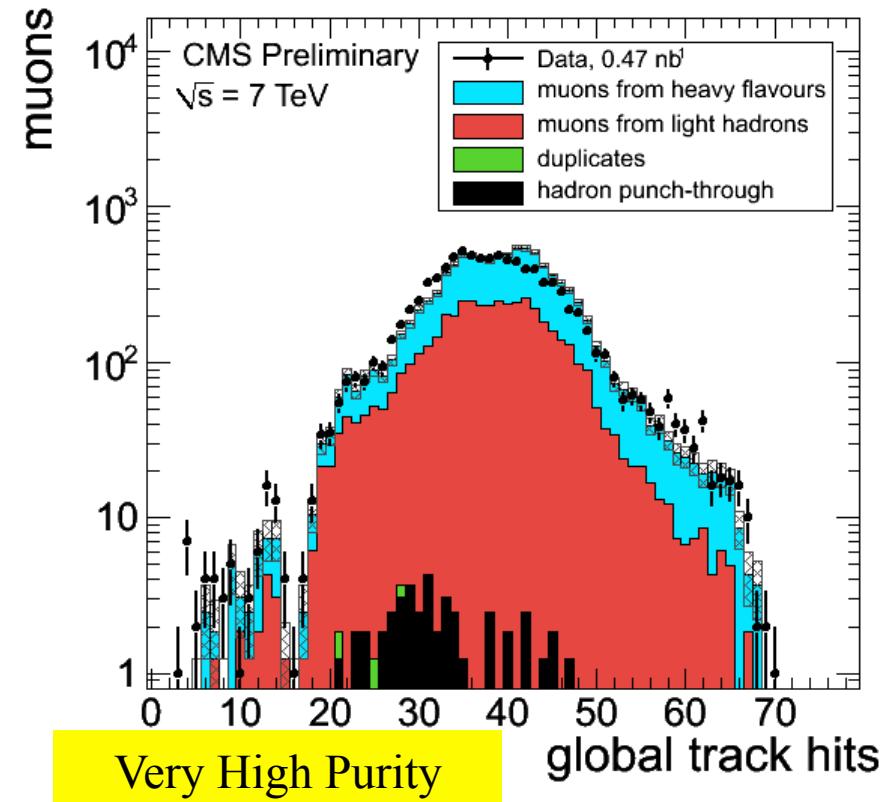


# Muon Detector Performance

“Soft muon”: a tracker track matched to at least one CSC or DT stub, to collect muons down to pT about 500 MeV in the endcaps (e.g. for J/ $\Psi$ )

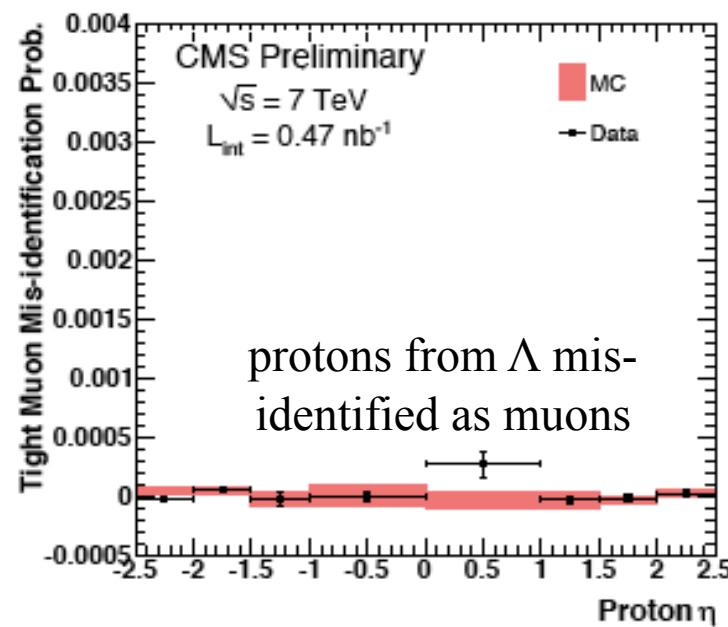
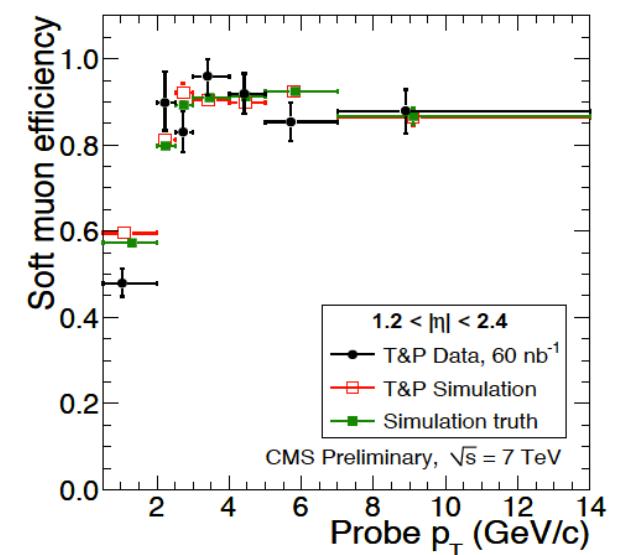
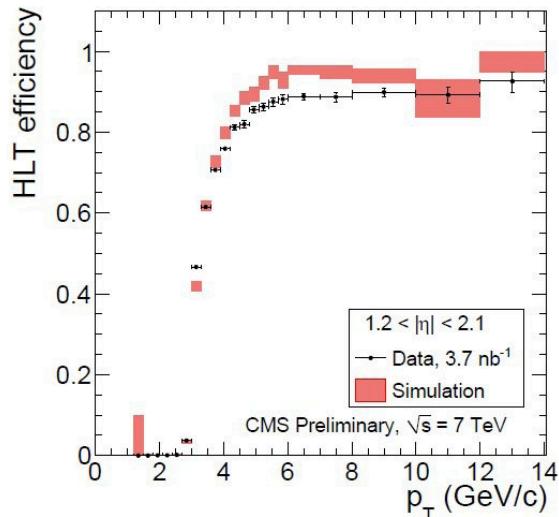
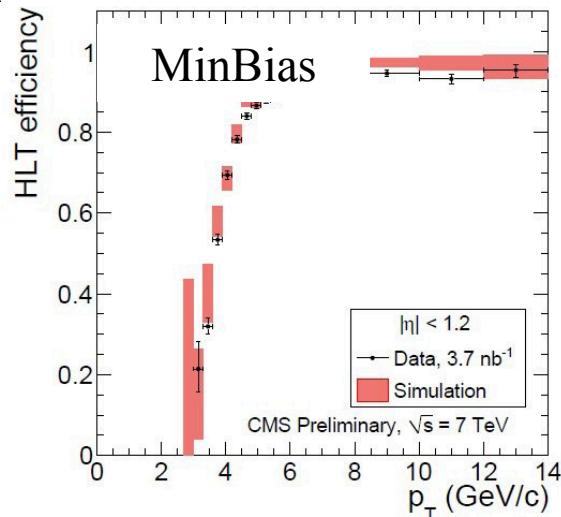


“Tight muon”: a good quality track from a combined fit of the hits in the tracker and muon system, requiring signal in at least two muon stations to improve purity.



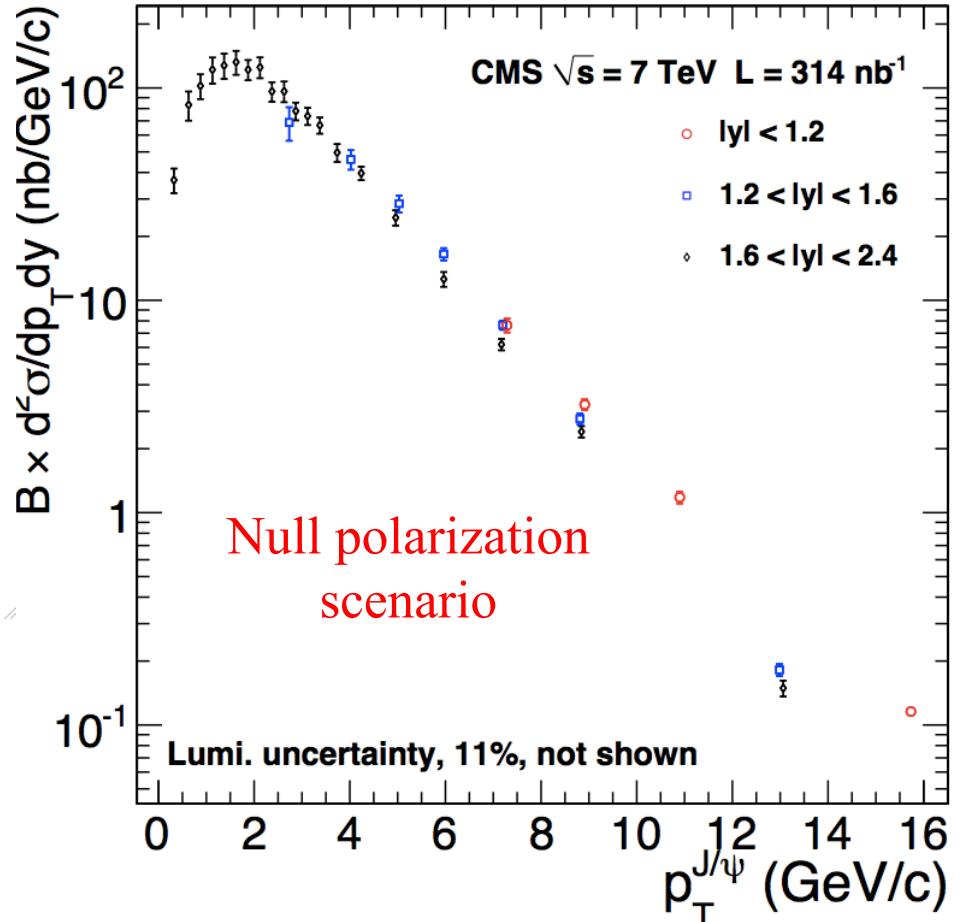
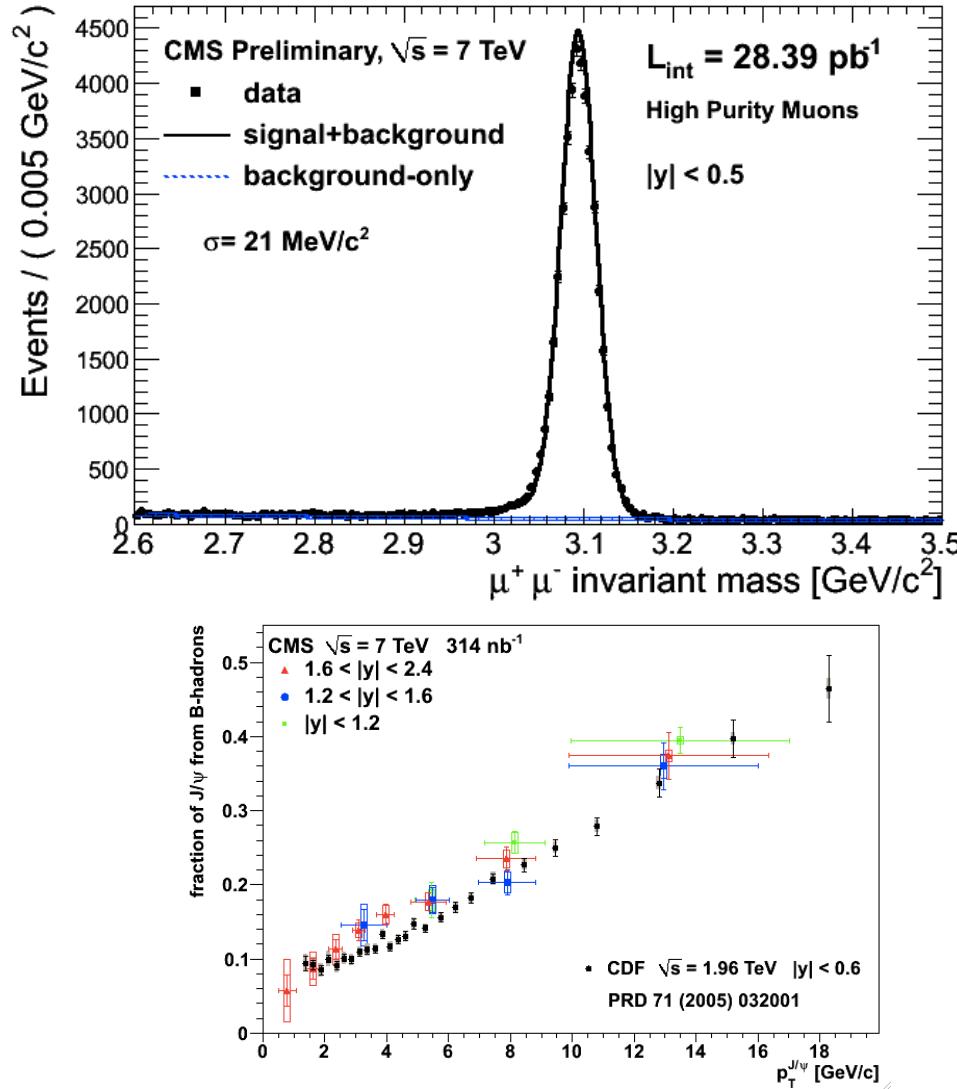


# Muon Performance





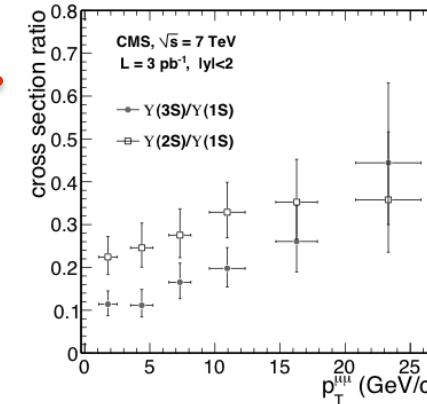
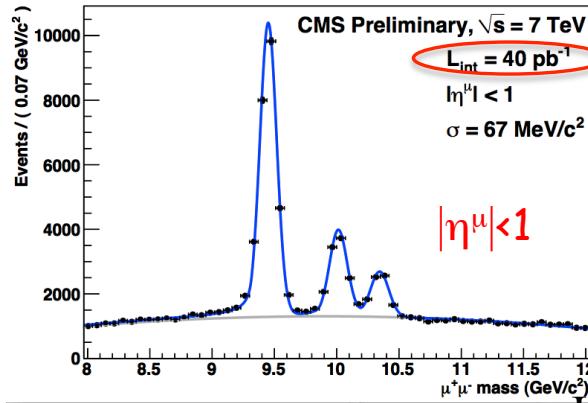
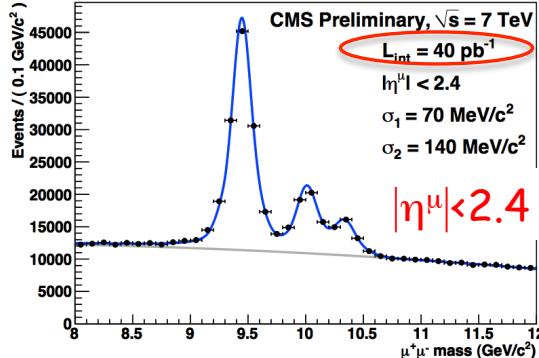
# J/ $\psi$ production cross sections



arXiv 1011.4193



# Y production



$\sigma$  Ratios  
 $|y^Y| < 2$

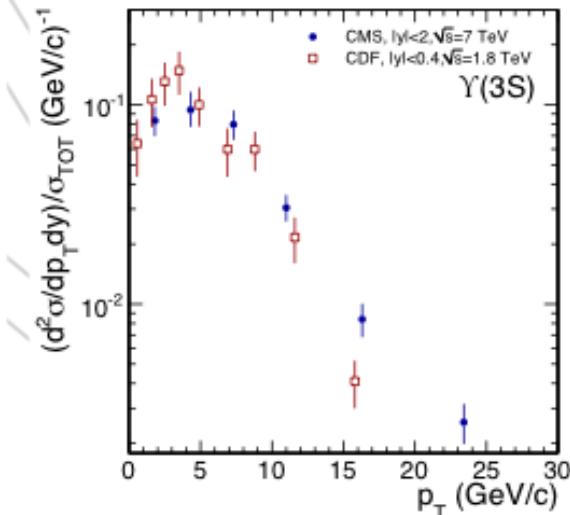
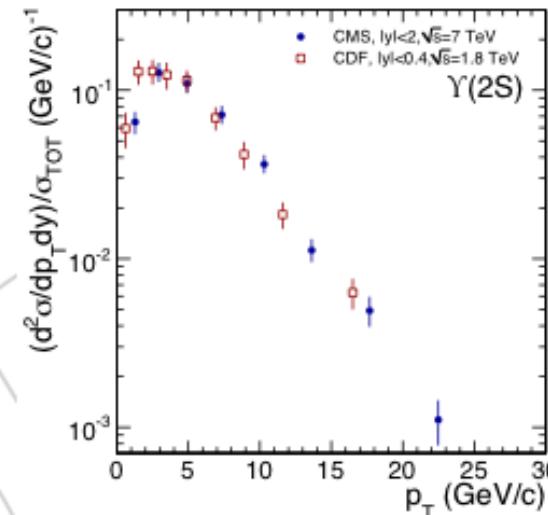
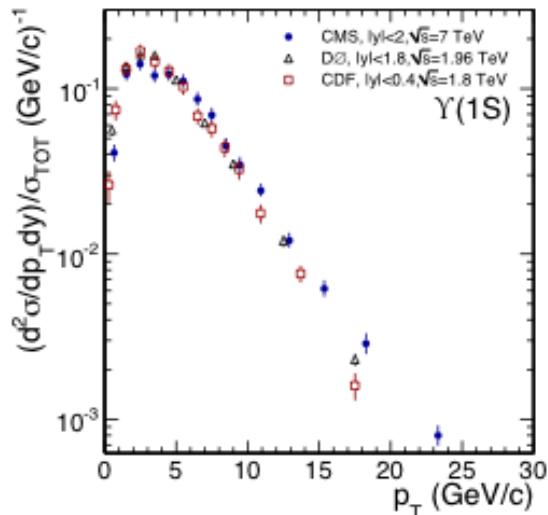
Unpolarized production assumption

$$\sigma(pp \rightarrow Y(1S)X \cdot \mathcal{B}(Y(1S) \rightarrow \mu^+\mu^-) = (7.49 \pm 0.13(\text{stat.})^{+0.67}_{-0.49}(\text{syst.}) \pm 0.82(\text{lumi.})) \text{ nb},$$

$$\sigma(pp \rightarrow Y(2S)X \cdot \mathcal{B}(Y(2S) \rightarrow \mu^+\mu^-) = (1.93 \pm 0.08(\text{stat.})^{+0.19}_{-0.14}(\text{syst.}) \pm 0.21(\text{lumi.})) \text{ nb},$$

$$\sigma(pp \rightarrow Y(3S)X \cdot \mathcal{B}(Y(3S) \rightarrow \mu^+\mu^-) = (1.04 \pm 0.07(\text{stat.})^{+0.12}_{-0.09}(\text{syst.}) \pm 0.11(\text{lumi.})) \text{ nb}.$$

CMS  
vs CDF  
& D0



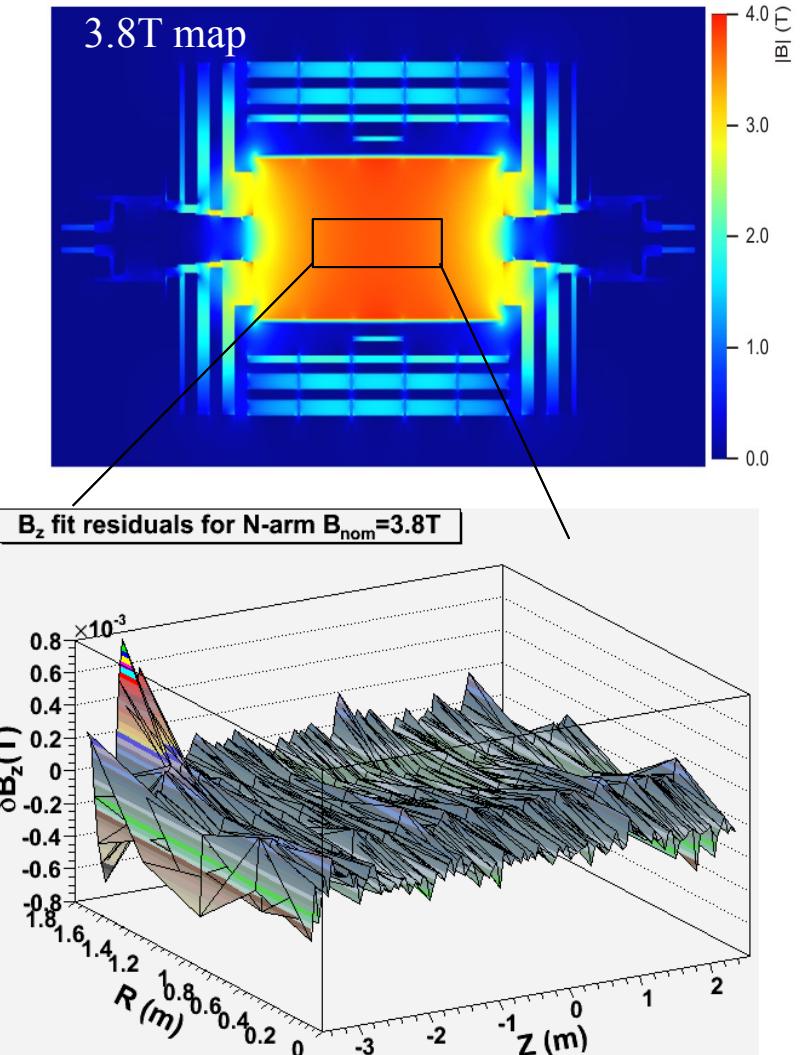


# Momentum Scale

- Measured by Field Mapper (at 2, 3, 3.5, 3.8, 4 T) in 2006 MTCC
- TOSCA field map agrees  $< 0.1\%$  →

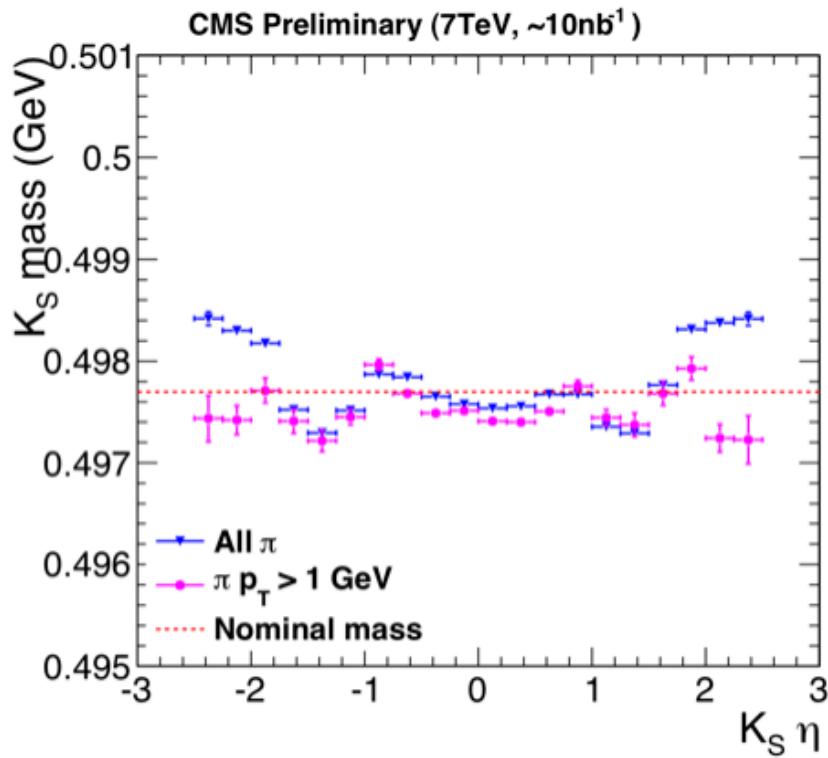
- analytical fit describes measurements to  $\sim 0.01\%$

NMR probes inside solenoid confirm agreement scale  $< 0.1\%$  between 2006 and 2008



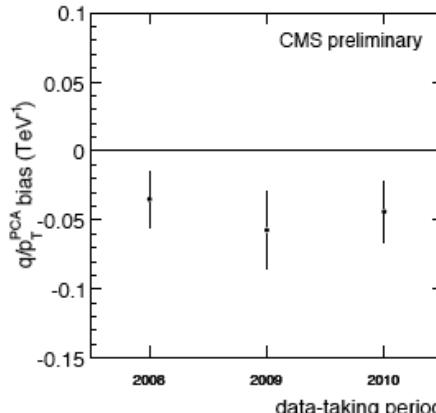
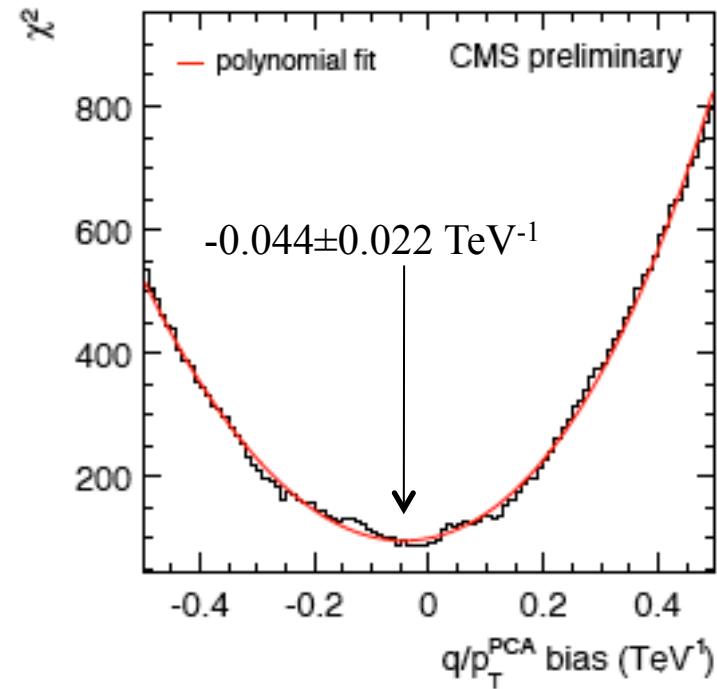


# Momentum Scale

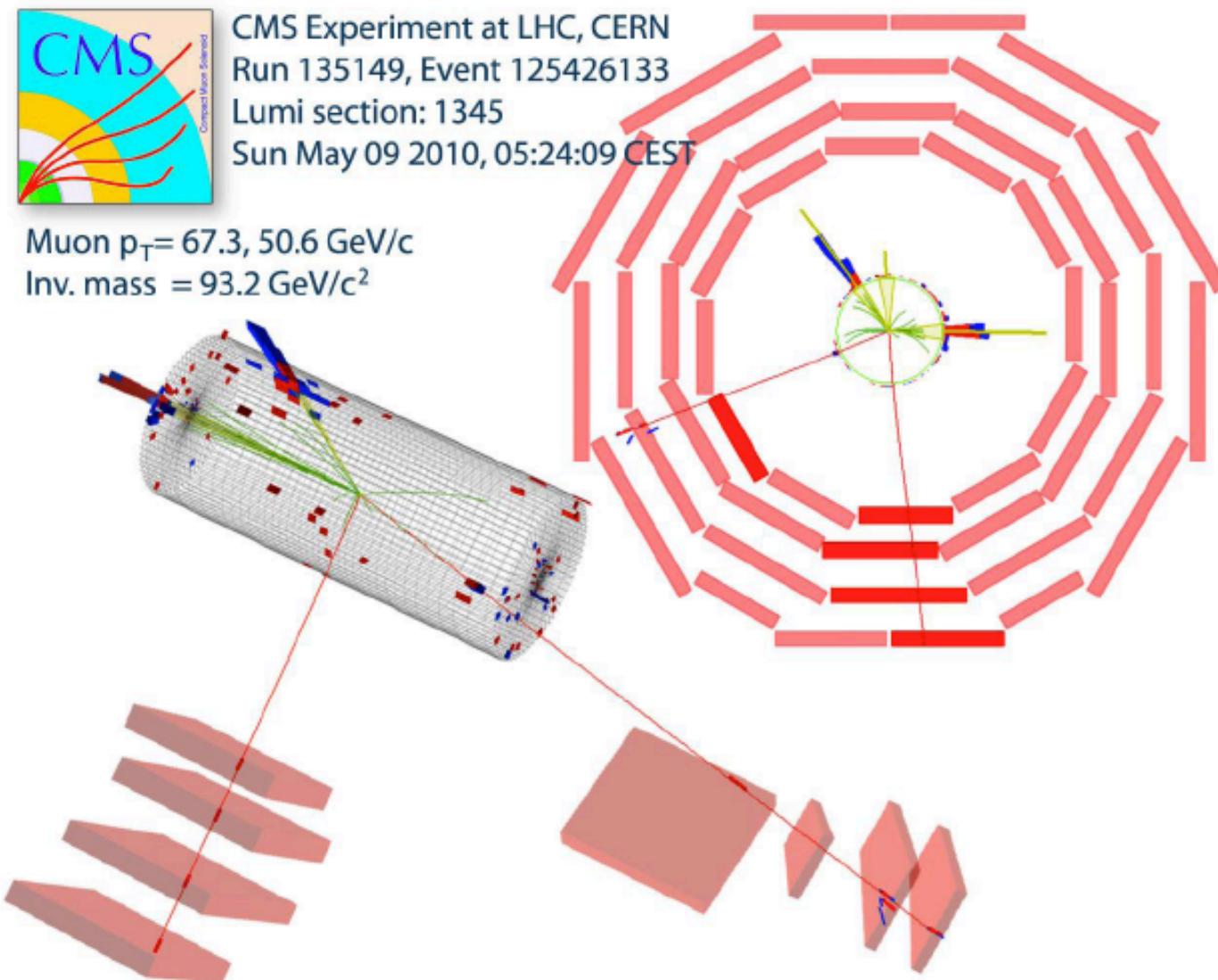


Using tracks with  $p_T > 1 \text{ GeV}$   
gives an agreement at the **0.6 per mille**  
**level.**

Cosmic ray spectrum

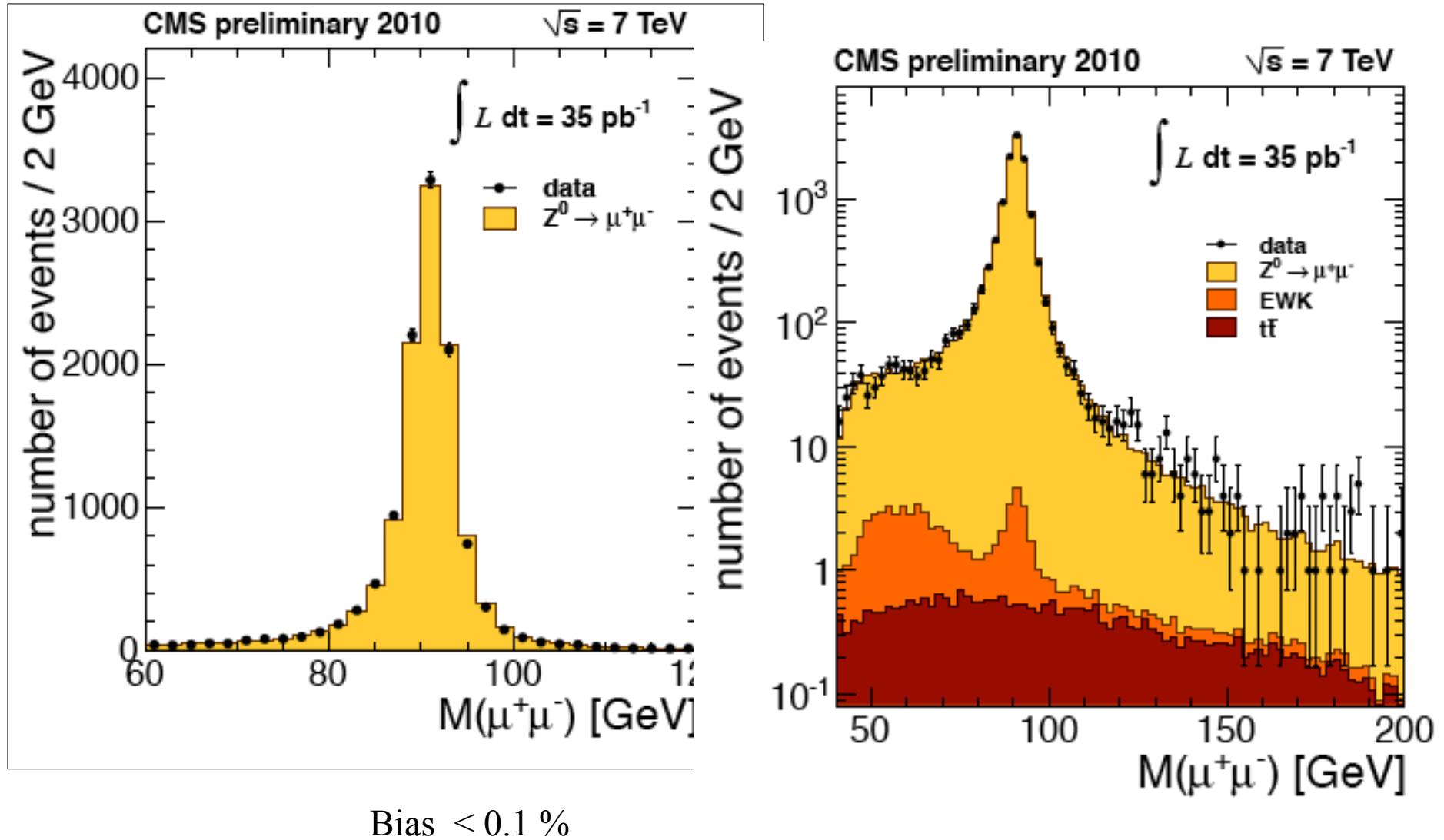


# First $Z \rightarrow \mu\mu$ candidate in CMS



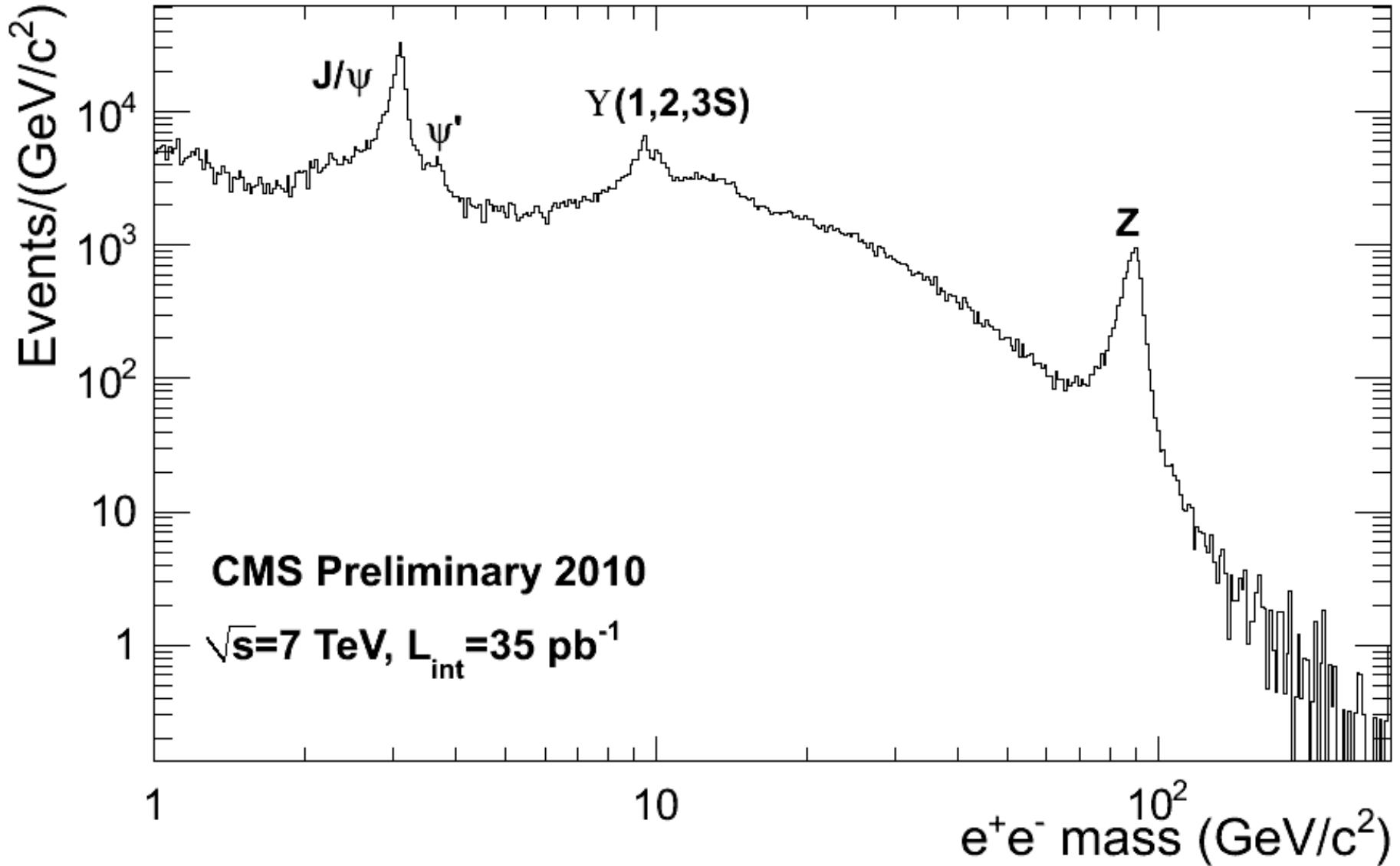


# Z to mu mu mass spectrum





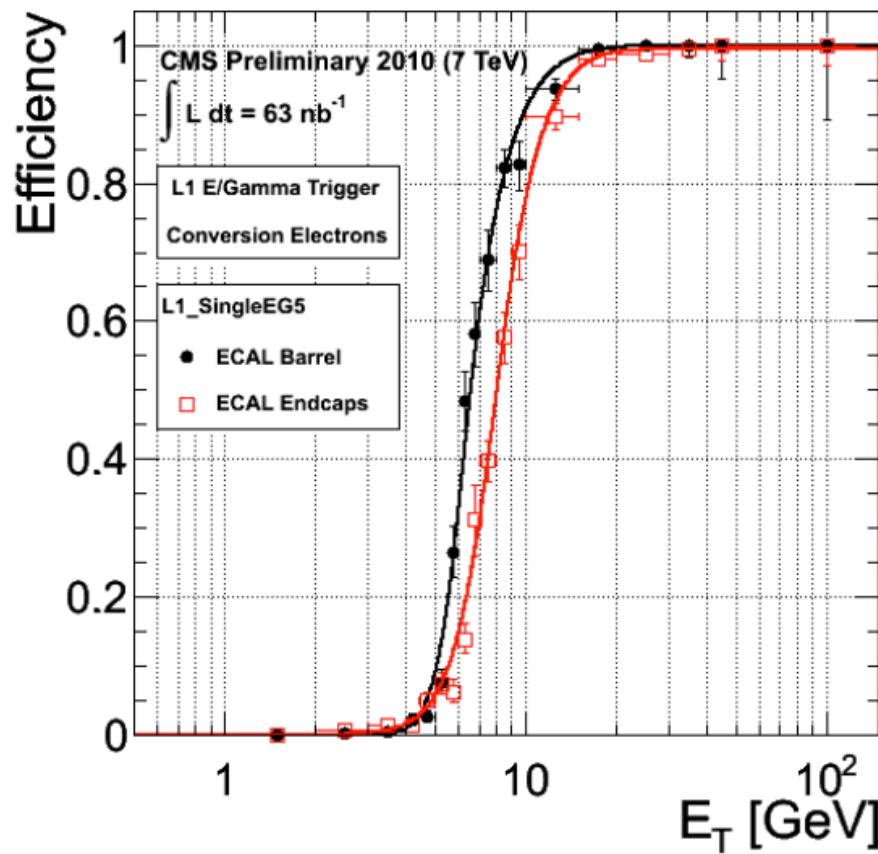
# ELECTRONS and PHOTONS



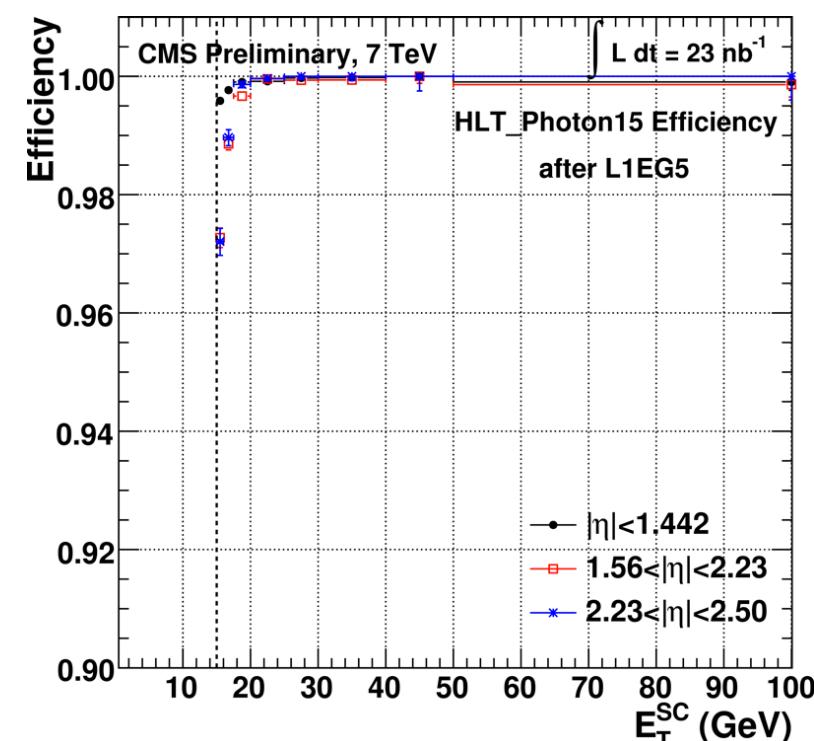


# Electron/Photon Trigger

L1 trigger efficiency



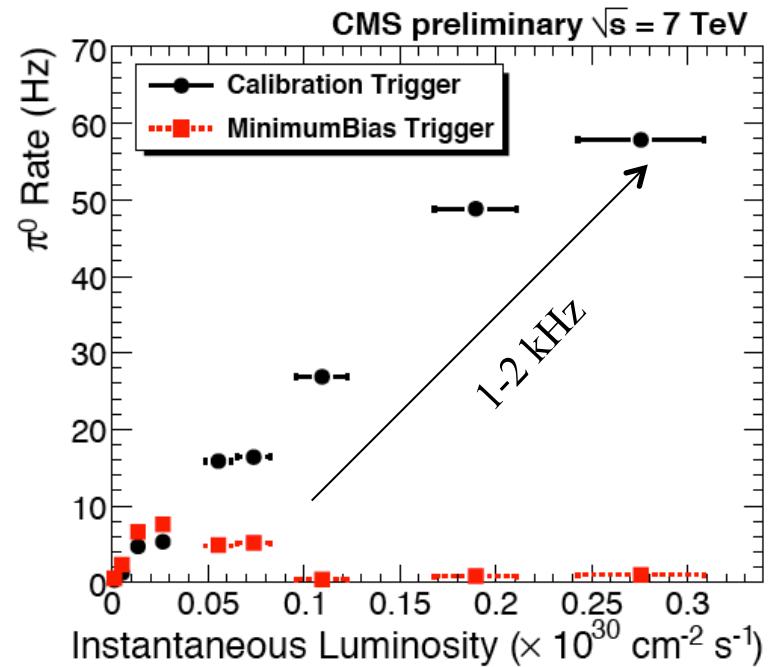
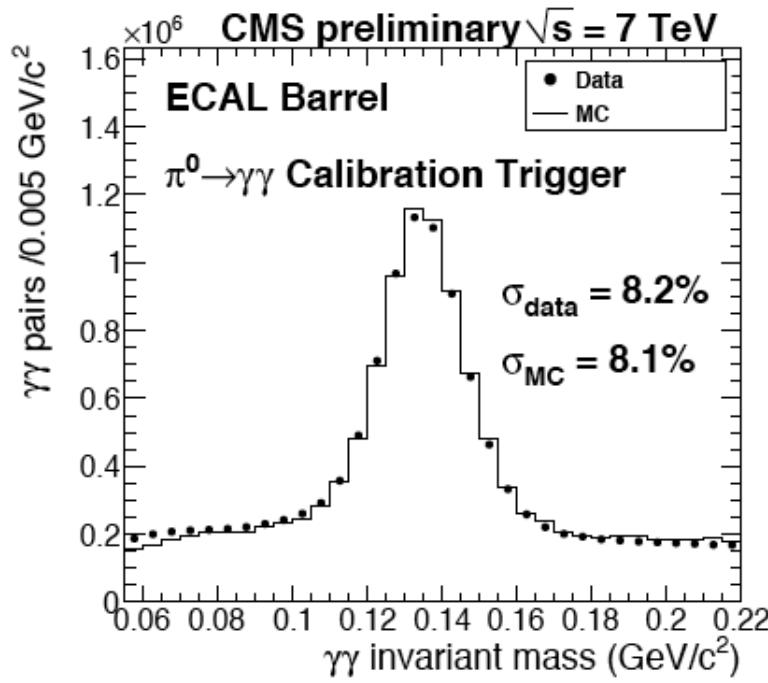
HLT Trigger efficiency vs energy of the supercluster measured in ECAL





# $\pi^0$ Calibration stream

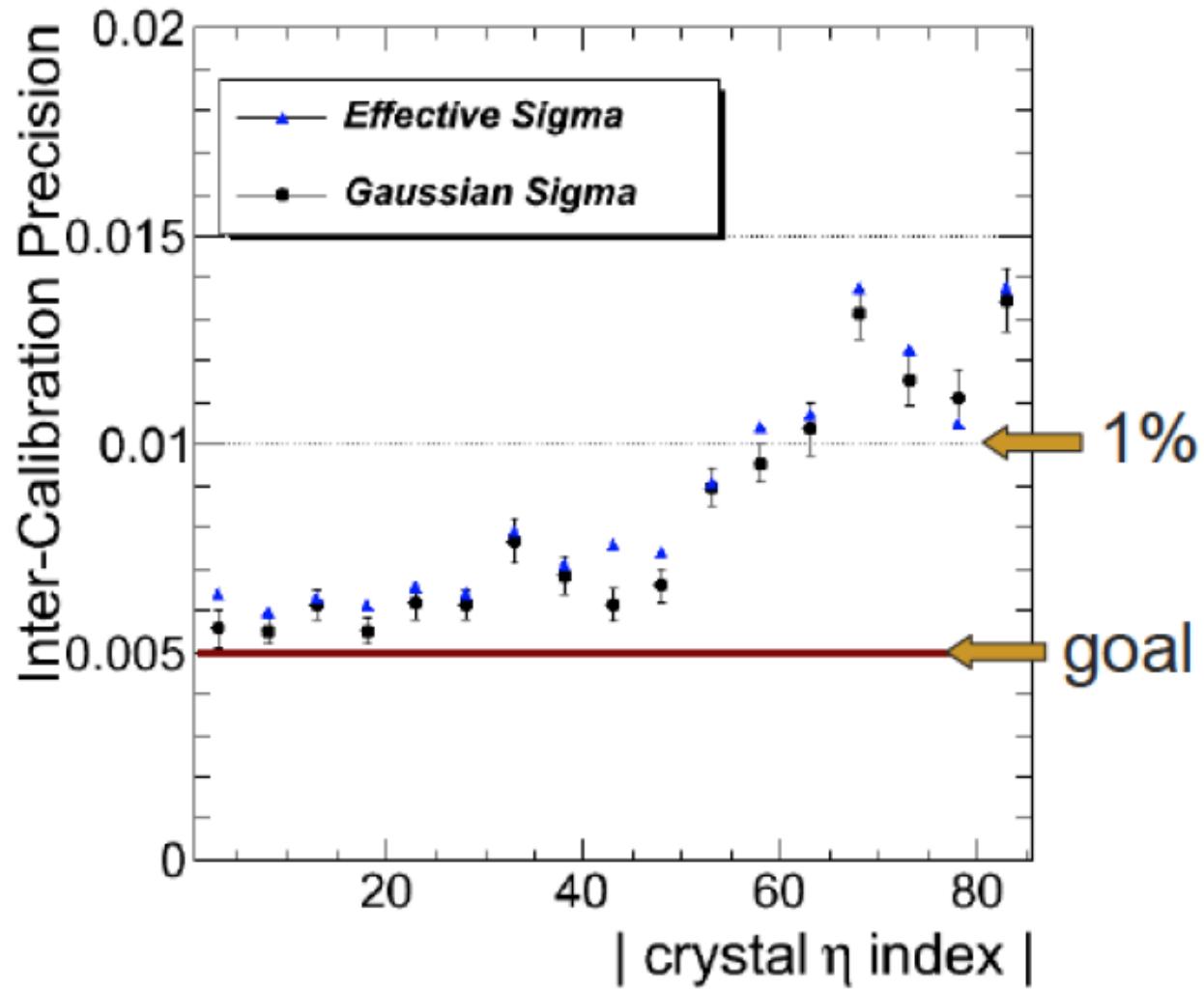
Candidate di-photon decays are selected directly from events passing single-e/ $\gamma$  and single-jet L1 triggers. After selection, only information about a limited region of ECAL (20 to 40 crystals) is stored for the actual calibration.



Today the barrel is 0.5%  $\rightarrow$  1.2% uniform depending on eta



# Crystal inter-calibration is on target



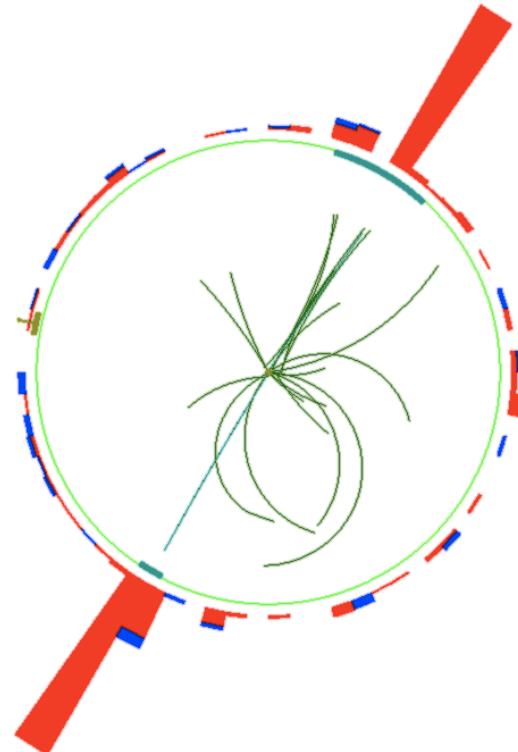
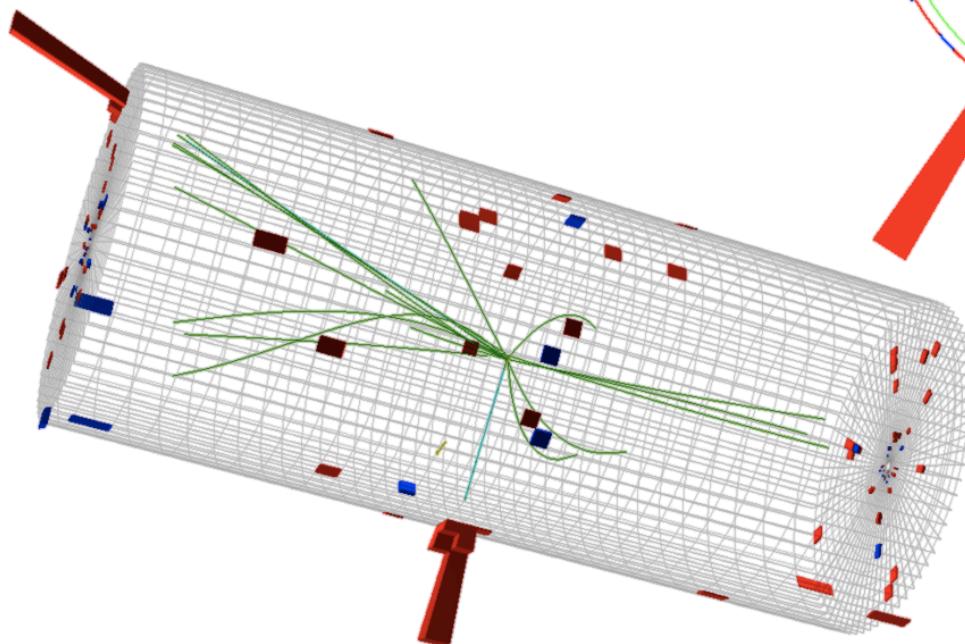


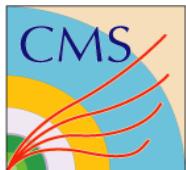
# Z $\rightarrow$ ee candidate



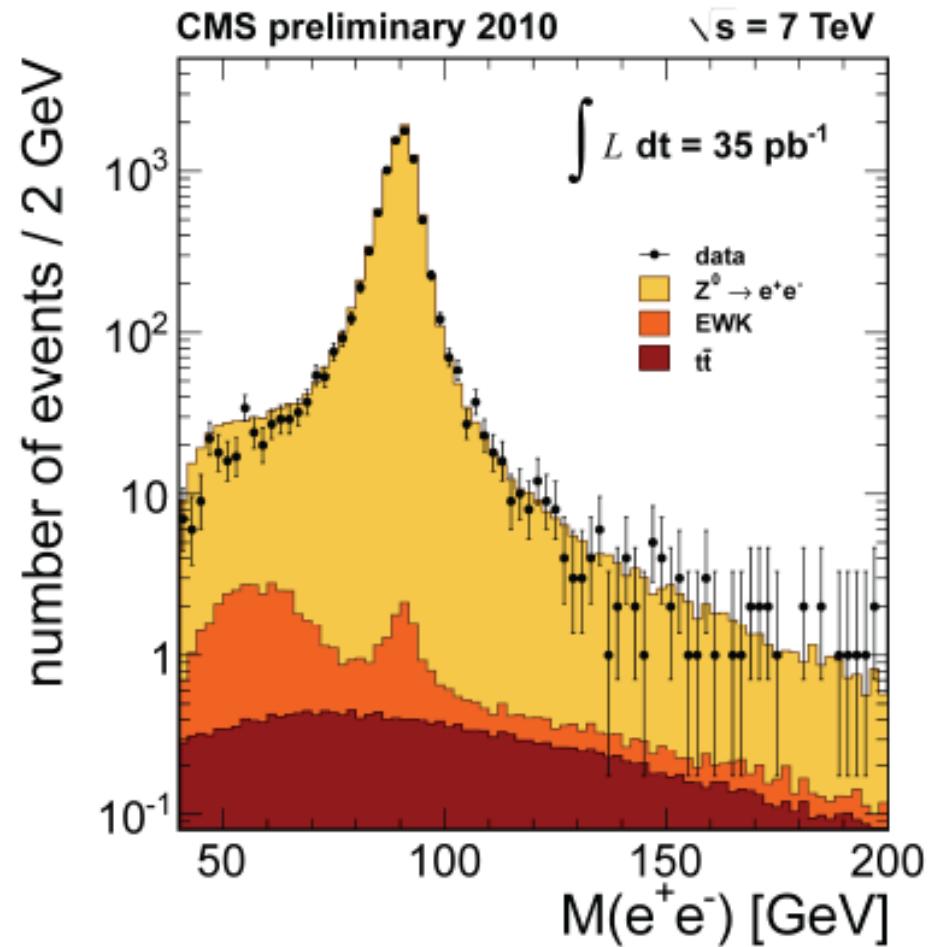
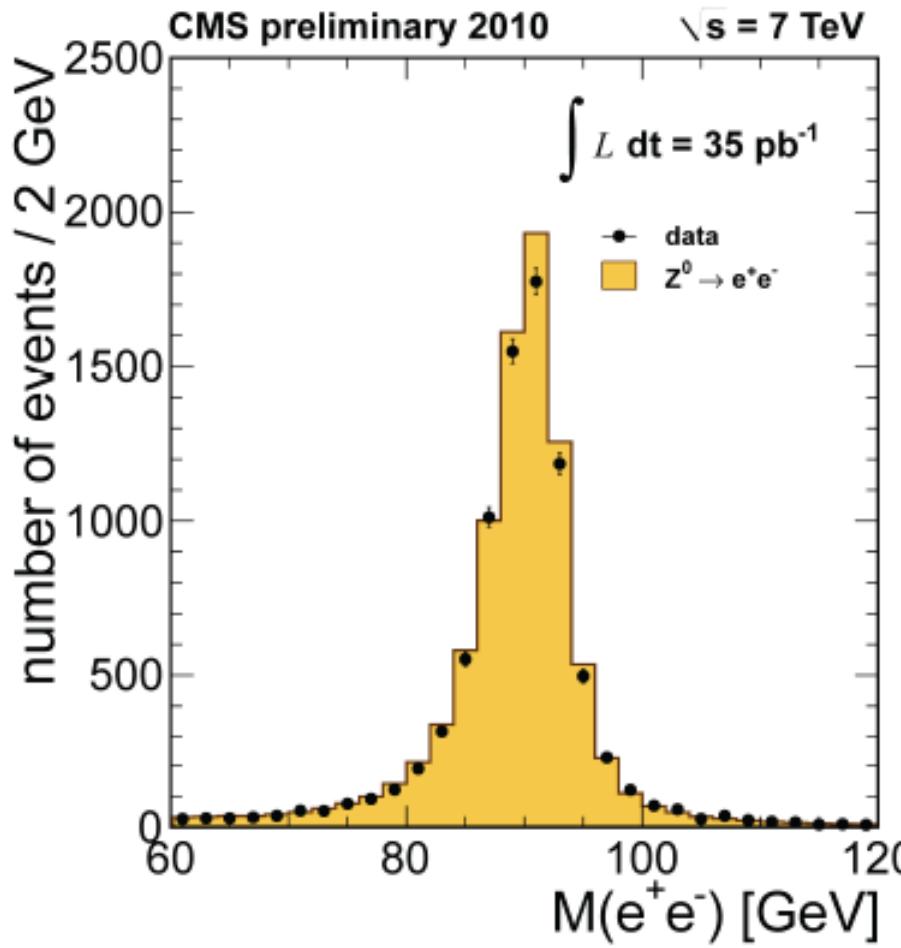
CMS Experiment at LHC, CERN  
Run 133877, Event 28405693  
Lumi section: 387  
Sat Apr 24 2010, 14:00:54 CEST

Electrons  $p_T = 34.0, 31.9 \text{ GeV}/c$   
Inv. mass =  $91.2 \text{ GeV}/c^2$





# Z ee mass spectrum





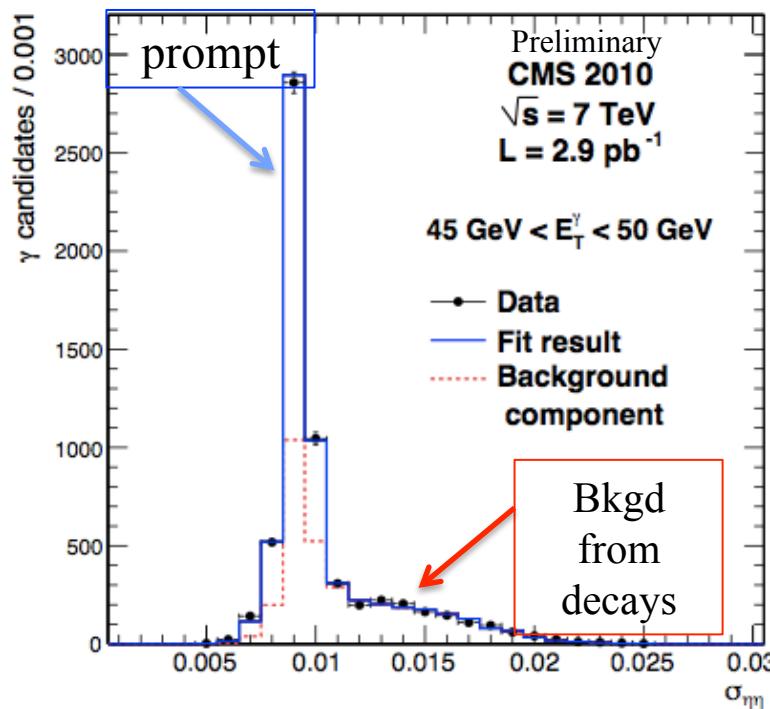
# QCD: prompt $\gamma$ production

arXiv 1012.0799

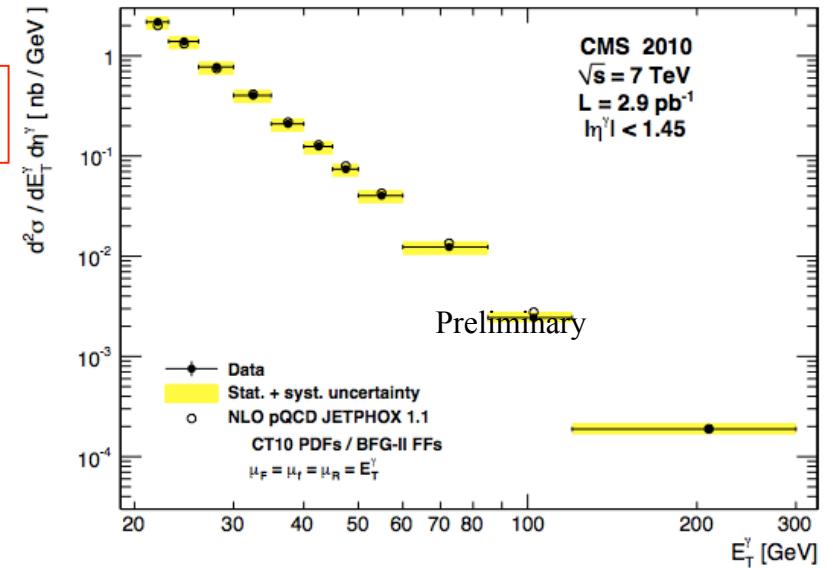
$$\sigma_{\eta\eta}^2 = \frac{\sum_{\substack{\text{crystal}-i \\ \text{in } 5 \times 5 \\ \text{around } m_x}} \omega_i (\eta_i - \bar{\eta})^2}{\sum_{\text{crystal}-i} \omega_i}$$

Discri variable:  $\sigma_{\eta\eta}$

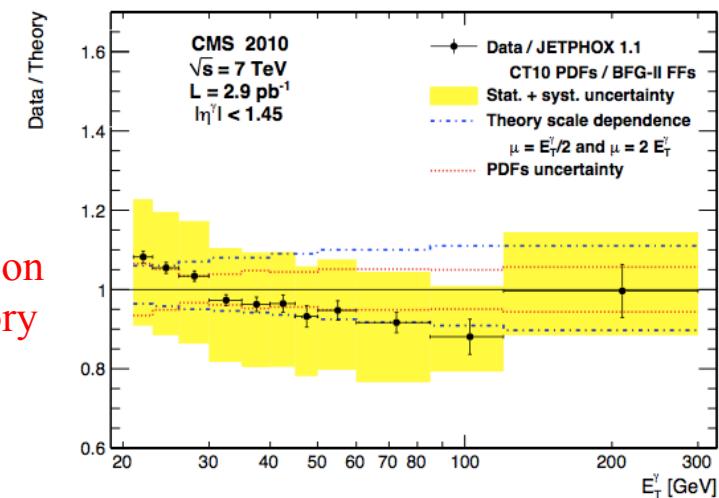
$$\omega_i = \max\left(0, 4.7 + \ln\left(\frac{E_i}{E_{5 \times 5}}\right)\right)$$



Measurement at higher  $Q^2$  and  
below  $E_T^\gamma / \sqrt{s}$  than Tevaton  
Challenges for precision physics at LHC



Lumi error (11%) not included



Comparison with theory

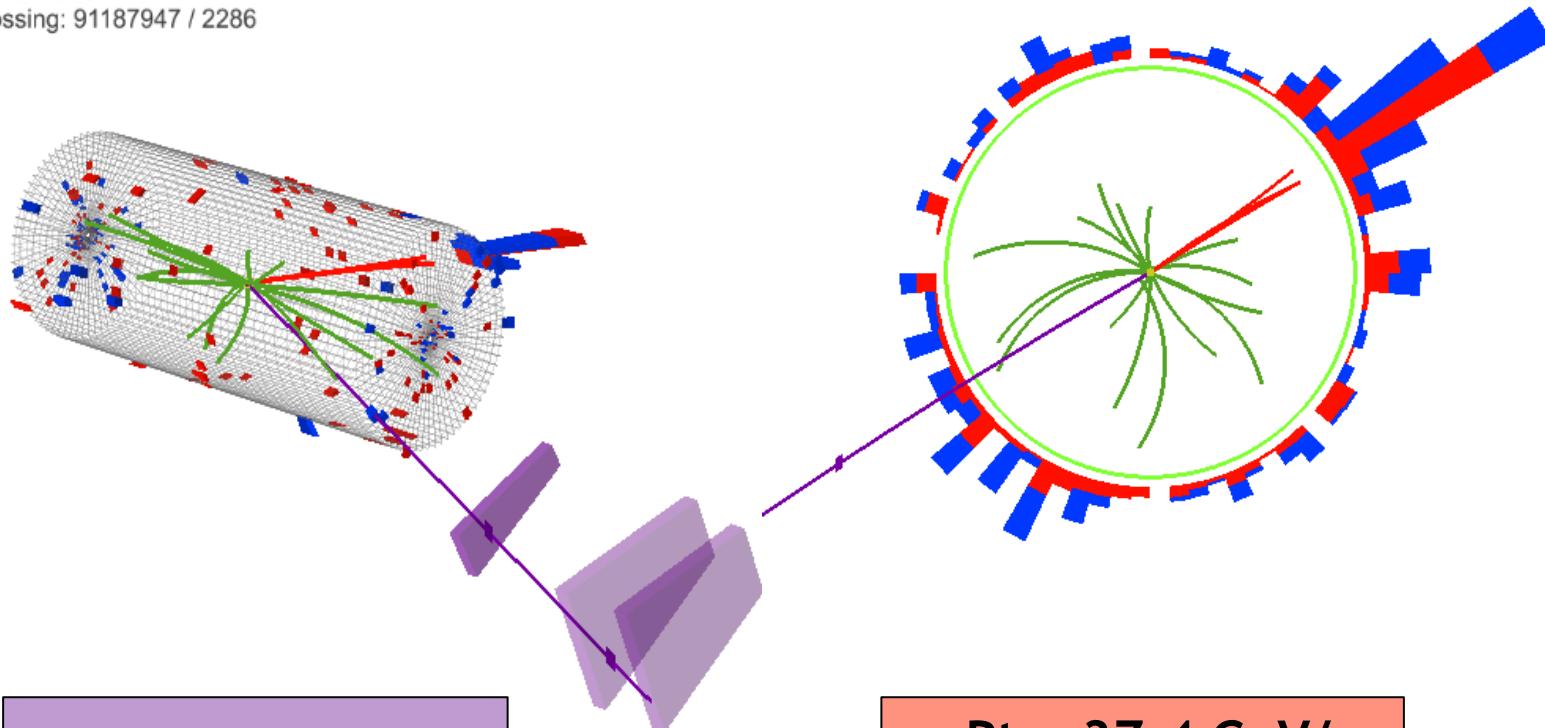


# TAU

$Z \rightarrow \text{tau tau} \rightarrow \mu + \text{tauhad}$  (three prong tau)



CMS Experiment at LHC, CERN  
Data recorded: Sun Aug 15 03:57:48 2010 CEST  
Run/Event: 142971 / 323188785  
Lumi section: 348  
Orbit/Crossing: 91187947 / 2286

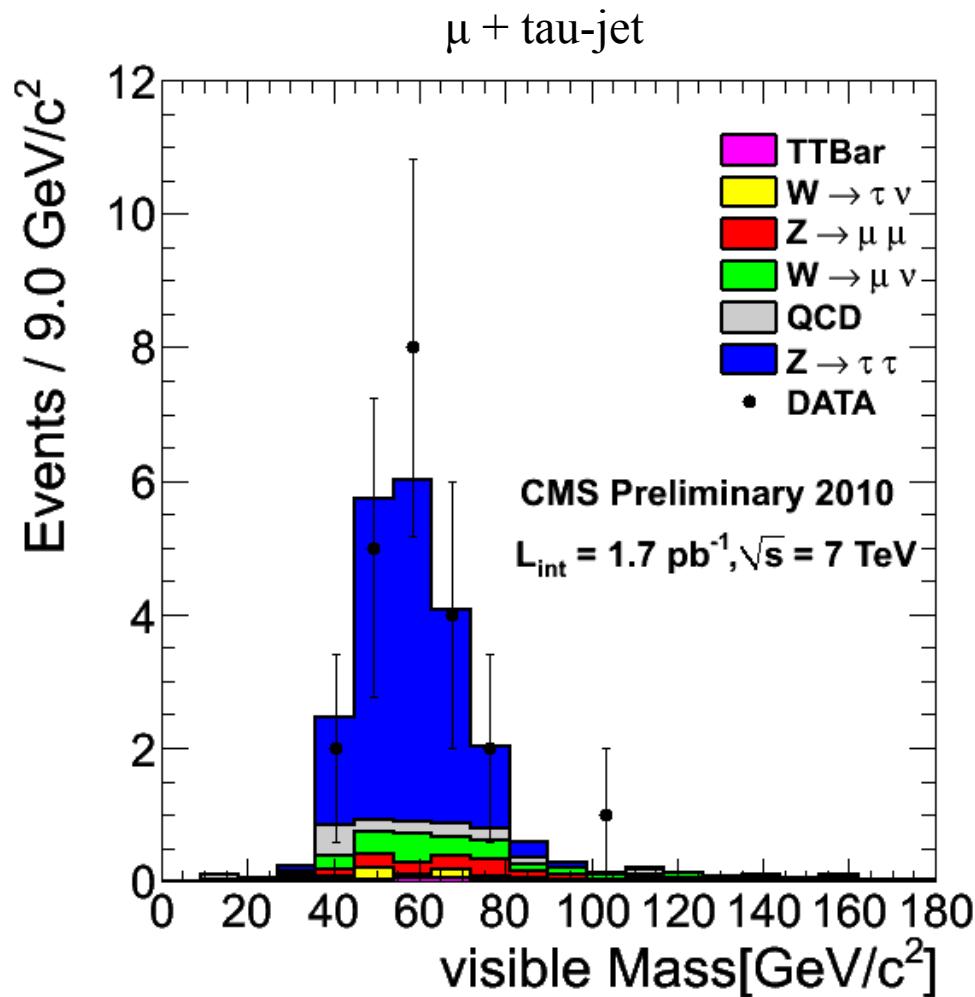


$\mu P_T = 32.4 \text{ GeV}/c$   
 $\eta = 1.7$

$\tau P_T = 37.4 \text{ GeV}/c$   
 $\eta = 1.5$   
Mass =  $1.2 \text{ GeV}/c^2$

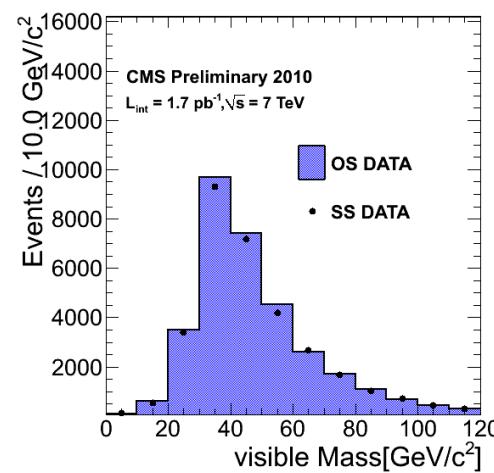


# Z->tau tau selection



QCD Bkgr  
Measured:  
 $\text{OS/SS} = 1.03 \pm 0.01(\text{stat})$

QCD MC expected value:  
 $\text{OS/LS} = 1.036 \pm 0.002$





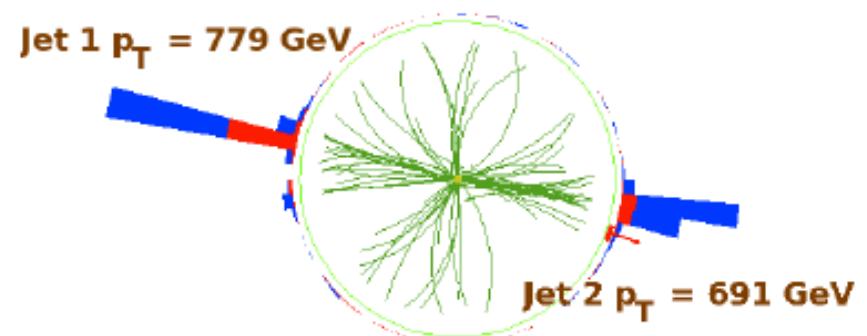
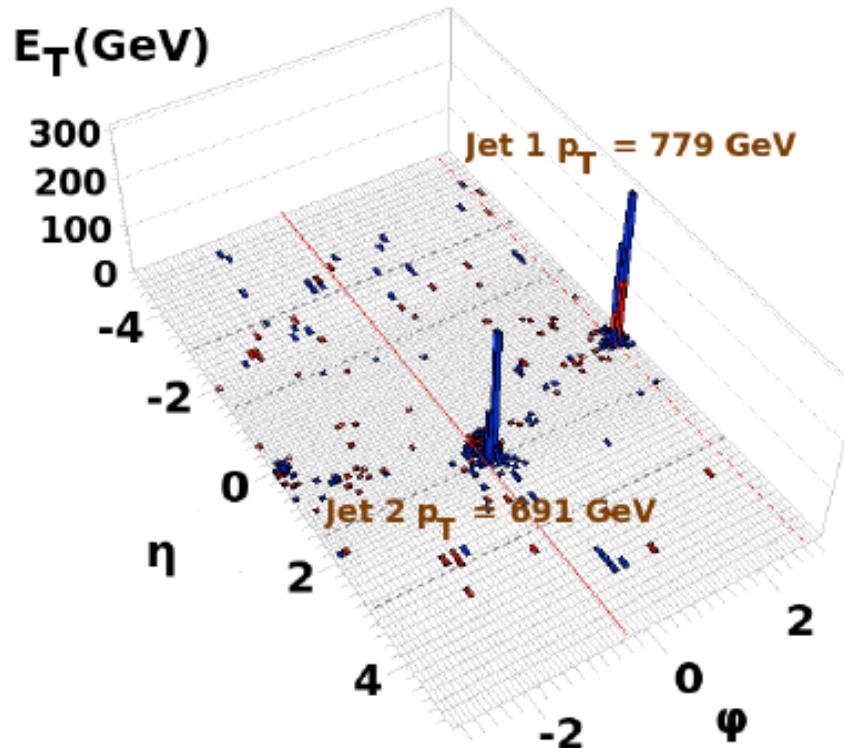
# JETS and MET



**Run : 143181**  
**Event : 177895396**  
**Dijet Mass : 1.695 TeV**

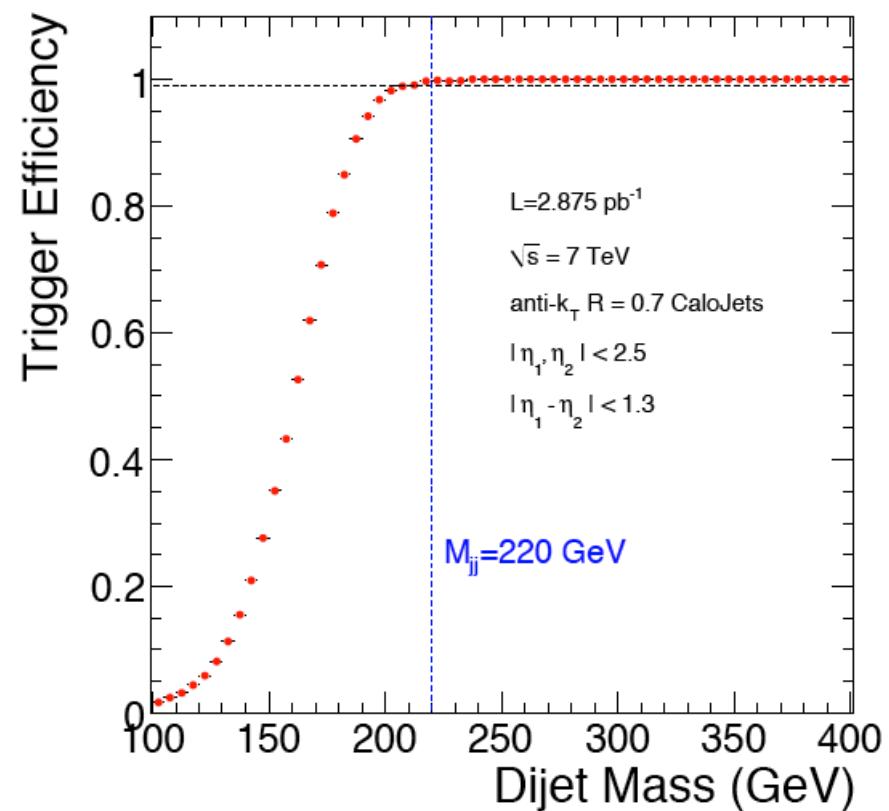
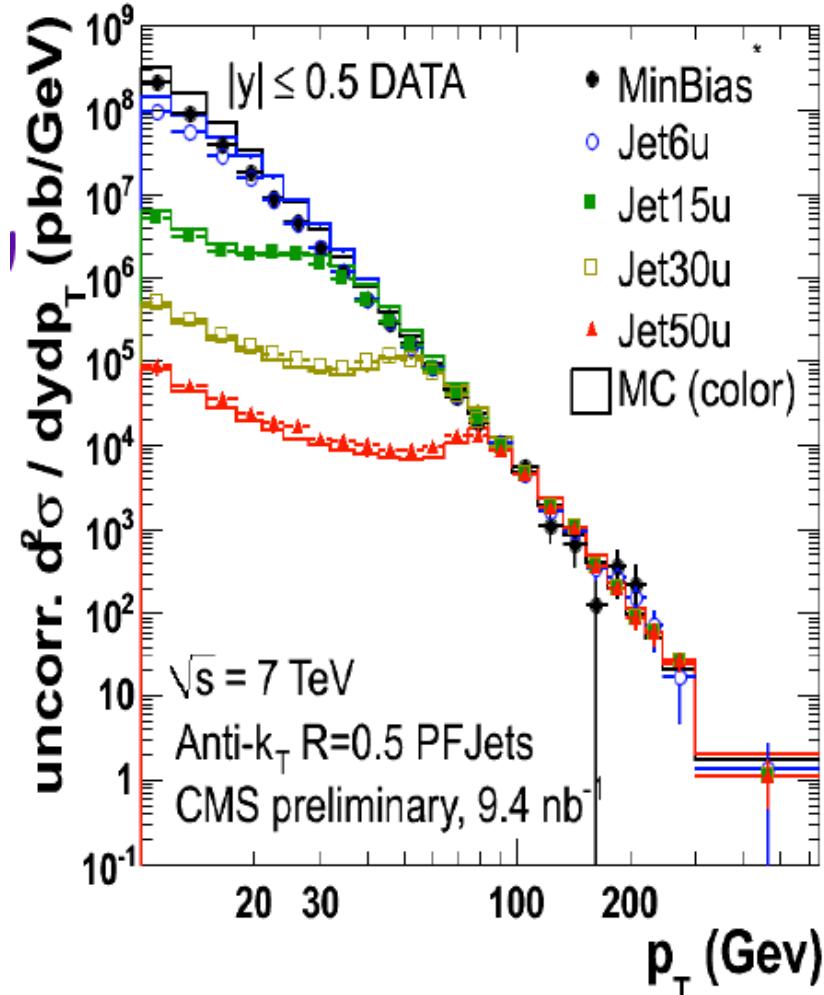


**Run : 143181**  
**Event : 177895396**  
**Dijet Mass : 1.695 TeV**



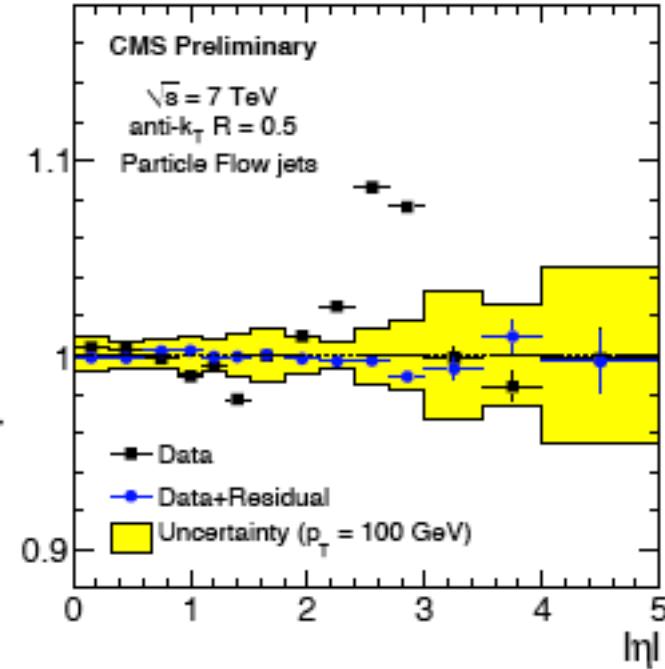
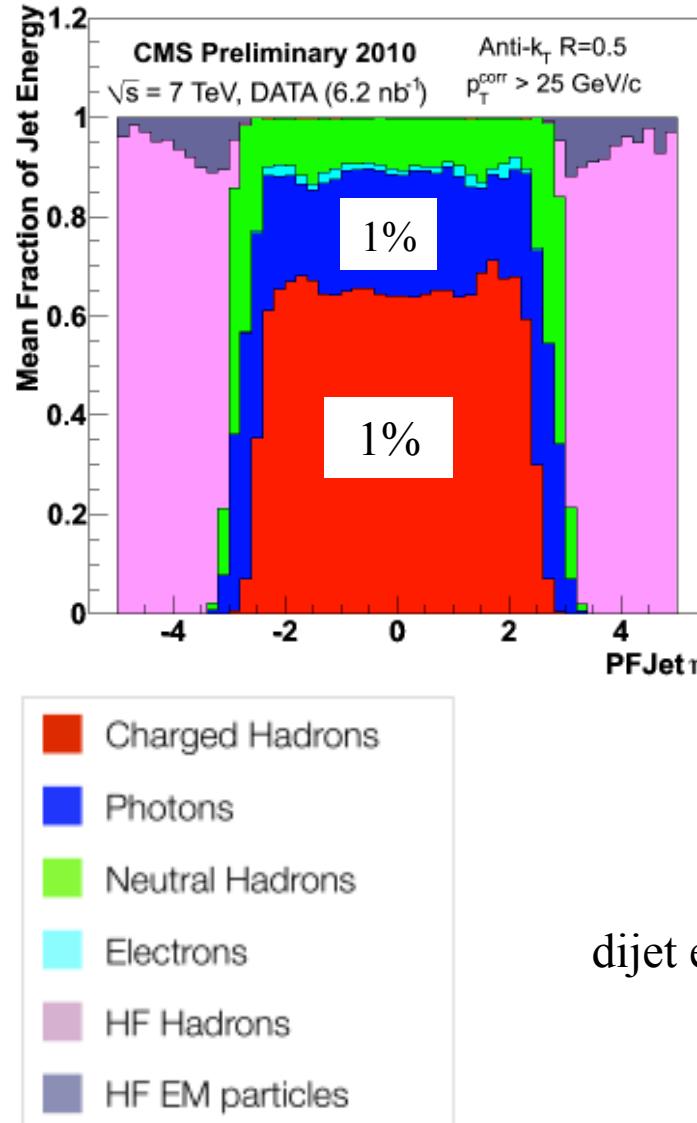


# JET Triggers





# Particle Flow Jets (1)

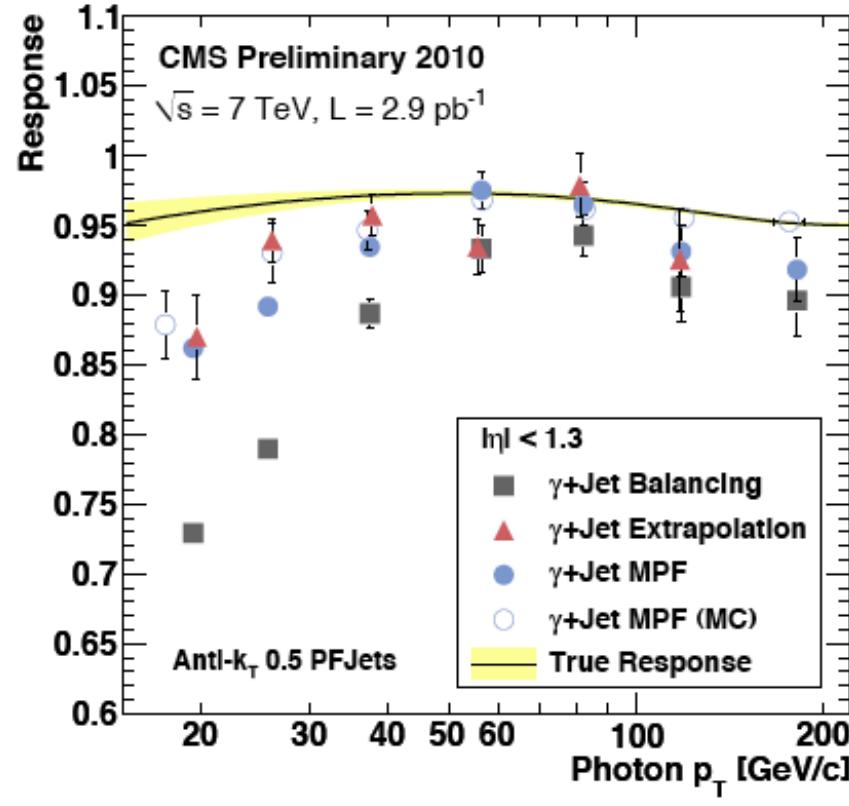


Calibration of the relative response as function of  $\eta$

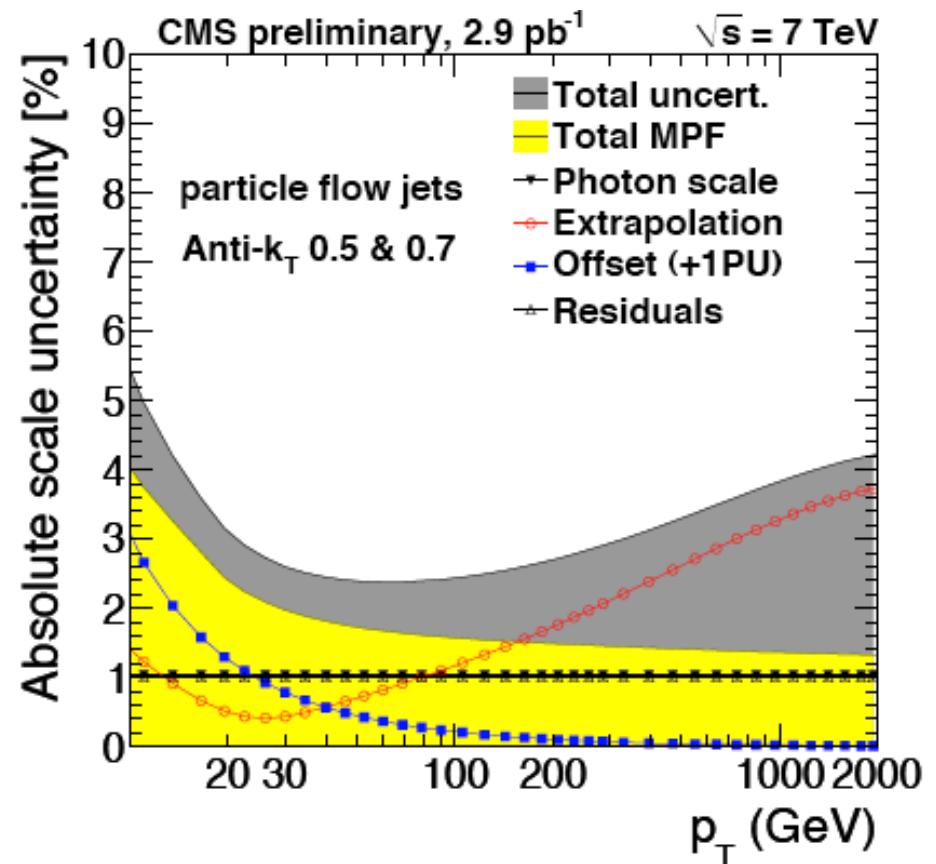
dijet events : comparing central jets with any jet



# Particle flow Jets (2)



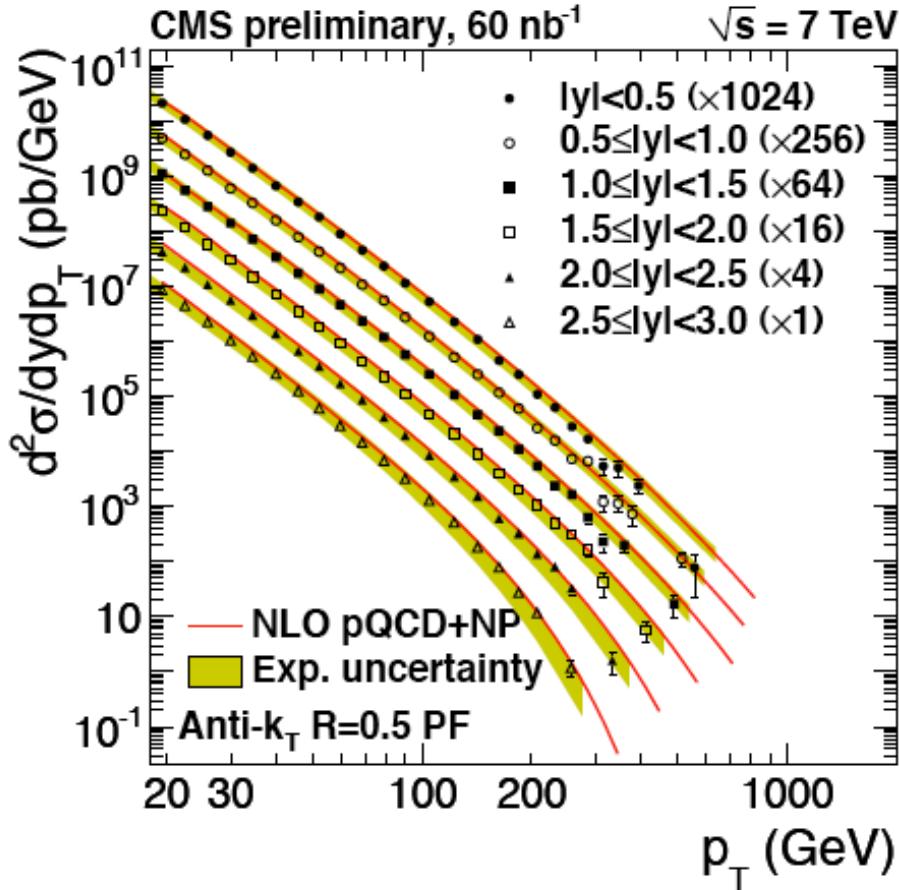
Absolute jet calibration against photon



Data/MC=0.993±004±0.026



# Inclusive Jet Cross Section

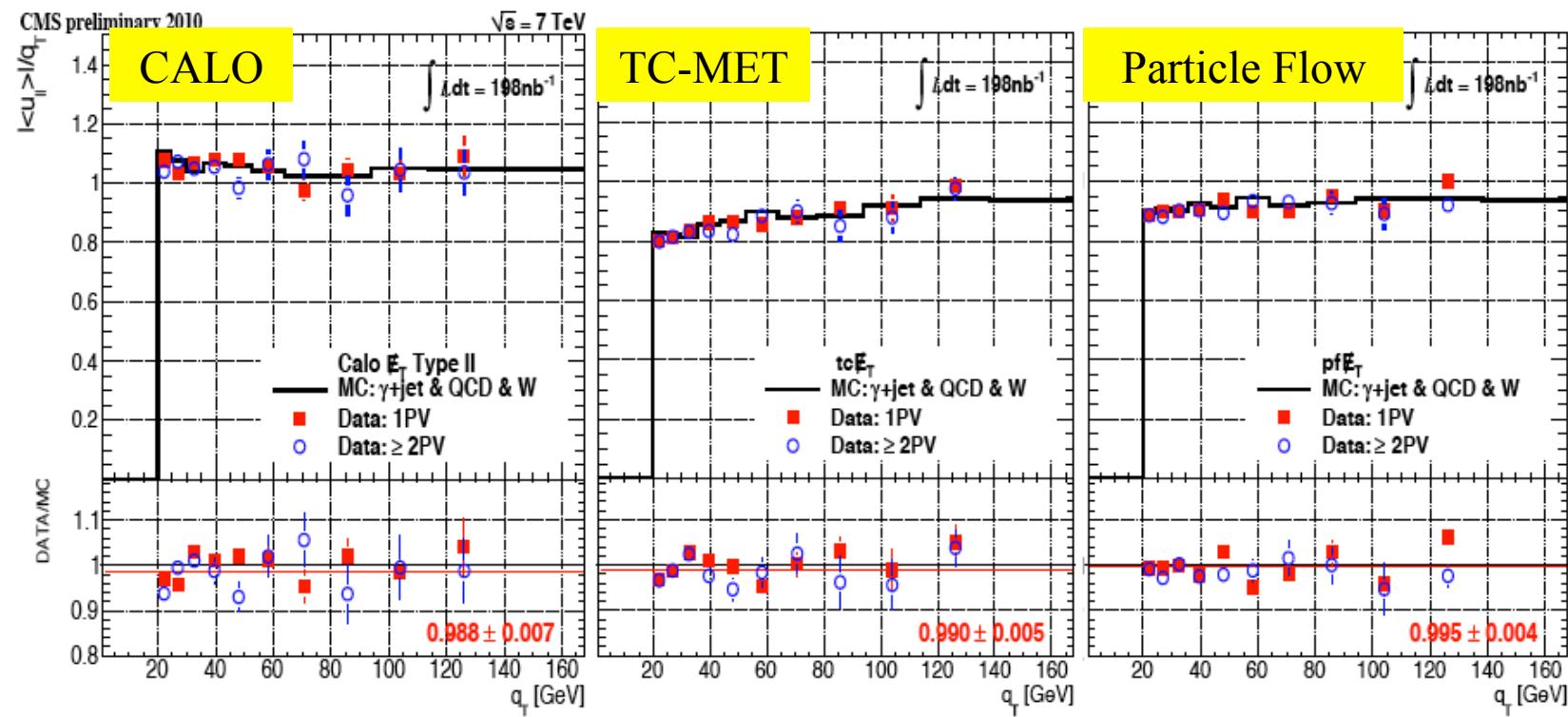
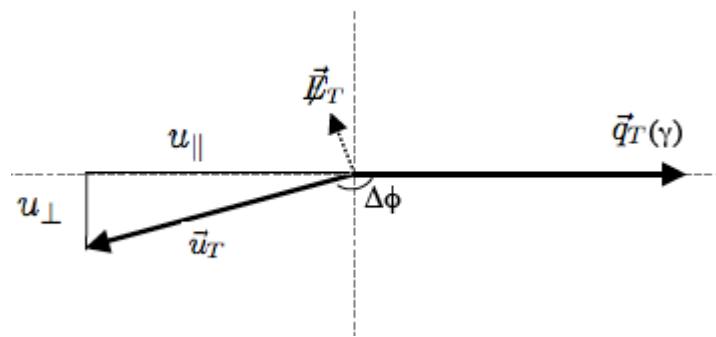
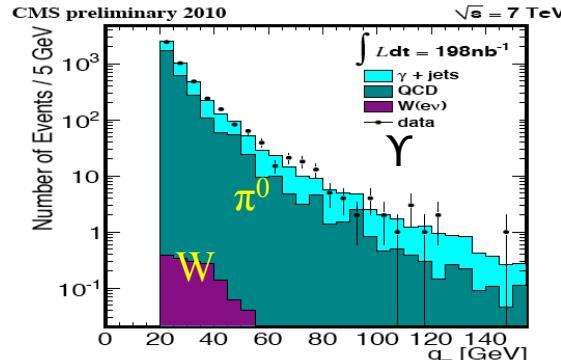


Preliminary result being updated  
to 3 pb-1 and 3% Jet Energy  
Scale

Down to  $p_T=20 \text{ GeV}$  and 5% JES

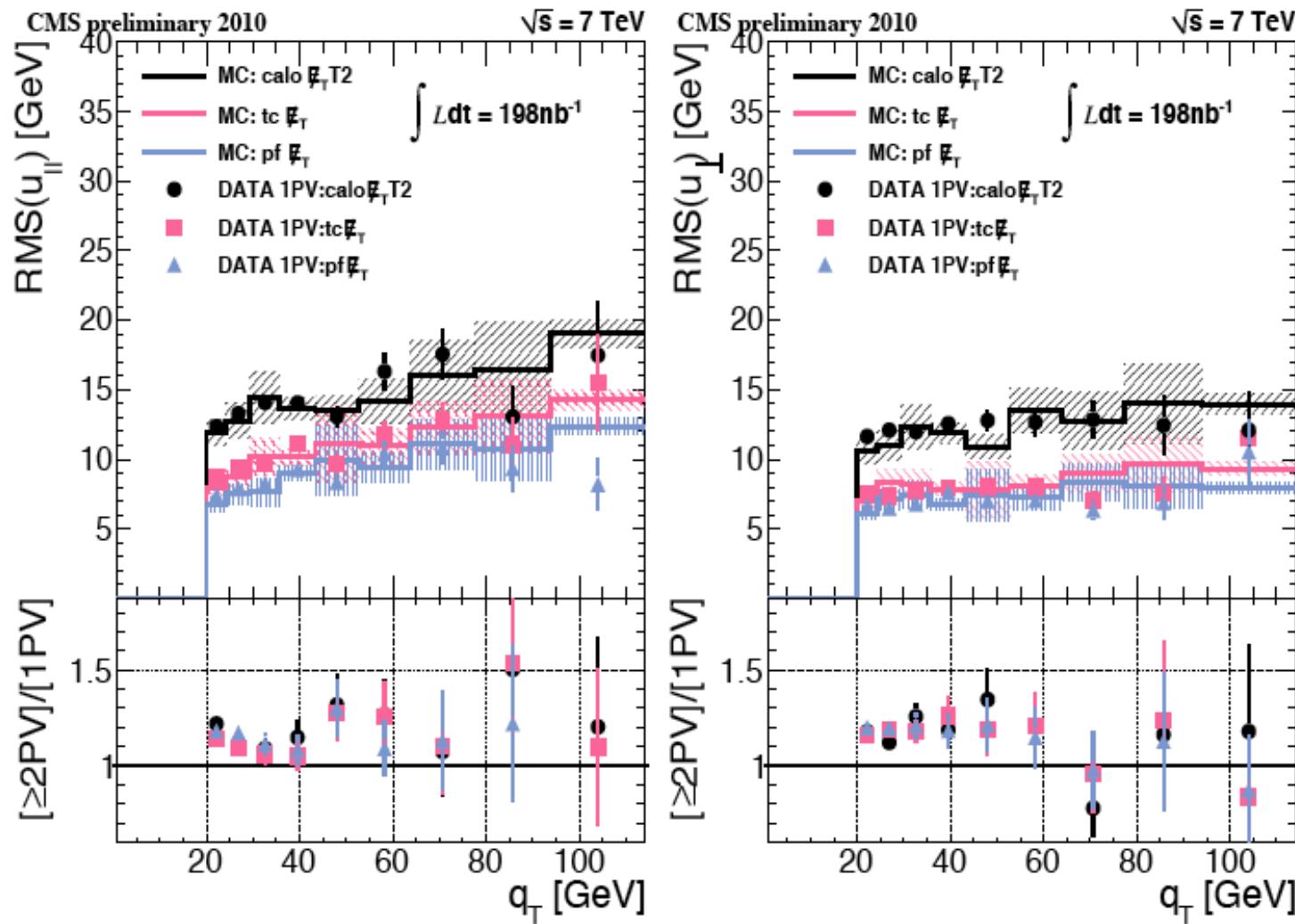


# Missing energy response measured in events with isolated photon



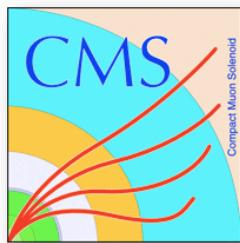


# Missing energy resolution in events with isolated photon





# $W \rightarrow \mu\nu$ candidate



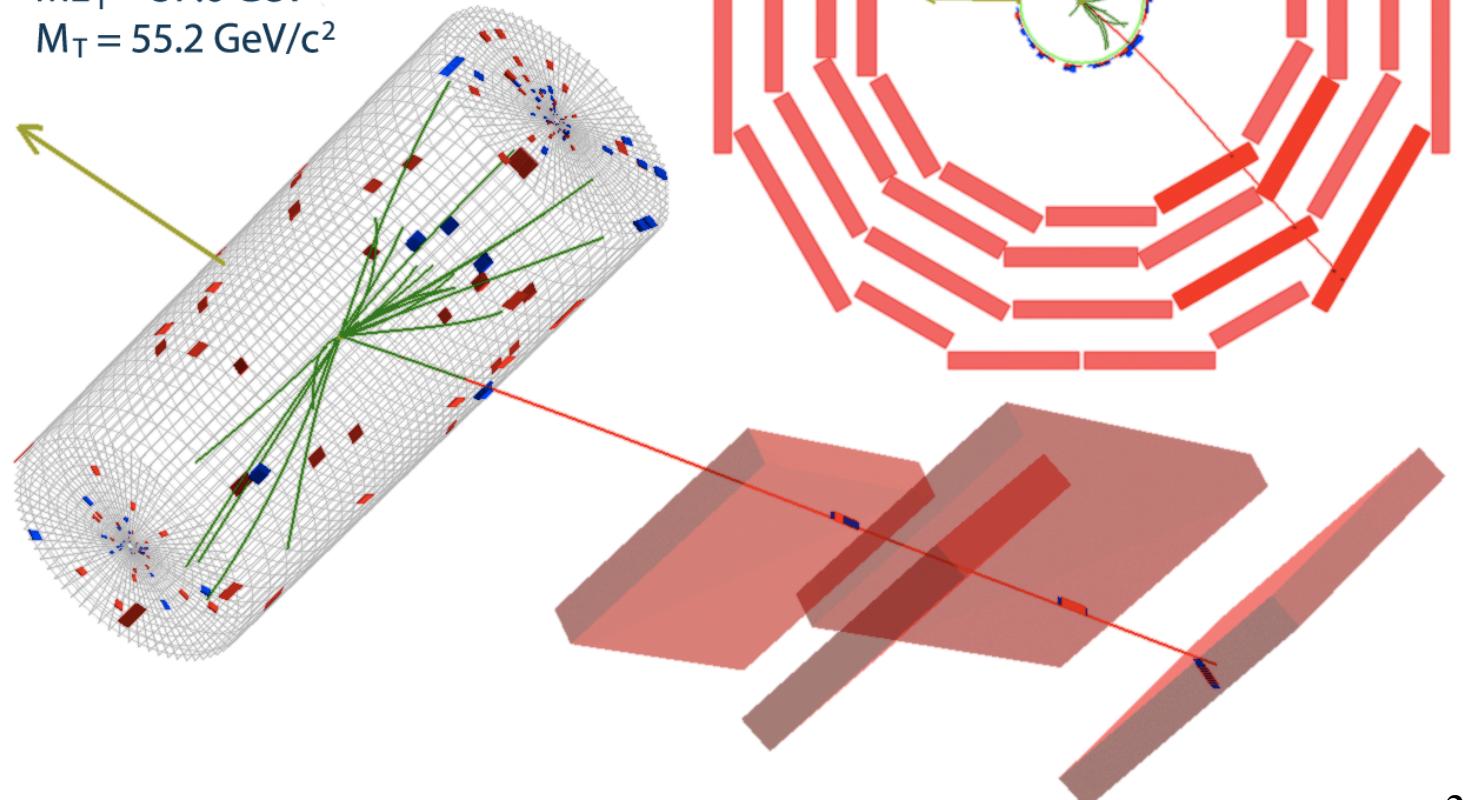
CMS Experiment at LHC, CERN

Run 133483, Event 19046084

Lumi section: 331

Sun Apr 18 2010, 13:03:43 CEST

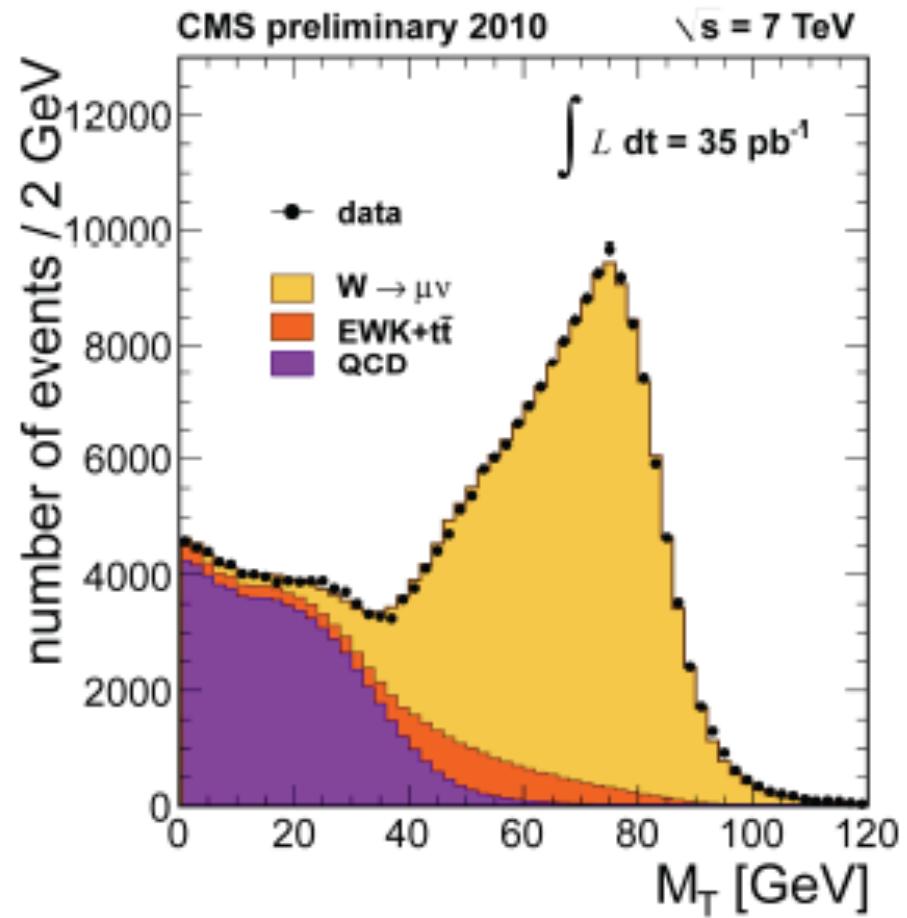
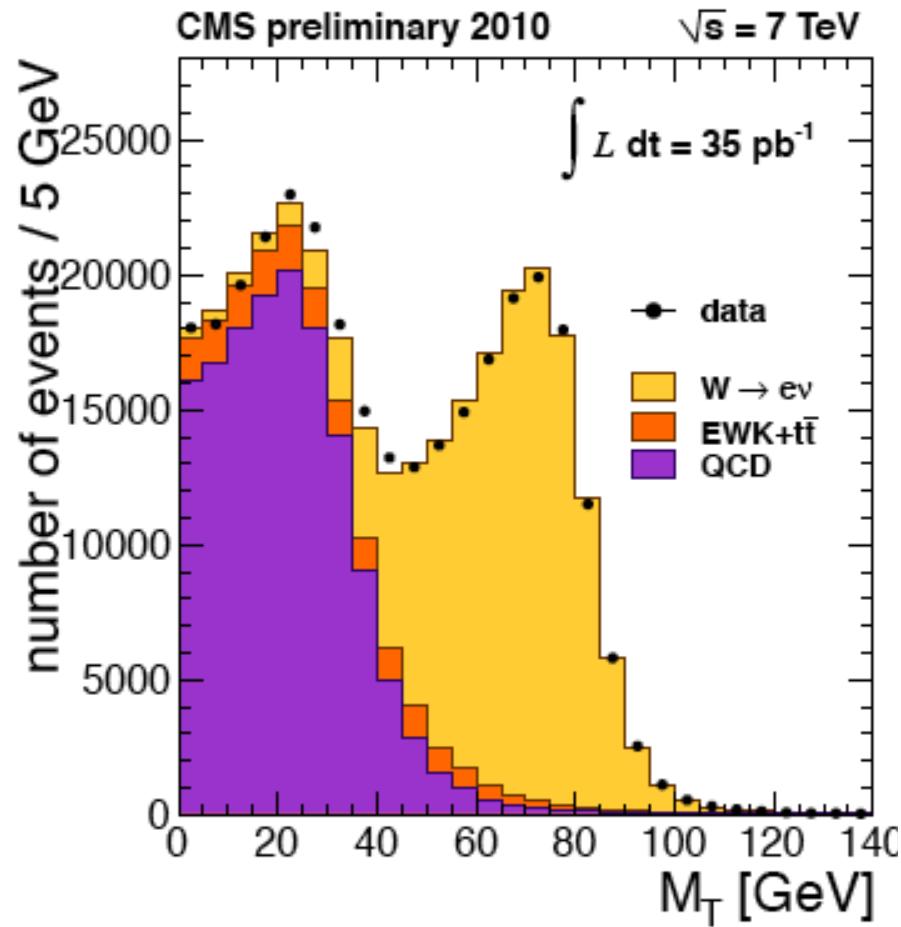
Muon  $p_T = 22.7 \text{ GeV}/c$   
 $ME_T = 37.6 \text{ GeV}$   
 $M_T = 55.2 \text{ GeV}/c^2$



Challenges for precision physics at LHC



# W Jacobian peaks



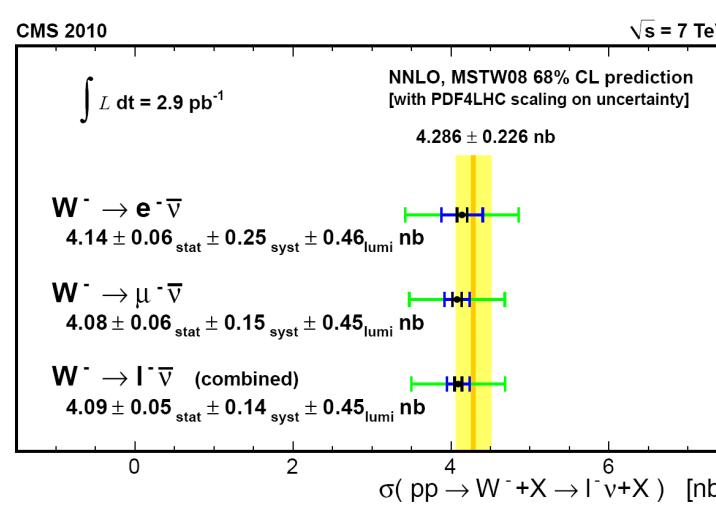
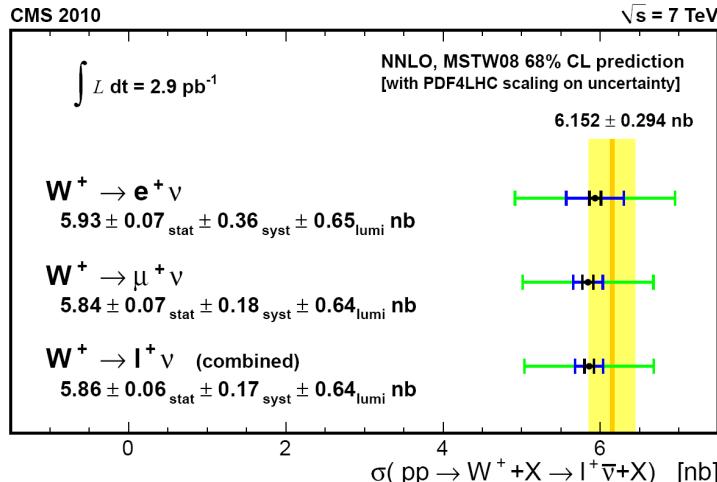
$M_T$ =transverse mass



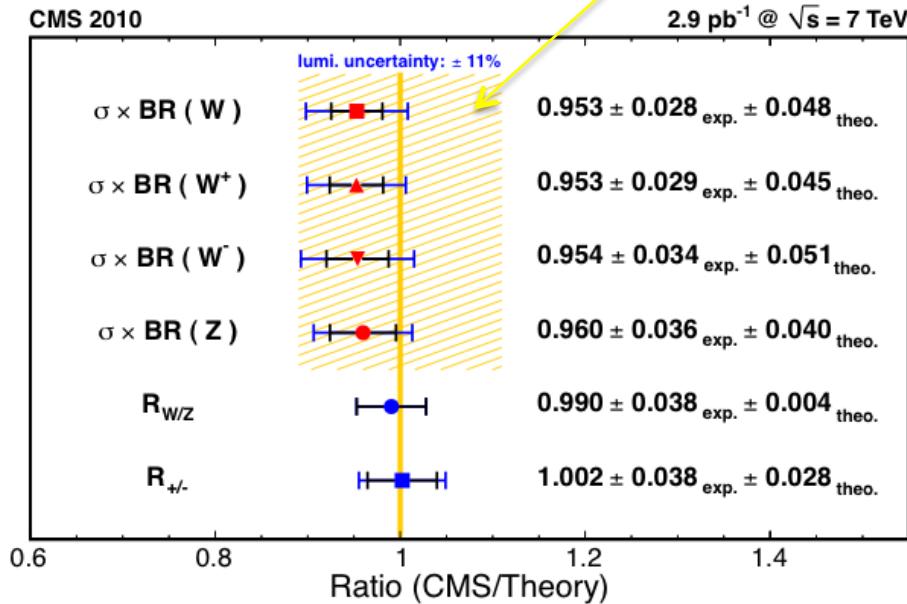
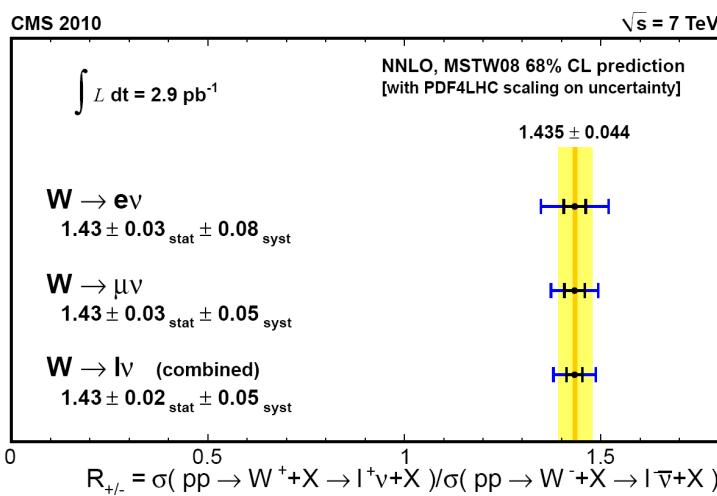
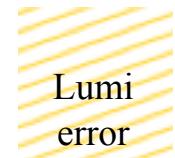
# $W^+$ and $W^-$ and theory

arXiv:1012.2466

more tomorrow : Kesisoglou

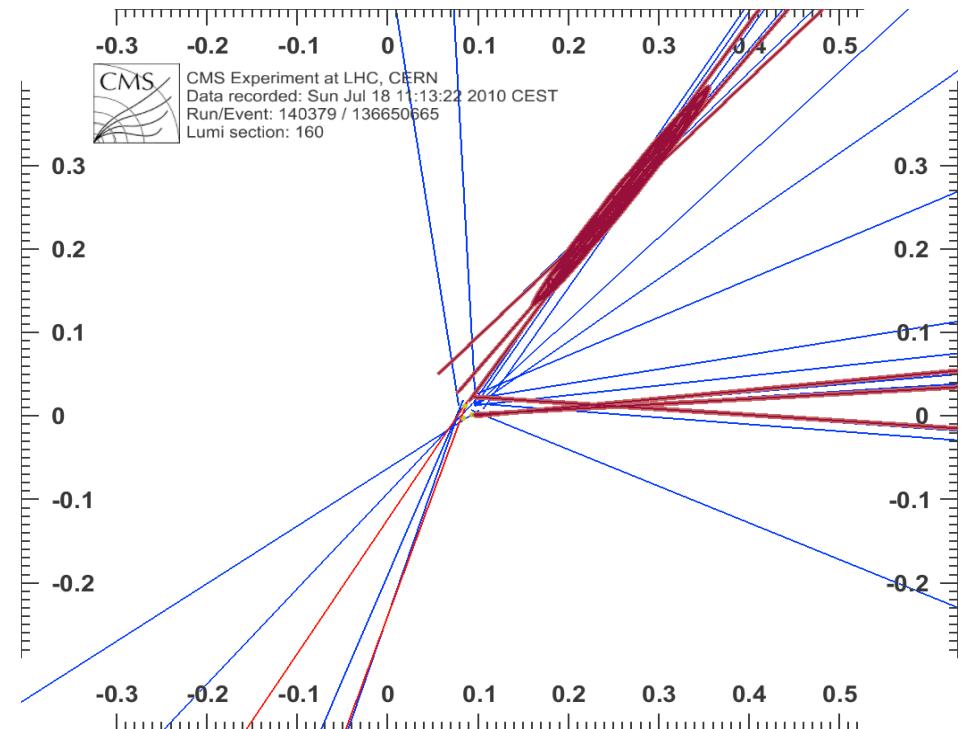
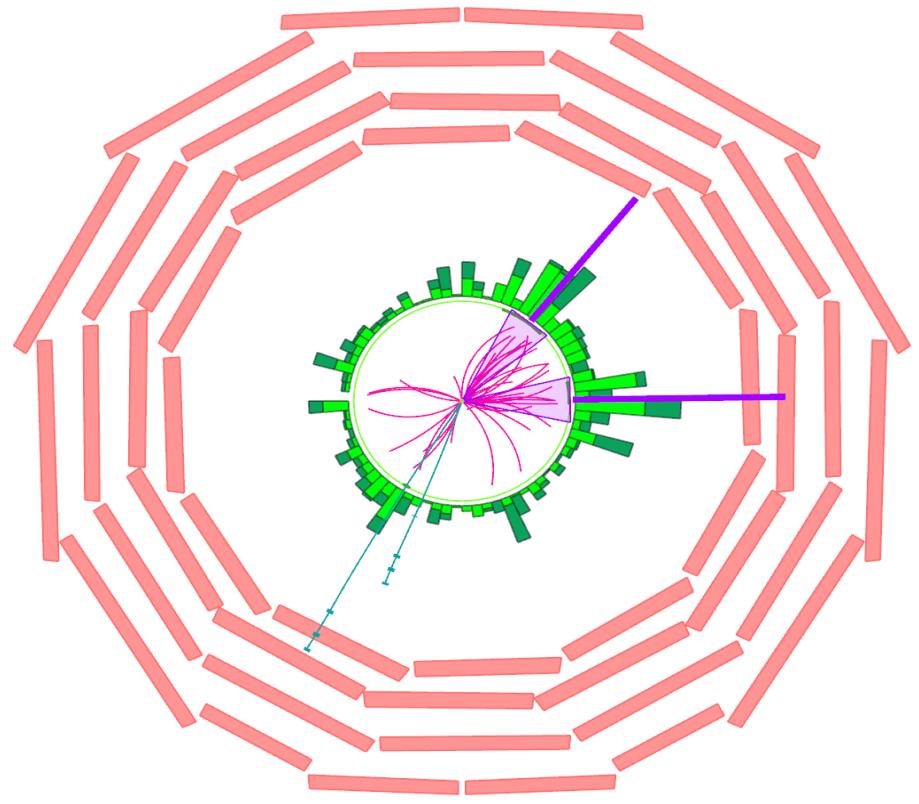


Clearly Lumi is the area with largest potential of improvement





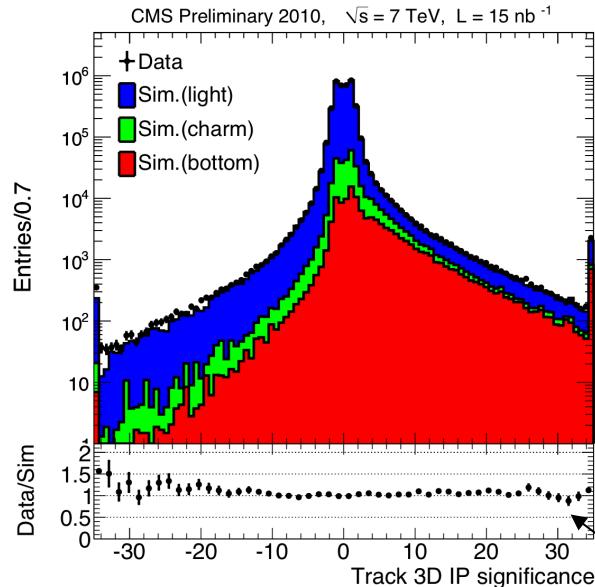
# b-tagging



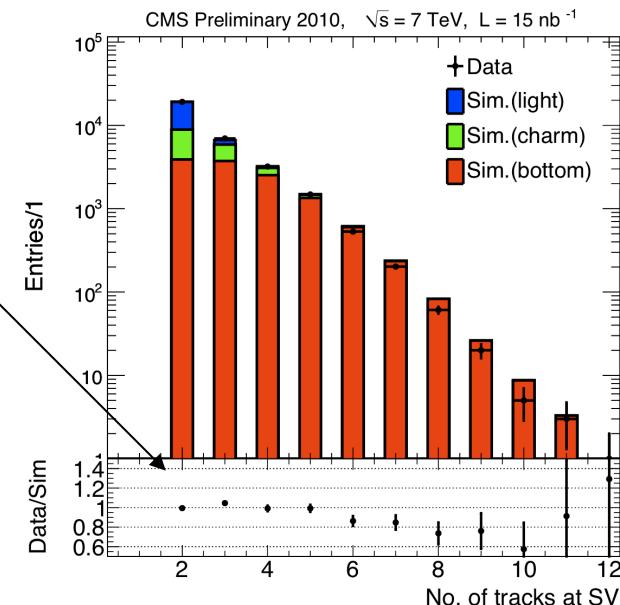
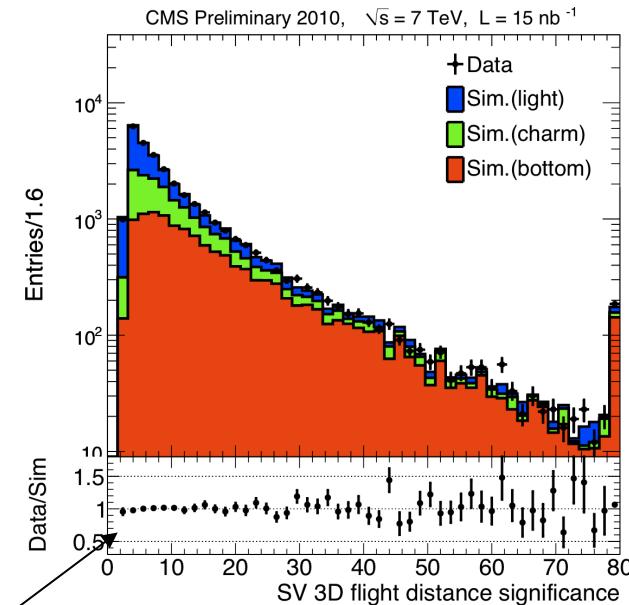
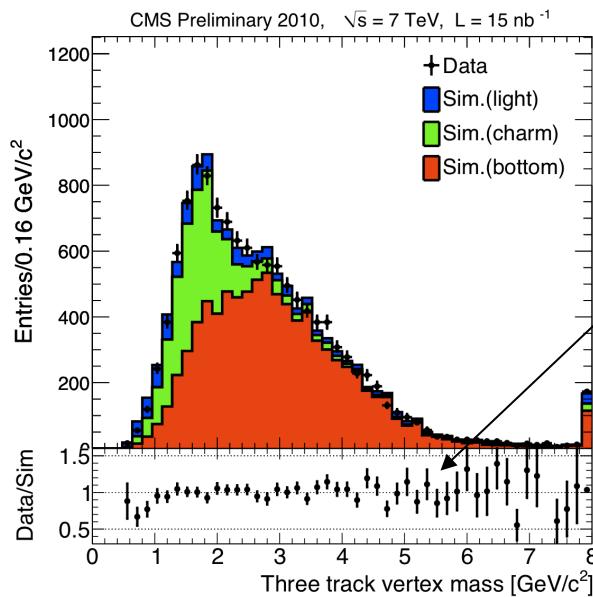
Top candidate event with two opposite sign muon



# Data-MC comparison for b-tagging observables

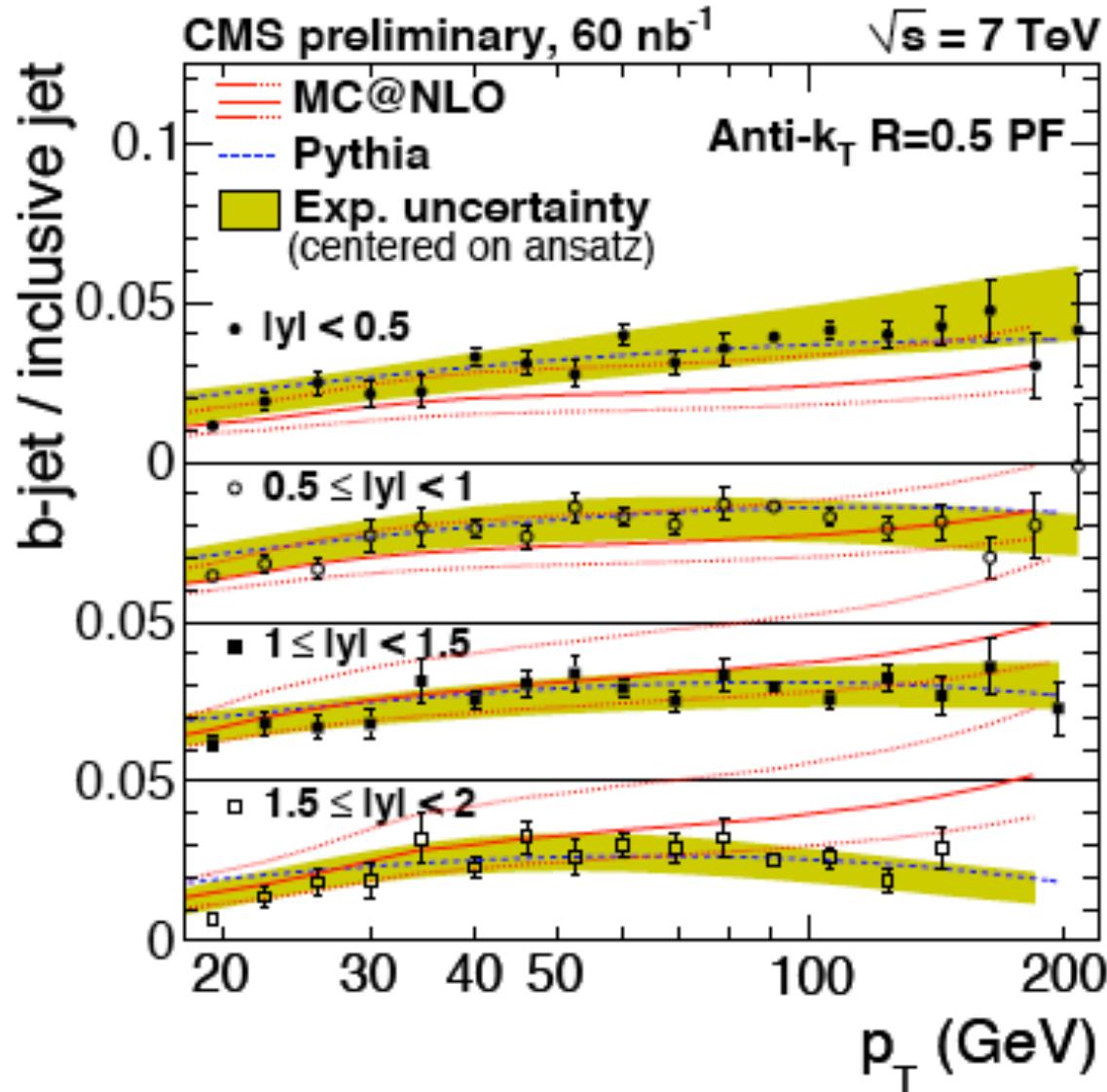


DATA/MC ratio is  
close to 1 for all  
observables





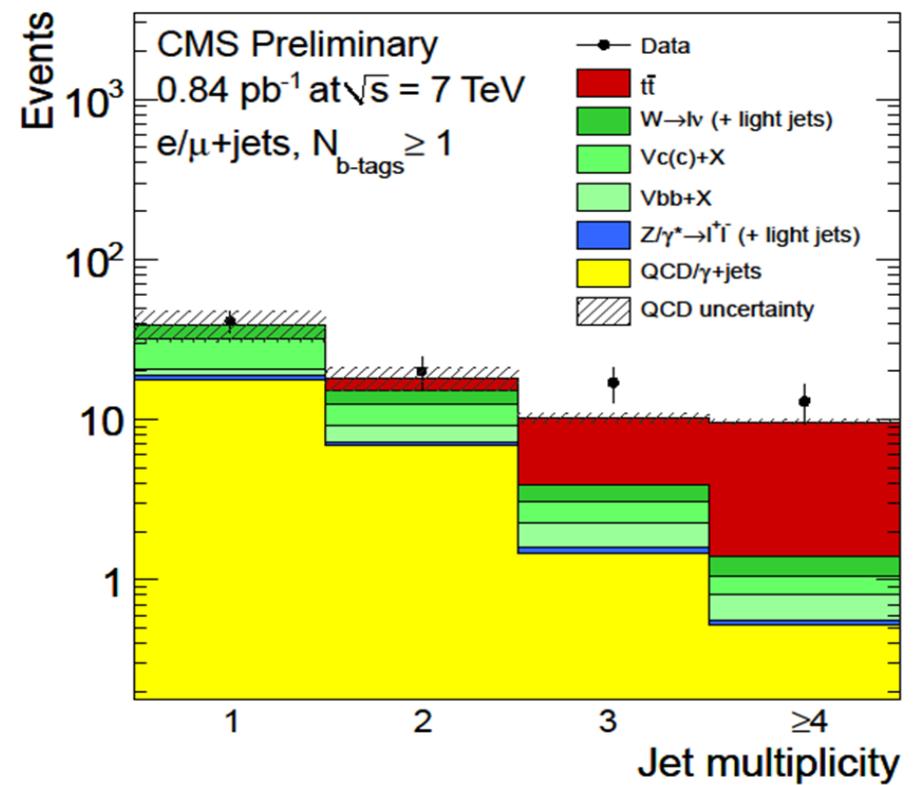
# Fraction of b-tagged jets





# t-tbar : lepton+jets

- Using  $0.84\text{pb}^{-1}$  and requiring at least 1 secondary vertex tagger with  $\geq 2$  tracks;
  - $\sim 50\%$  efficiency  $\sim 1\%$  fake rate
- $N(\text{jets}) \geq 3$ 
  - 30 signal candidates over a predicted background of 5.3
- $t\bar{t}$  rate consistent with NLO cross section
  - Up to experimental (JES, b-tagging) and theoretical (scale, PDF, HF modeling, ...) uncertainties.



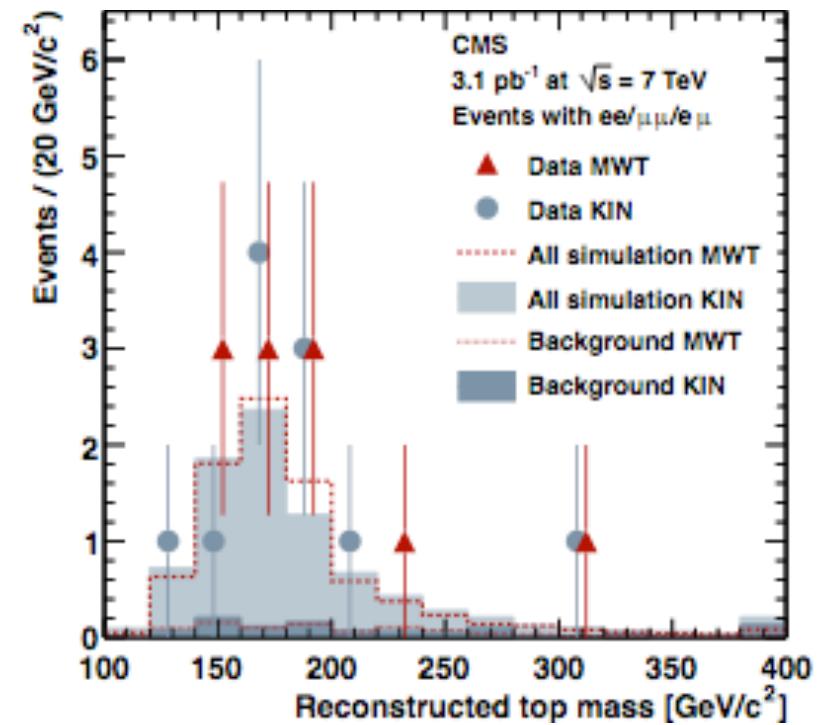
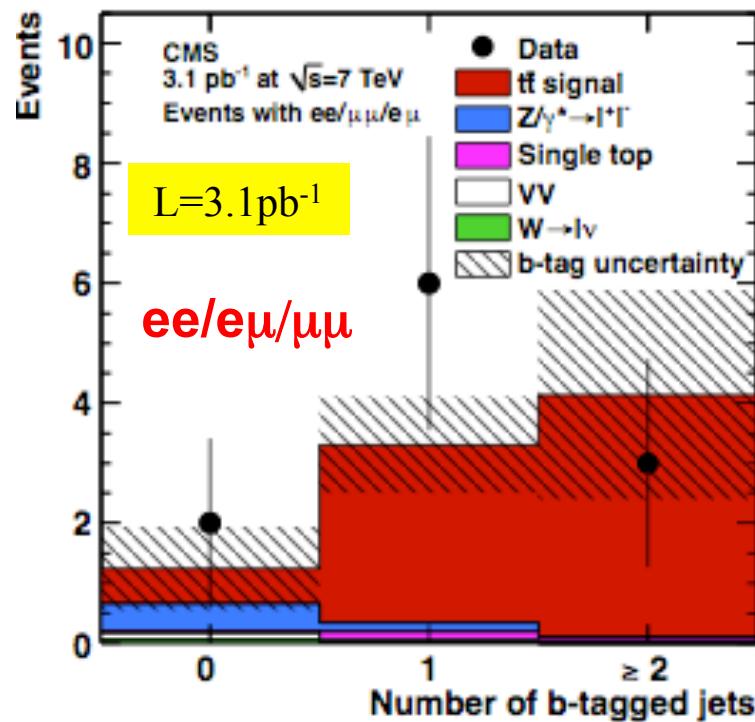


# Top cross section in the di-leptonic channel

arXiv:1010.5994

Full selection applied: Z-Veto,  $|M(l\bar{l}) - M(Z)| > 15 \text{ GeV}$   
 $\text{MET} > 30 \text{ (20) GeV in ee, }\mu\mu, (\text{e}\mu); N(\text{jets}) \geq 2$

$$\bar{\sigma}(\text{pp} \rightarrow t\bar{t}) = 194 \pm 72(\text{stat.}) \pm 24(\text{syst.}) \pm 21(\text{lumi.}) \text{ pb}$$

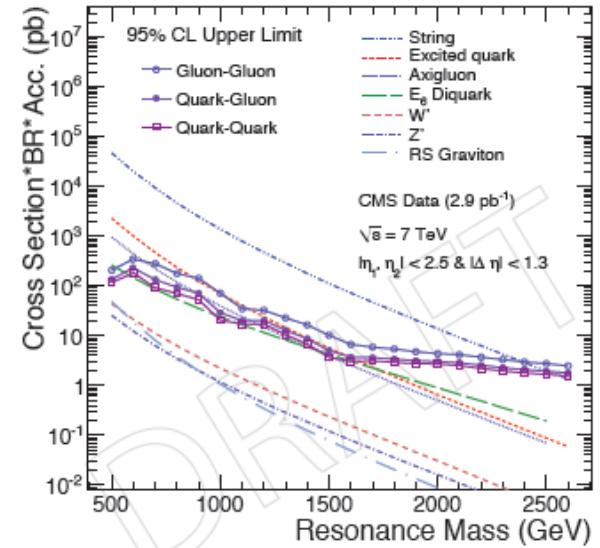
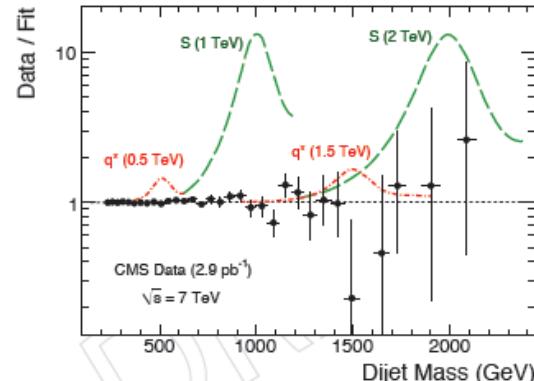
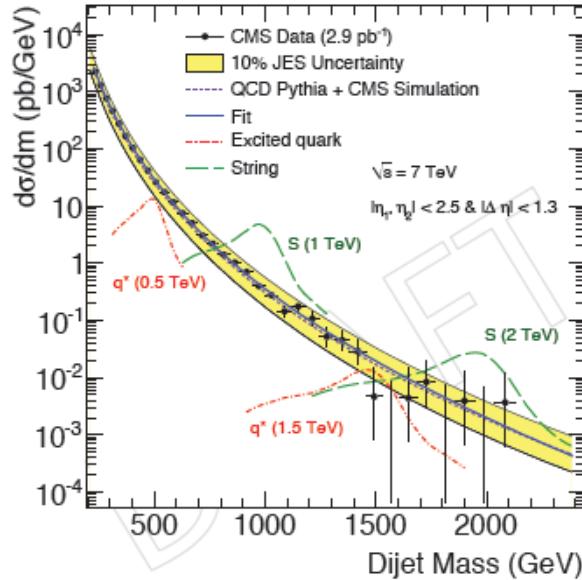


# First Searches for new Physics



# Di-Jet resonances

arXiv:1010.0203



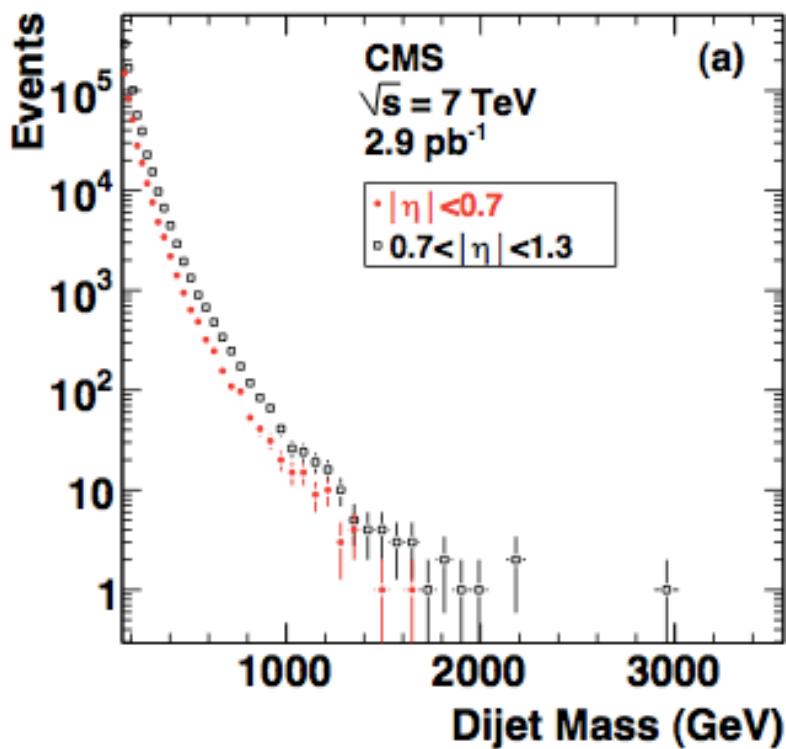
- ◆ **Search for narrow resonances in di-jet final states.**
  - ❖ Differential cross section for  $|\eta_1, \eta_2| < 2.5$  and  $|\Delta\eta_{12}| < 1.3$ .
    - Sensitive to coupling of any new massive object to quarks and gluons.
  - ❖ 95% CL mass limits
    - String resonances  $> 2.5$  TeV, Excited quarks  $> 1.58$  TeV
    - Axigluons/Colorons  $> 1.17$  TeV



# Quark compositeness/QCD

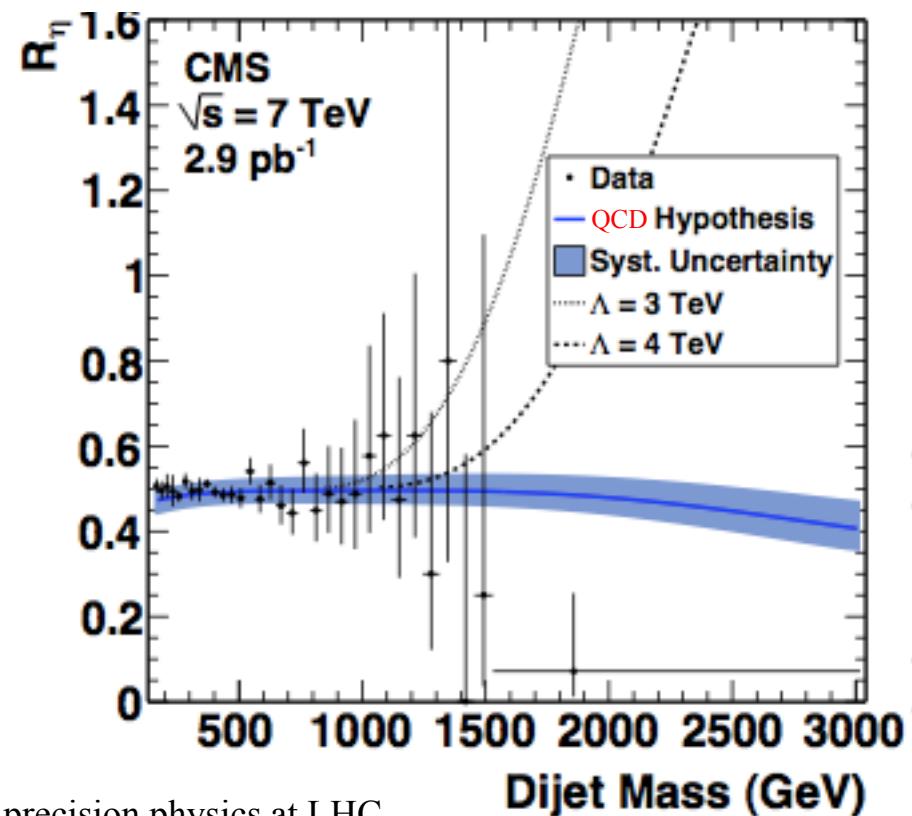
Centrality ratio

$$R_\eta = \frac{\sum_{|\eta|<0.7} Dijets}{\sum_{0.7<|\eta|<1.3} Dijets}$$



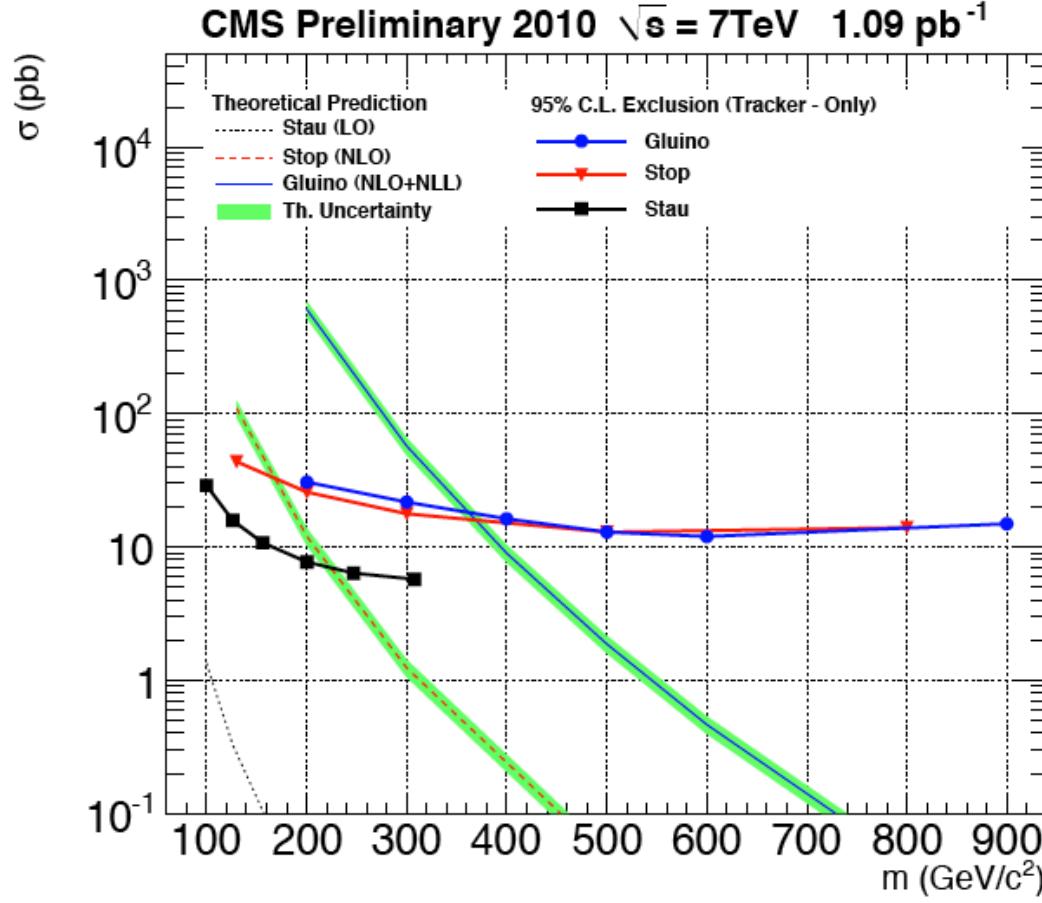
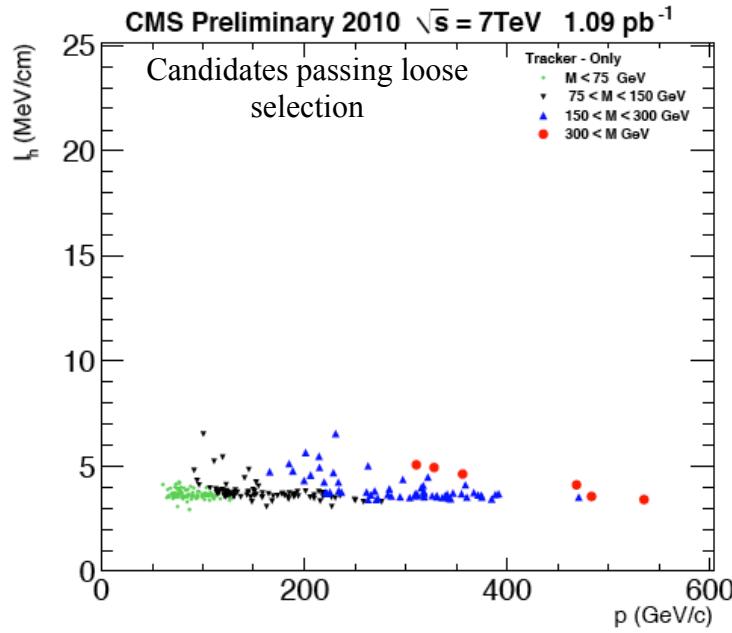
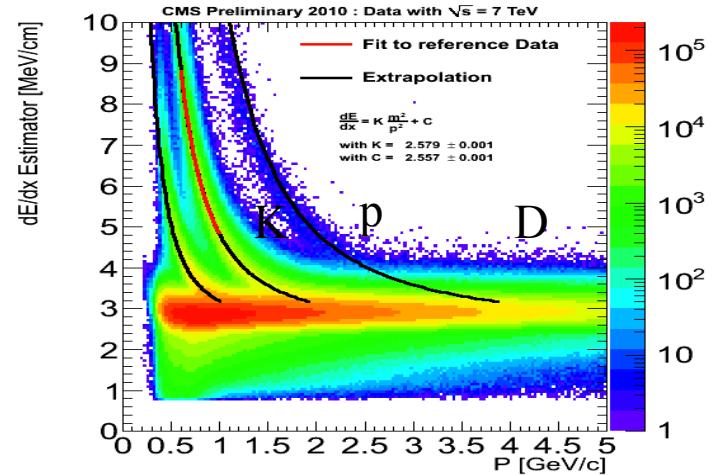
arXiv:1010.4439

Contact interaction: excluded for  $\Lambda < 4 \text{ TeV}$   
( higher than expected -2.9 TeV- due to fewer-than-expected events at high Dijet mass)





# Heavy Stables Charged Particles



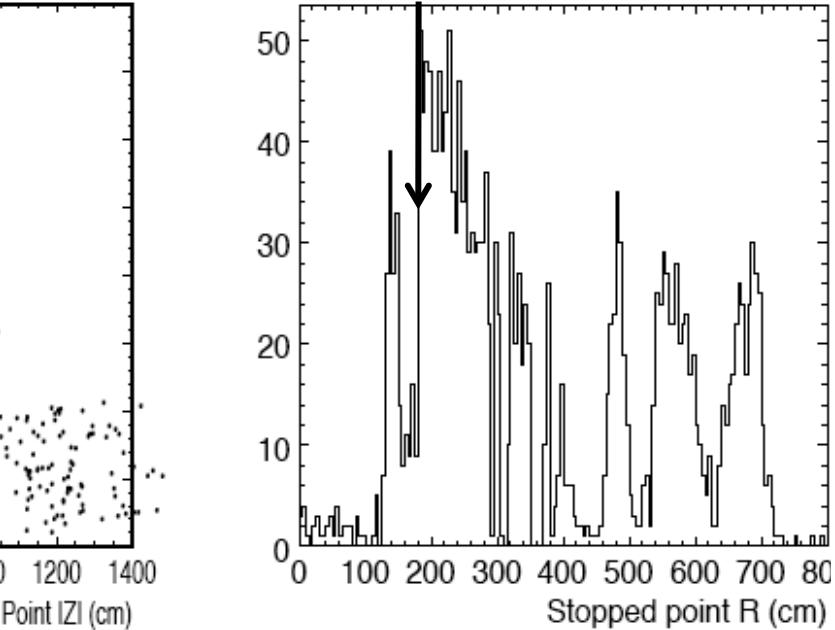
Tight Selection:  $0.088 \pm 0.021$  expected ;  
0 observed



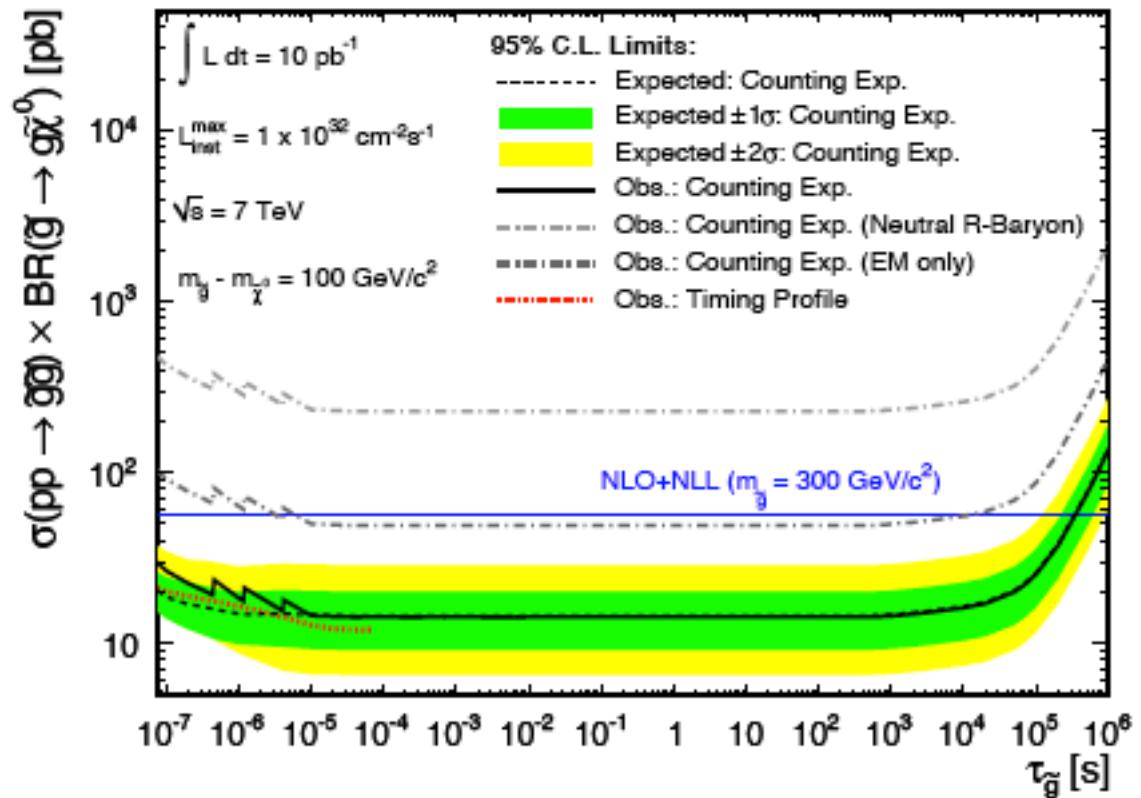
# Search for gluinos stopped in CMS

arXiv:1011.5861

HCAL



Data Taken out of collision time

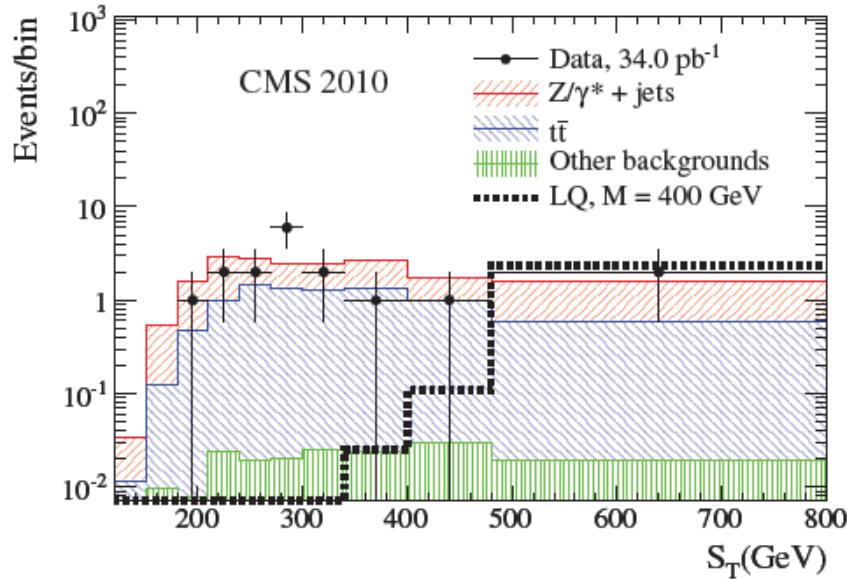


Gluinos with long lifetime hadronize to R-Hadrons that are stopped inside CMS and decay to gluon+ Neutralino, If the mass difference is large enough there is enough energy detected in the calorimeter to trigger.

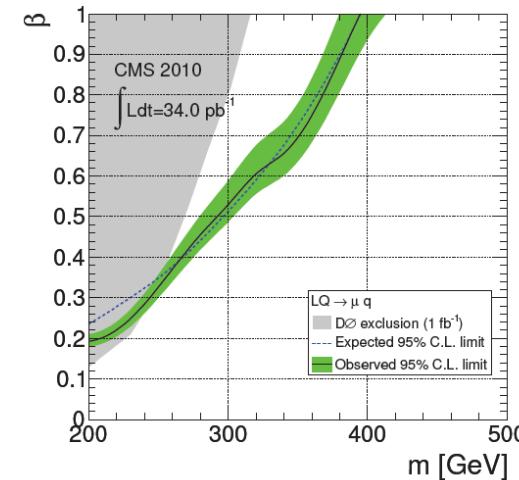


# Leptoquark search

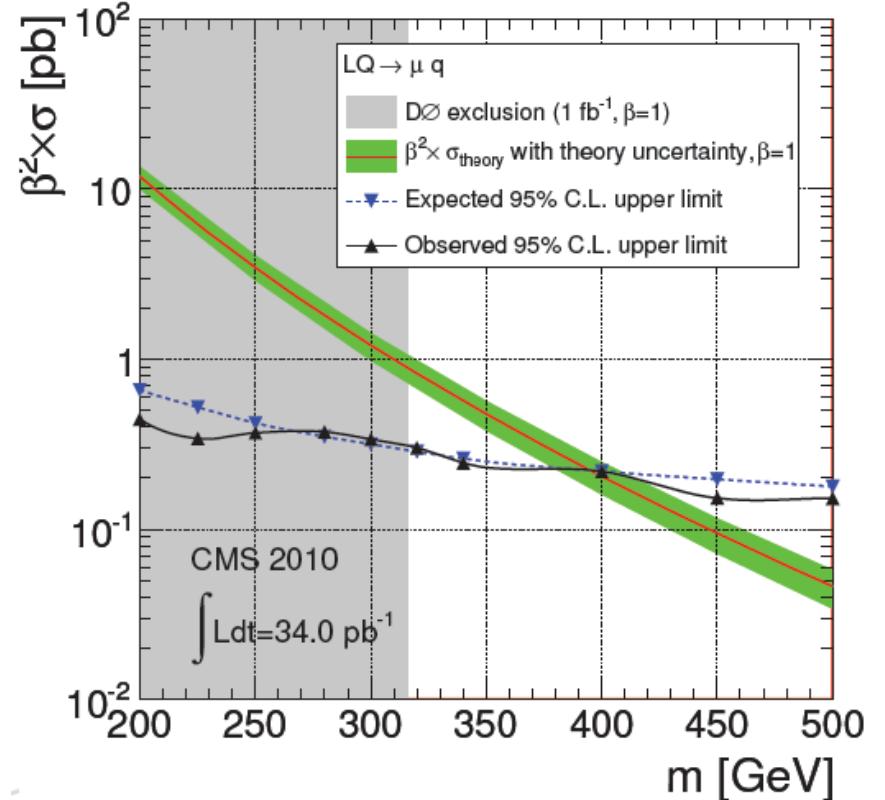
- ◆ Search for pair produced LQ decaying  $\beta\%$  in  $\mu + \text{jet}$



As a function of  $\beta$

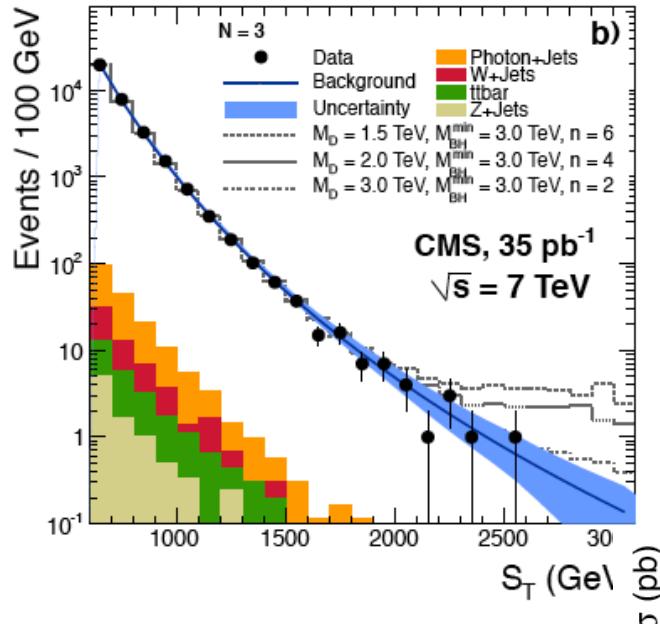


$$\text{Final discr variable } S_T = \sum_{u_1, u_2} p_t^\mu + \sum_{Jet_1, Jet_2} p_t^{jet}$$

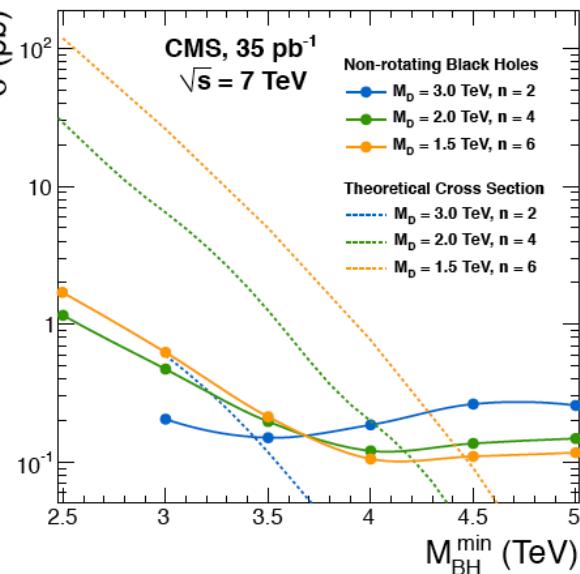
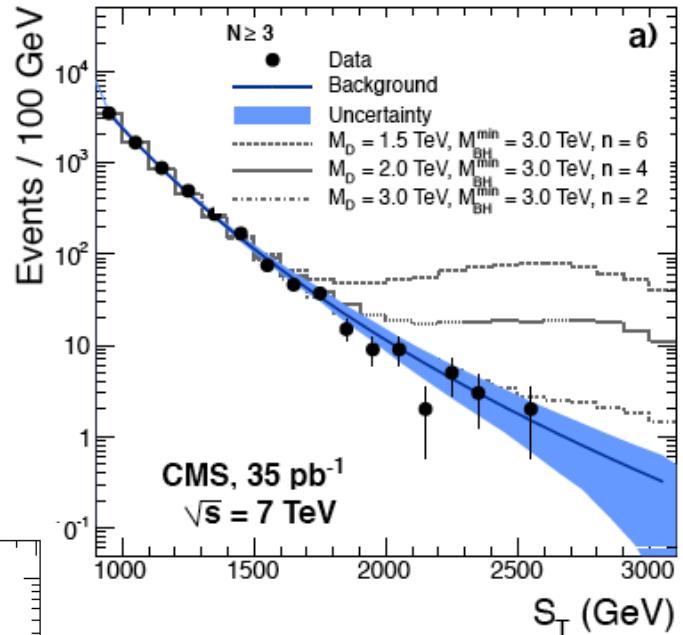




# Search for microscopic black holes



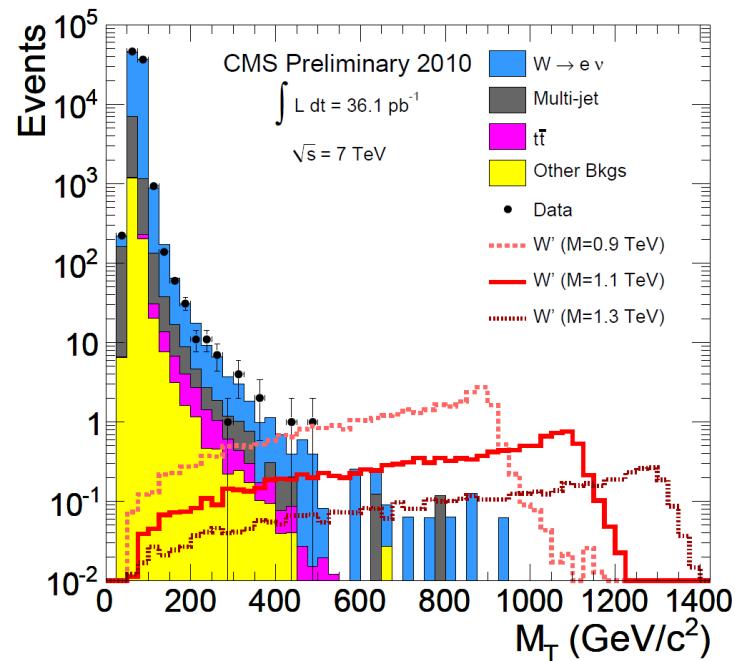
arXiv:1011.3375



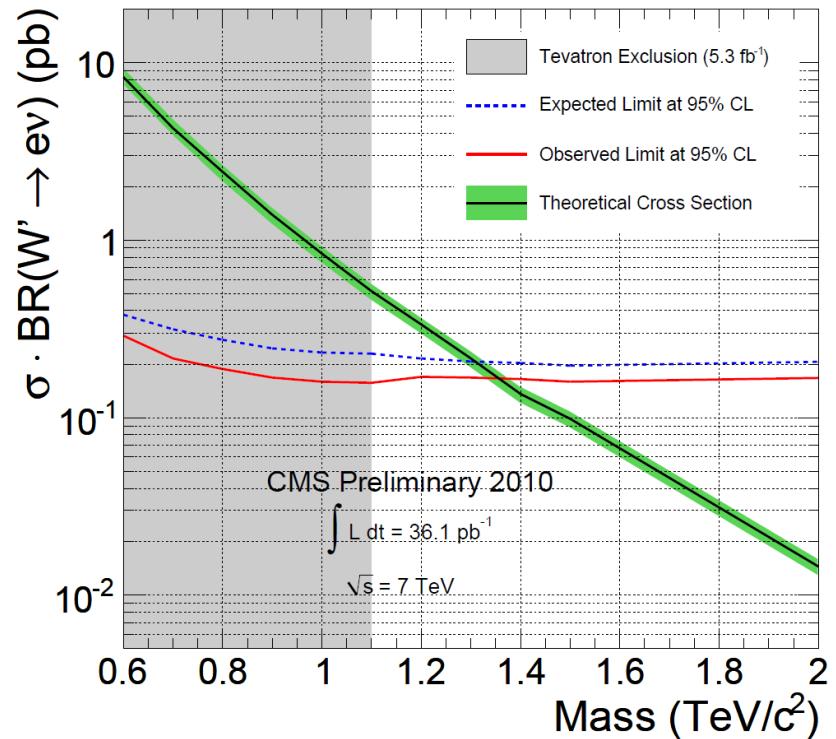
measuring ST as a function of the number of “objects”



# Search for W'

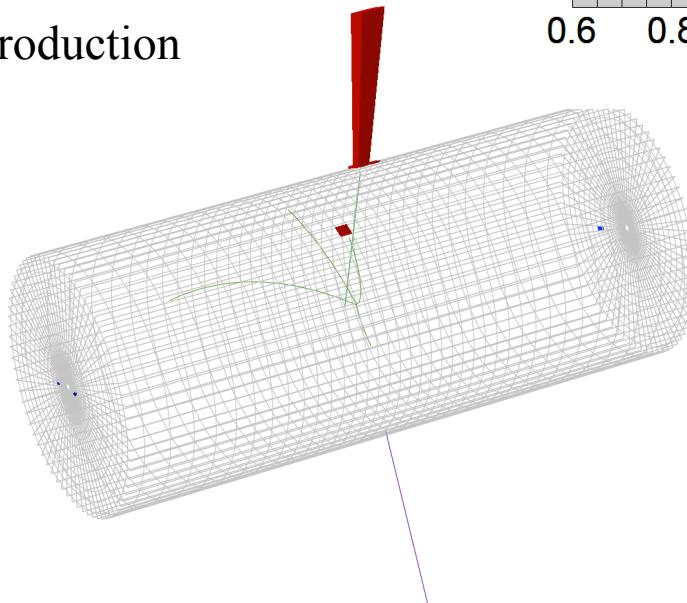


BKG dominated by W production



**Expected Limit = 1.31 TeV**  
**Observed Limit = 1.36 TeV**

$m_T = 493 \text{ GeV}$



December 16, 2010

at LHC



# Search for Supersymmetry

perspective January 2010

All hadronic – based on missing energy

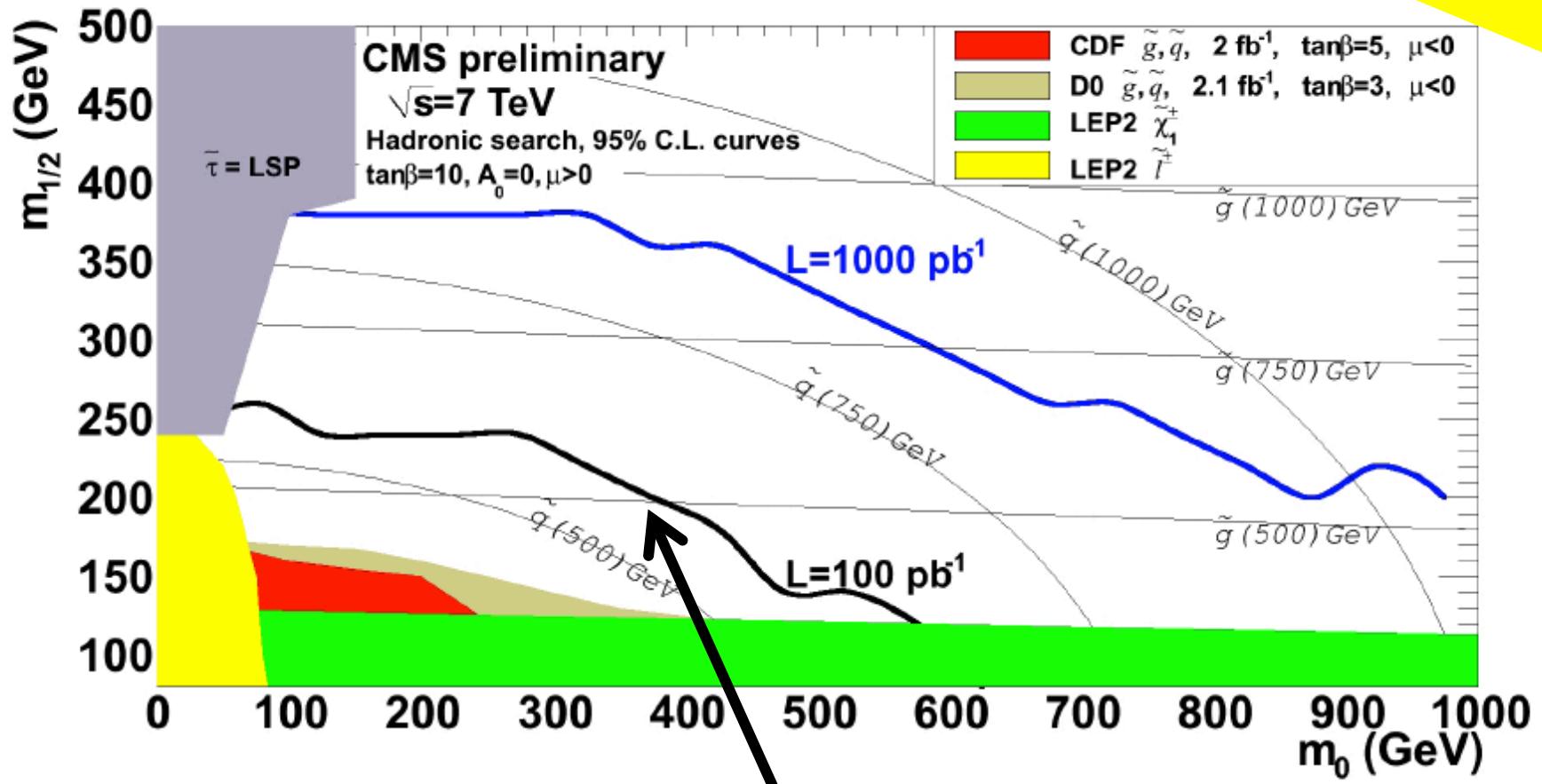
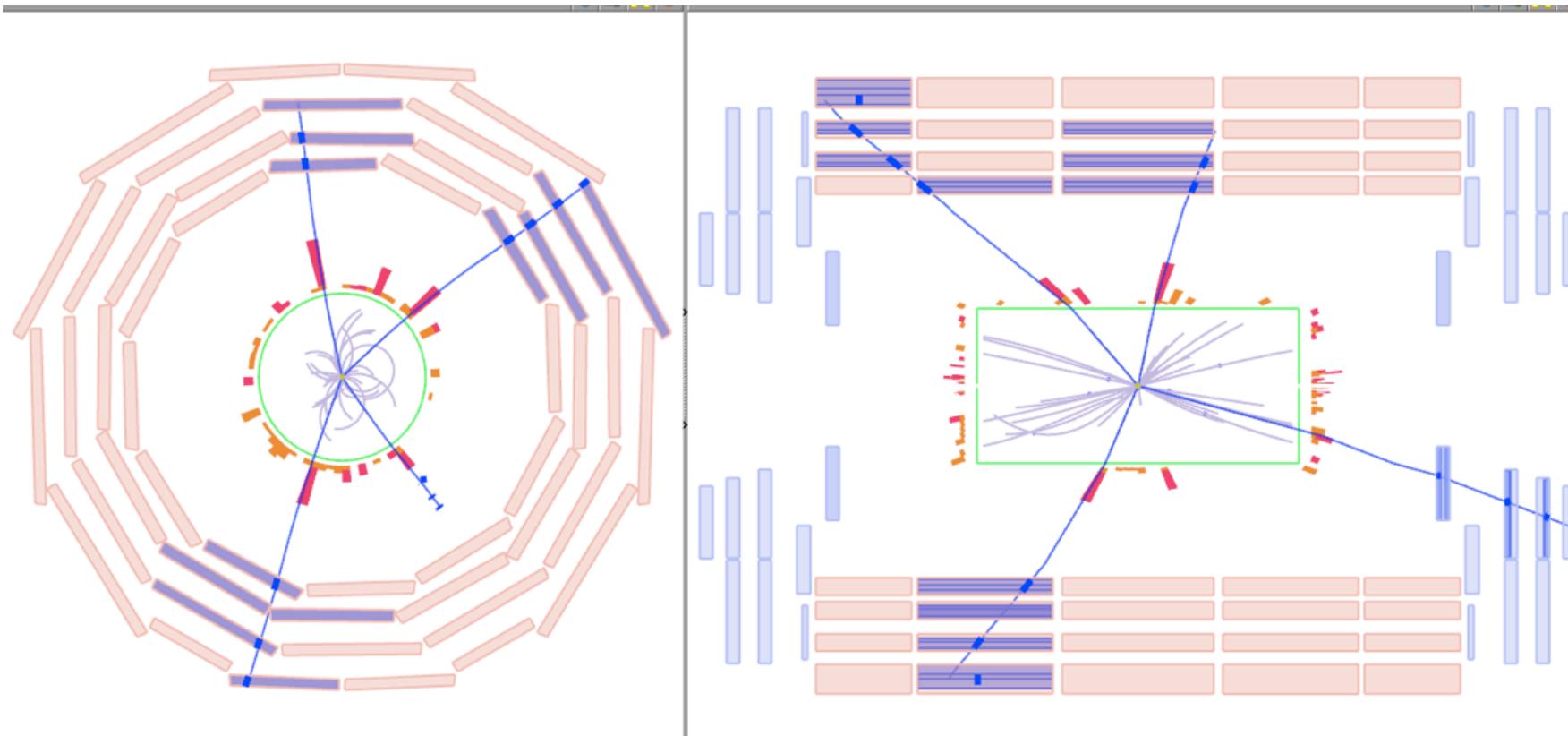


Fig. a limit similar to this one will be set by CMS with the data of the 2010 run parameter space.



# A beautiful ZZ event



## Invariant Masses

$\mu_0 + \mu_1$ : 92.15 GeV (total( $Z$ )  $p_T$  26.5 GeV,  $\phi$  -3.03),  
 $\mu_2 + \mu_3$ : 92.24 GeV (total( $Z$ )  $p_T$  29.4 GeV,  $\phi$  +.06),  
 $\mu_0 + \mu_2$ : 70.12 GeV (total  $p_T$  27 GeV),  
 $\mu_3 + \mu_1$ : 83.1 GeV (total  $p_T$  26.1 GeV).



December 16, 2010

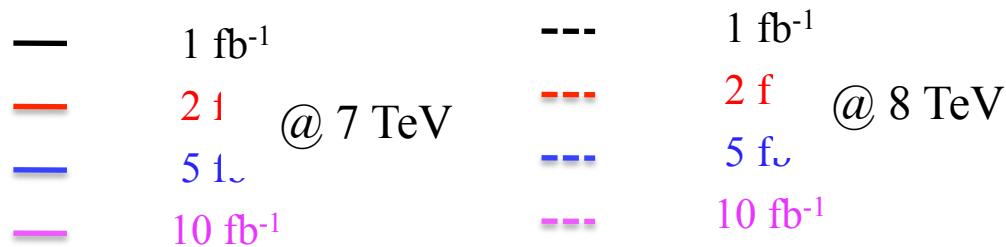
Challenges for precision physics at LHC

**Invariant Mass of  $4\mu$ : 201 GeV**

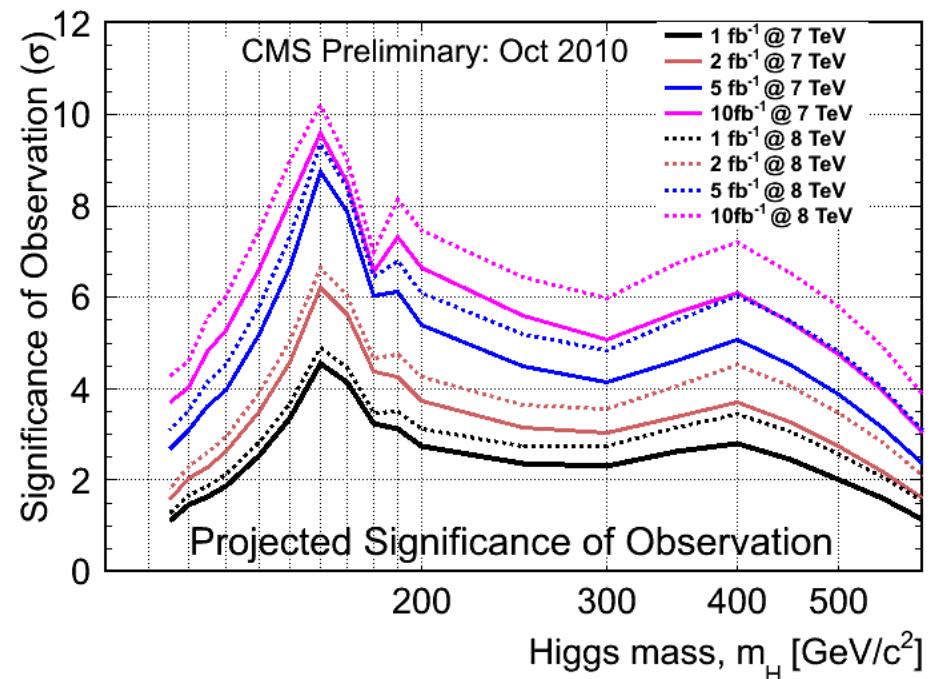
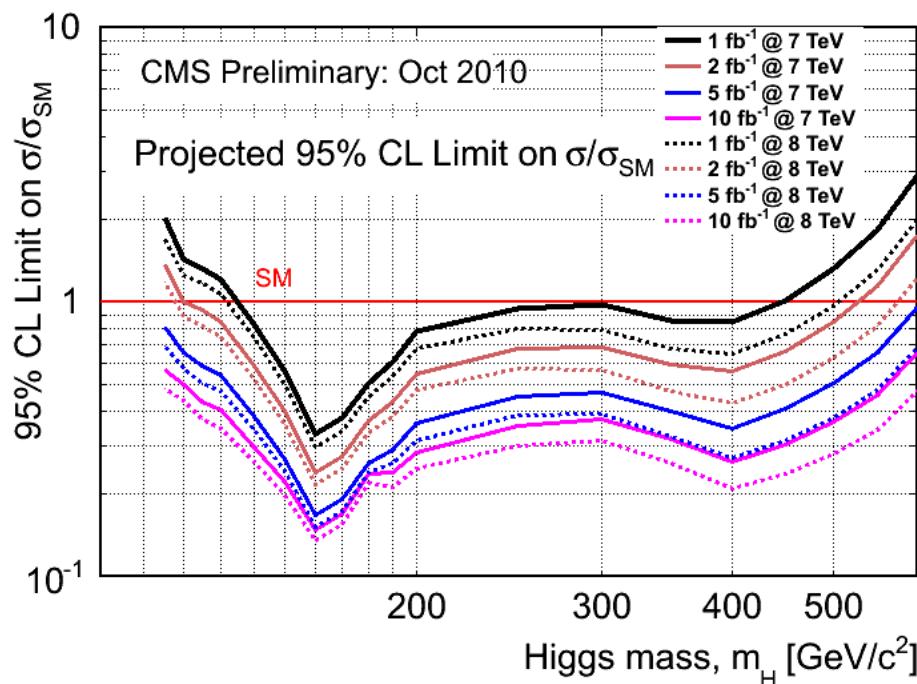


# Higgs search perspectives

5 to 10  $\text{fb}^{-1}$  of accumulated lumi become very interesting



With  $5 \text{ fb}^{-1}$  can exclude or have  
3  $\sigma$  evidence from 114 to 600  
GeV



# Observation of an unexpected angular correlation in high multiplicity events

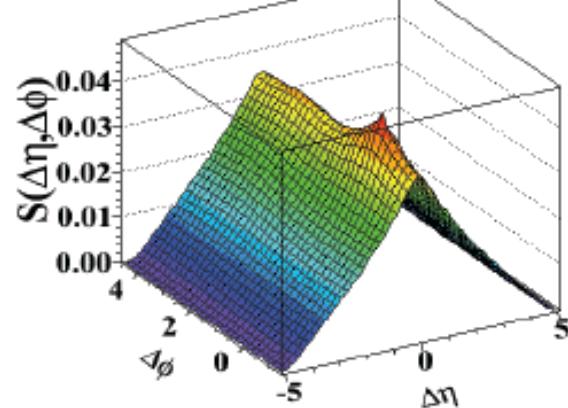
arXiv:1009.4122



# Correlation Function Definition

Signal distribution:

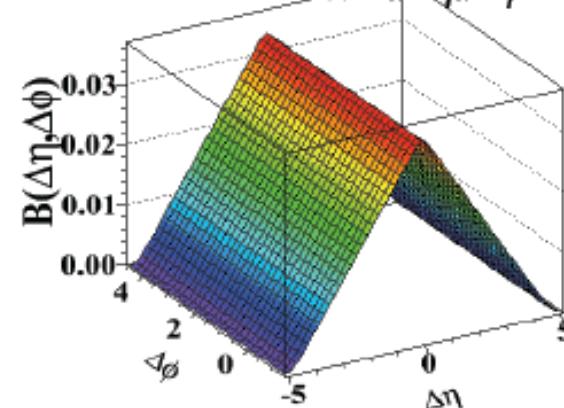
$$S_N(\Delta\eta, \Delta\varphi) = \frac{1}{N(N-1)} \frac{d^2 N^{signal}}{d\Delta\eta d\Delta\varphi}$$



Same event pairs

Background distribution:

$$B_N(\Delta\eta, \Delta\varphi) = \frac{1}{N^2} \frac{d^2 N^{bkg}}{d\Delta\eta d\Delta\varphi}$$

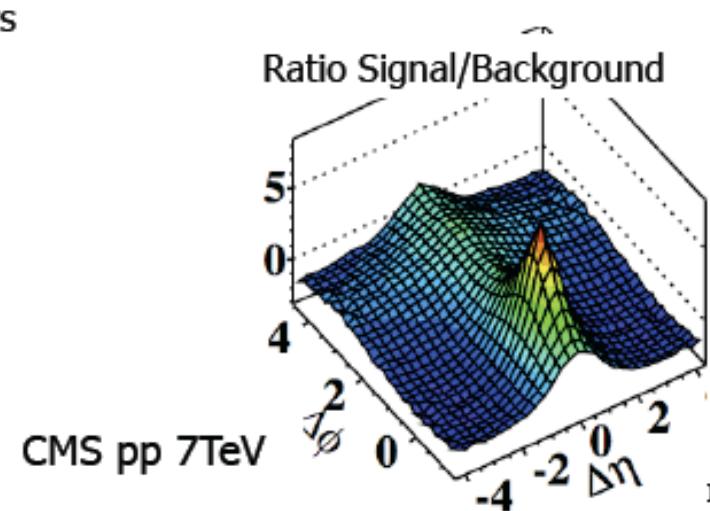


Mixed event pairs

Ratio Signal/Background

$$R(\Delta\eta, \Delta\varphi) = \left\langle (N-1) \left( \frac{S_N(\Delta\eta, \Delta\varphi)}{B_N(\Delta\eta, \Delta\varphi)} - 1 \right) \right\rangle_N$$

p<sub>T</sub>-inclusive two-particle angular correlations in min bias collisions



$$\Delta\eta = \eta_1 - \eta_2$$

$$\Delta\varphi = \varphi_1 - \varphi_2$$

# Results

Intermediate  $p_T$ : 1-3 GeV/c

MinBias

(b) MinBias,  $1.0 \text{ GeV}/c < p_T < 3.0 \text{ GeV}/c$

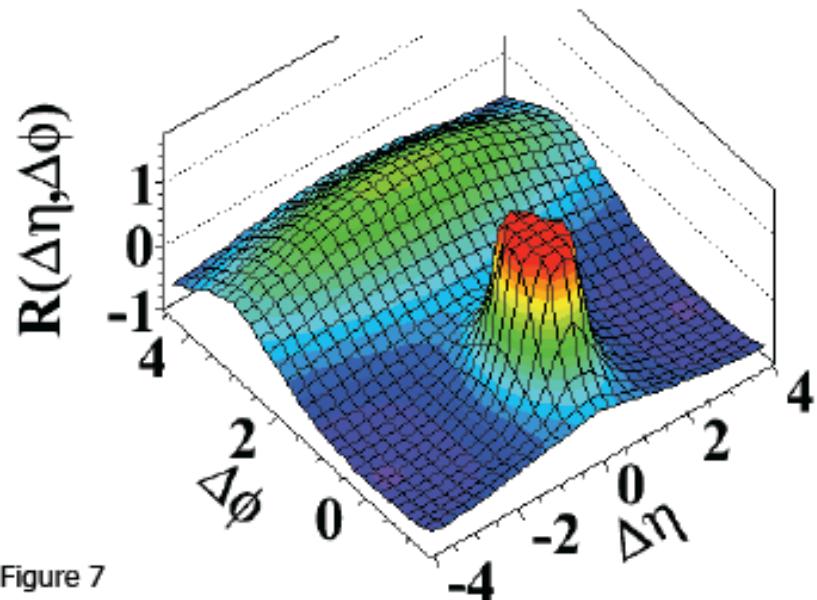
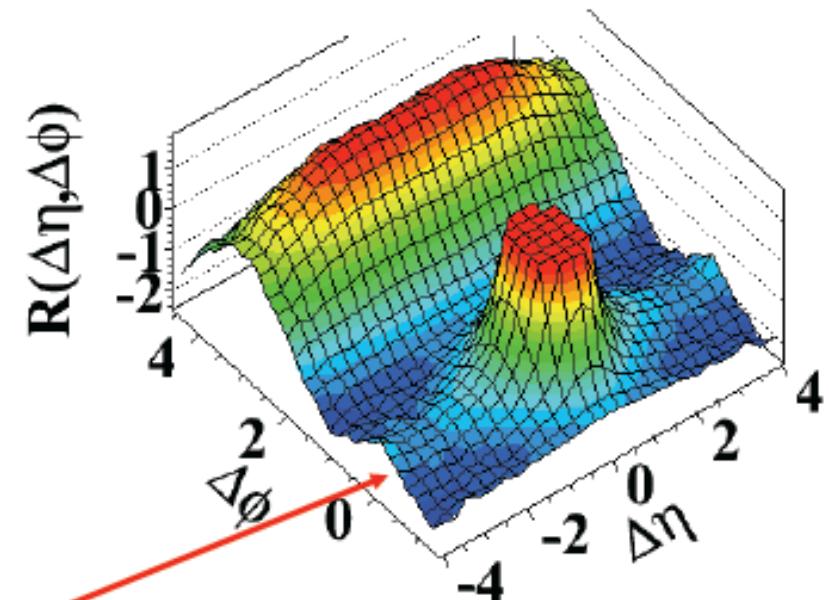


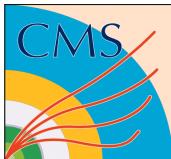
Figure 7

high multiplicity ( $N > 110$ )

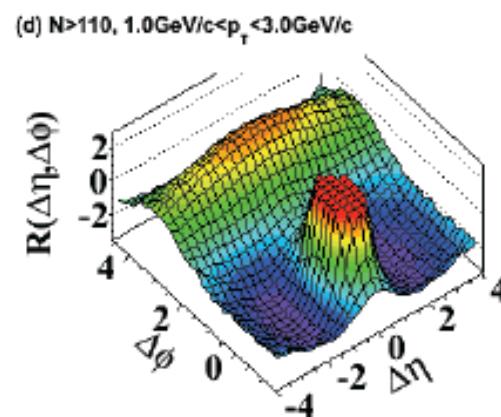
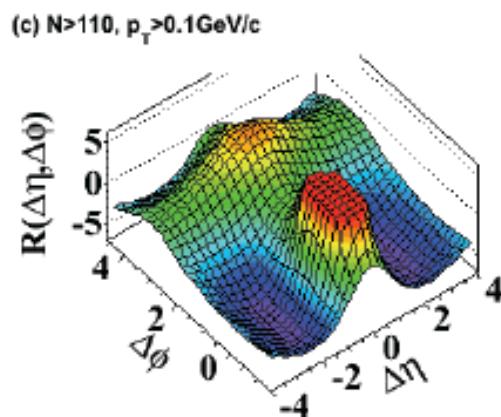
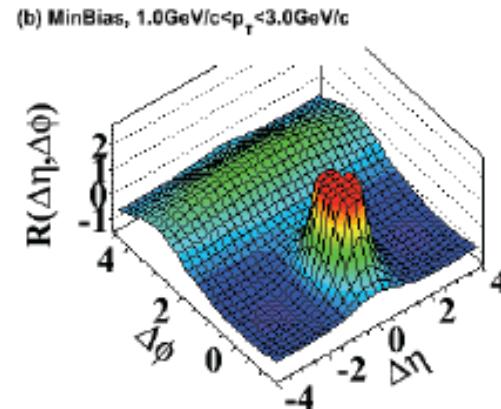
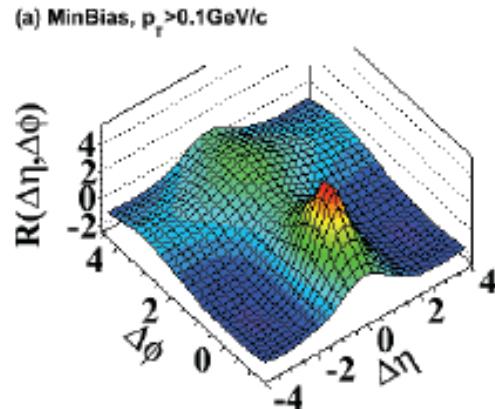
(d)  $N > 110$ ,  $1.0 \text{ GeV}/c < p_T < 3.0 \text{ GeV}/c$



Pronounced structure at large  $\delta\eta$  around  $\delta\phi \sim 0$  !



# Structure not present in QCD Monte Carlo



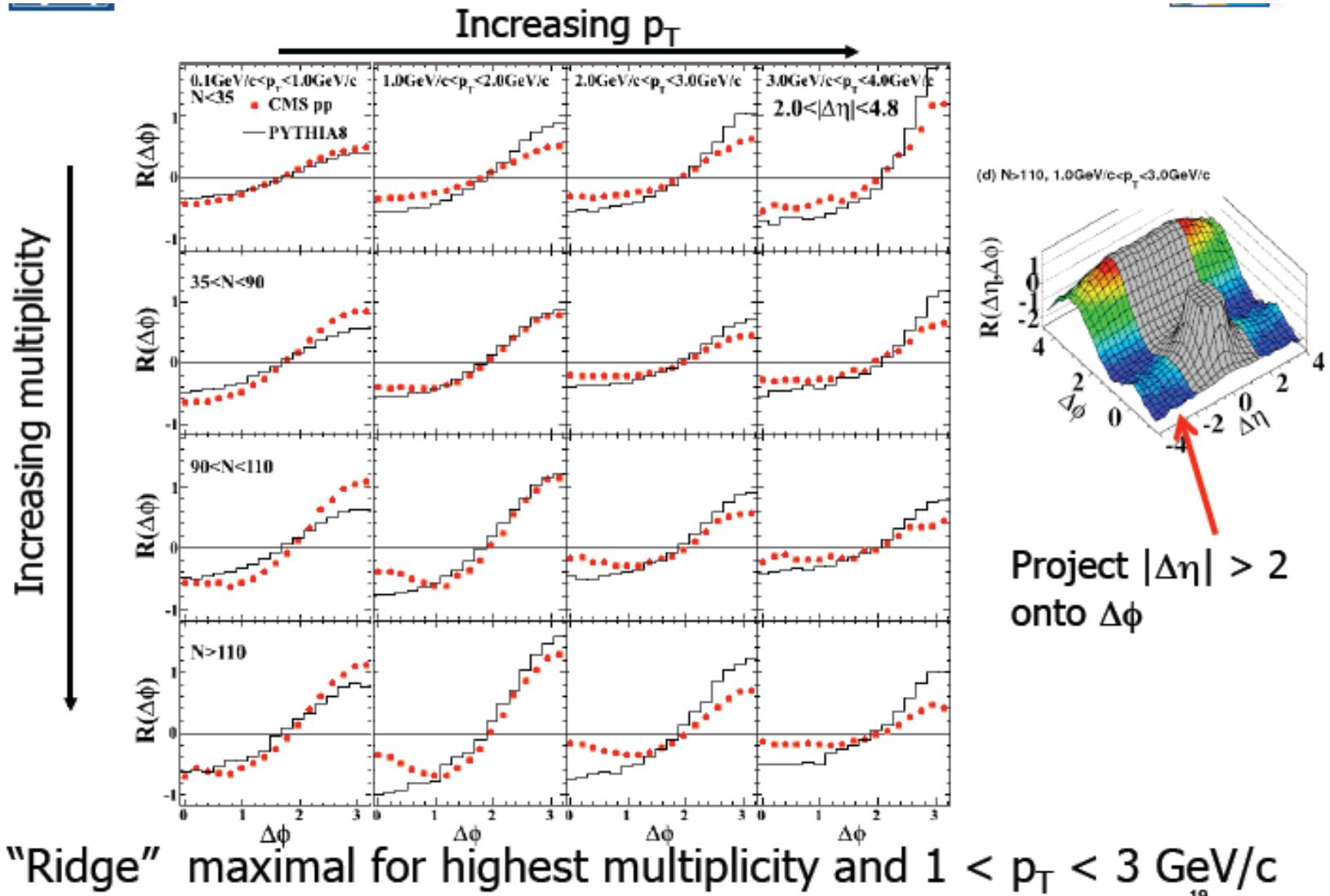
Many data driven tests done to  
assess systematic effect (pileup,  
beam background, tracking,  
trigger)

The signal is stable and  
observed also using photons  
detected in the electromagnetic  
calorimeter

No  $\delta\phi \sim 0$  structure in PYTHIA 8 at large  $\delta\eta$   
Same for Herwig++, madgraph, PYTHIA6



# Multiplicity and Pt dependence



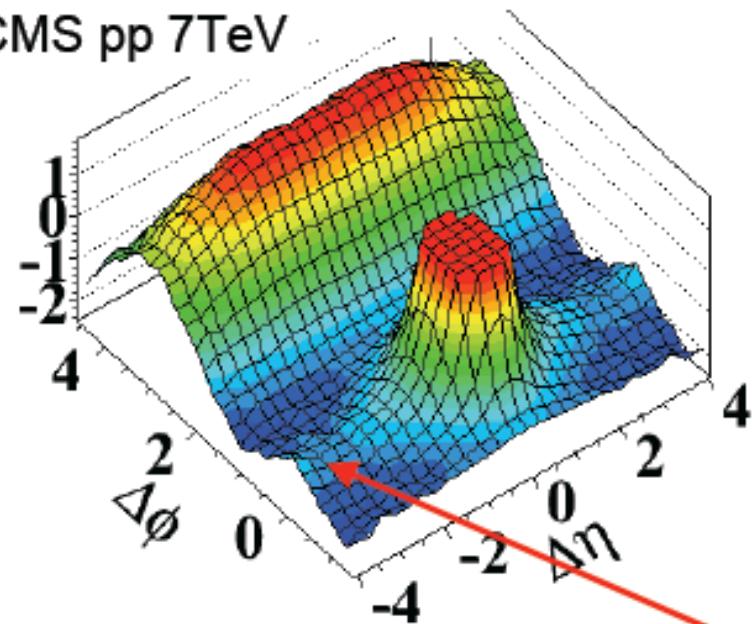


# Correlation in Heavy Ions Collisions

(d)  $N > 110$ ,  $1.0 \text{ GeV}/c < p_T < 3.0 \text{ GeV}/c$

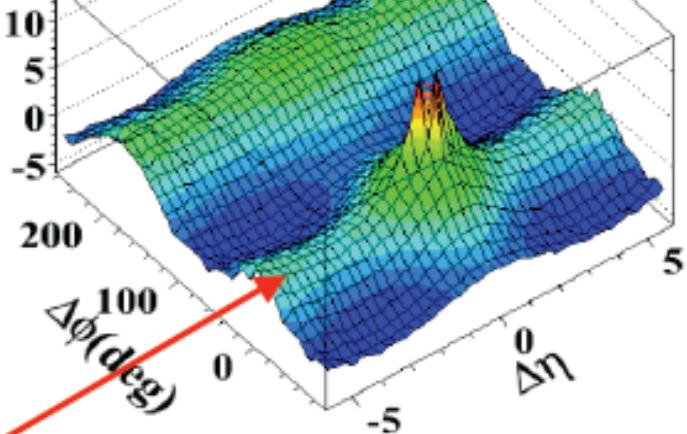
CMS pp 7TeV

$R(\Delta\eta, \Delta\phi)$



PHOBOS AuAu 200GeV

$R(\Delta\eta, \Delta\phi)$



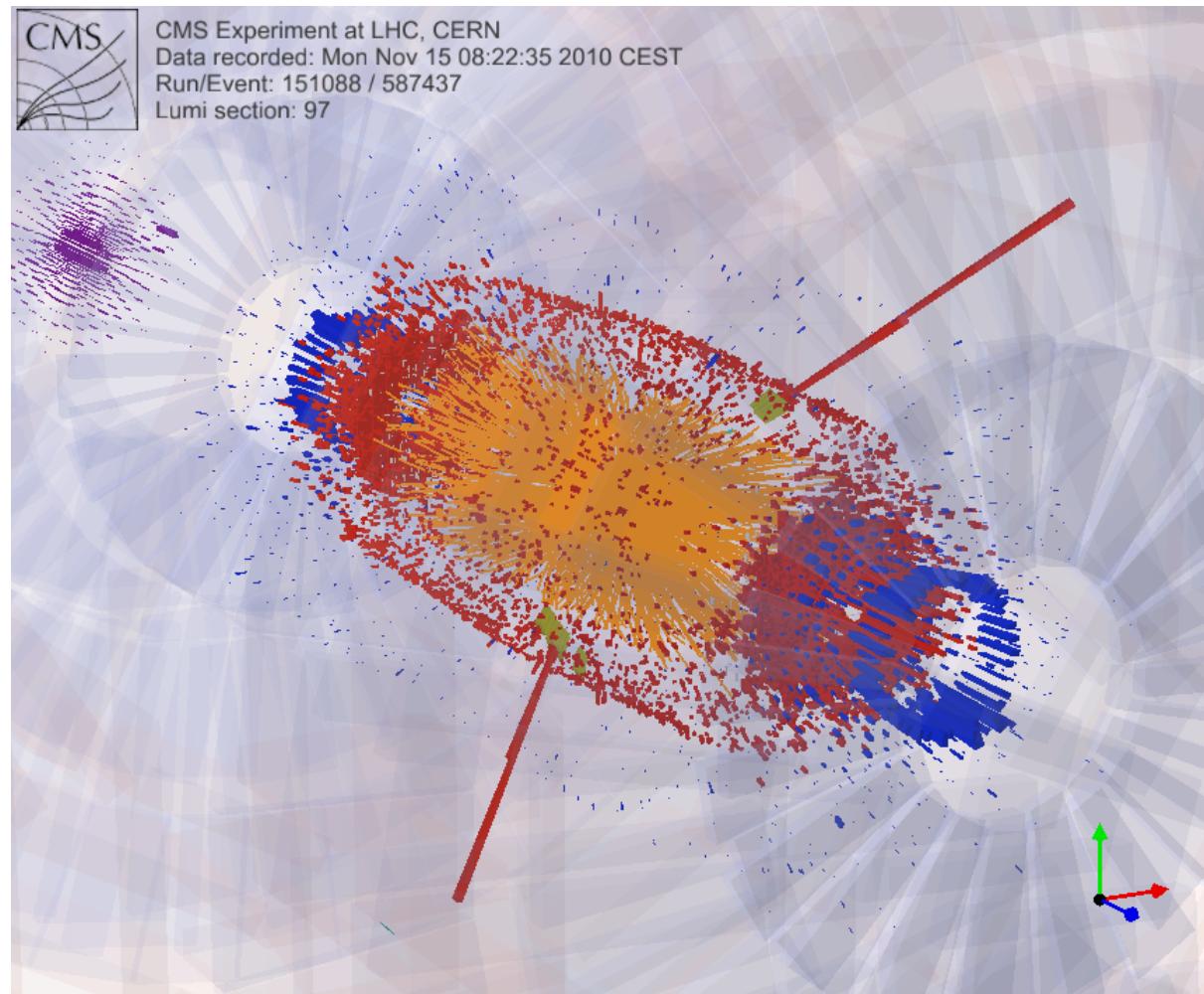
Similar “ridge” in high multiplicity pp and HI  
(even similar  $p_T$  dependence)

# CMS Heavy Ions Run



# Heavy Ions: $e^+e^- Z$ candidate

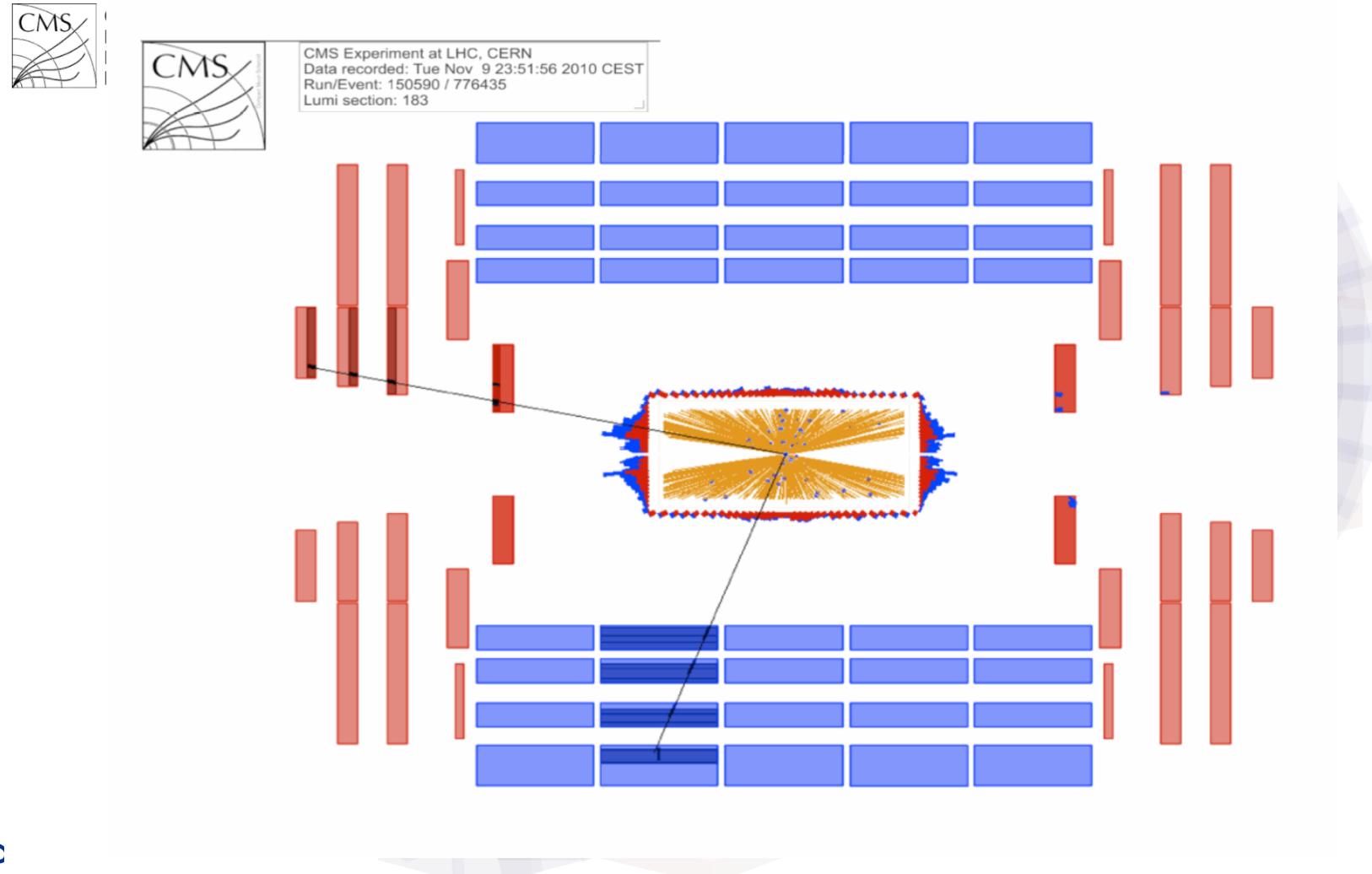
$M_{e^+e^-} = 96 \text{ GeV}$   
( $E_e$  not corrected for underlying event)

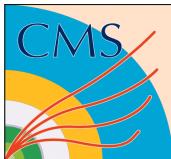
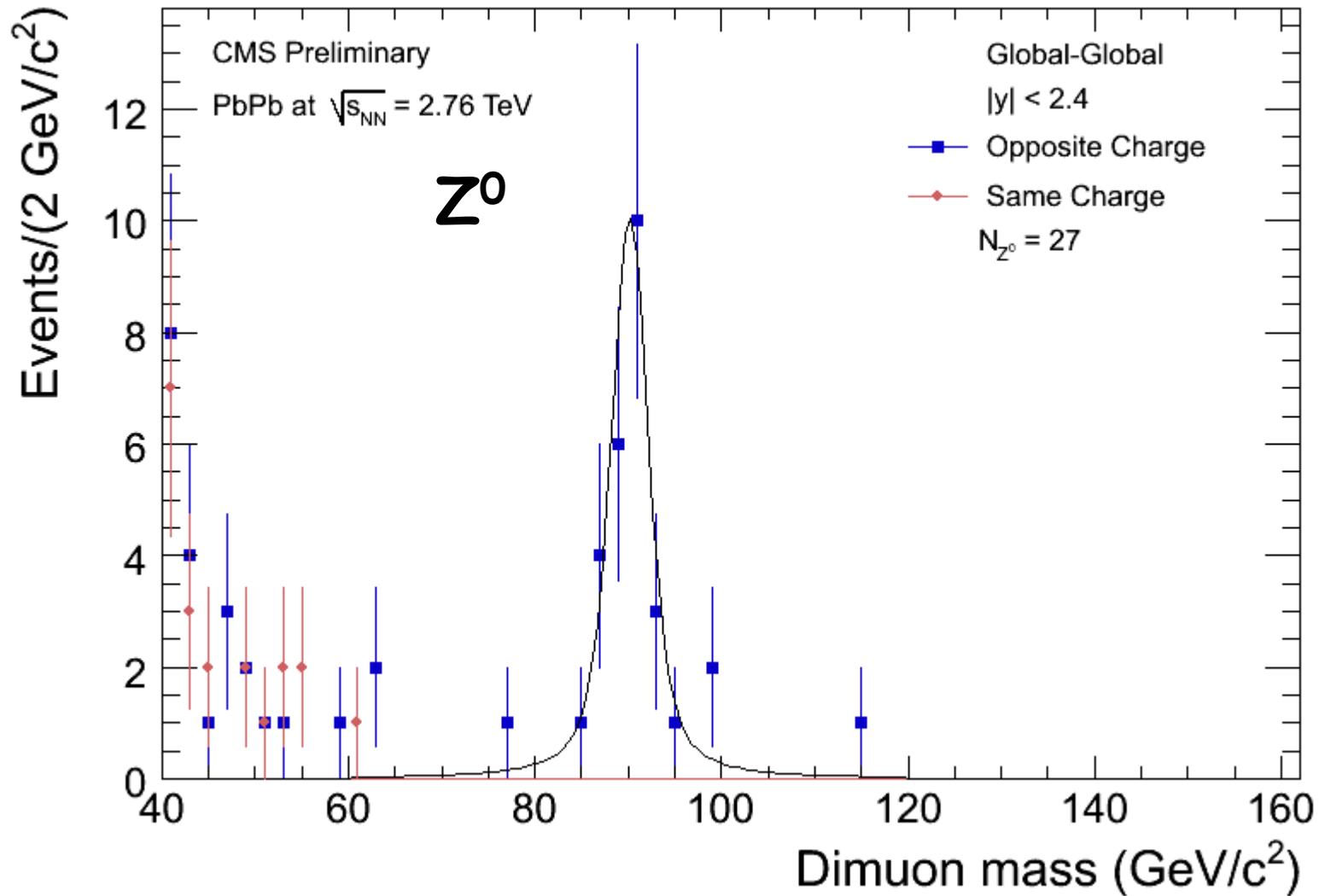




# Our first $\mu^+\mu^-$ Z candidate

$M_{\mu^+\mu^-} = 93 \text{ GeV}$  : possibly the first Z ever seen in HI

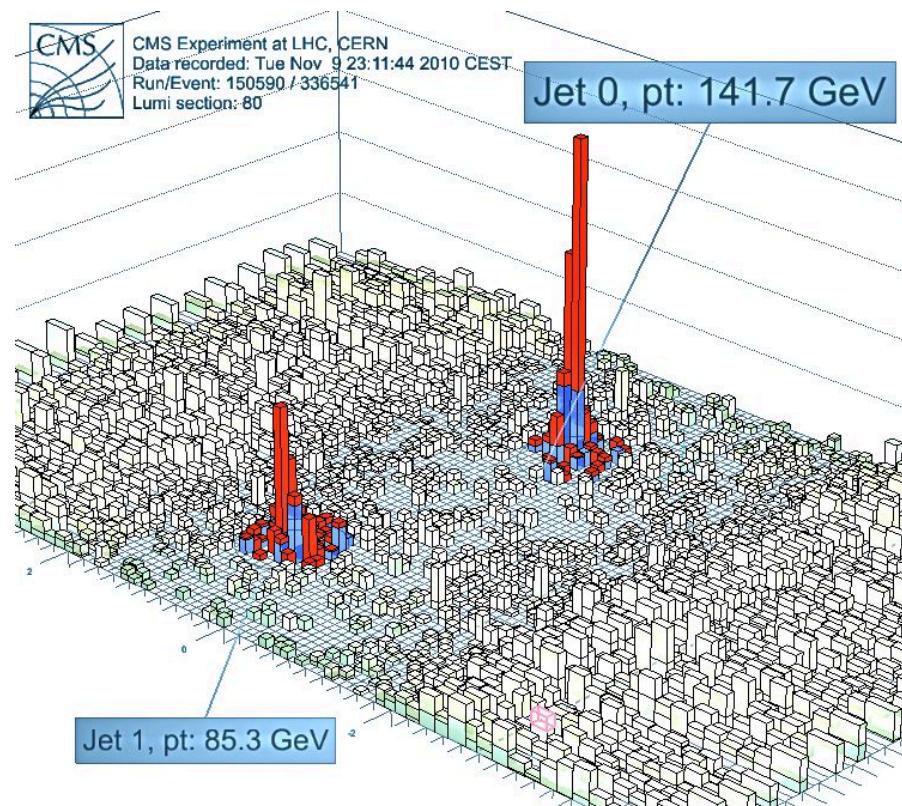
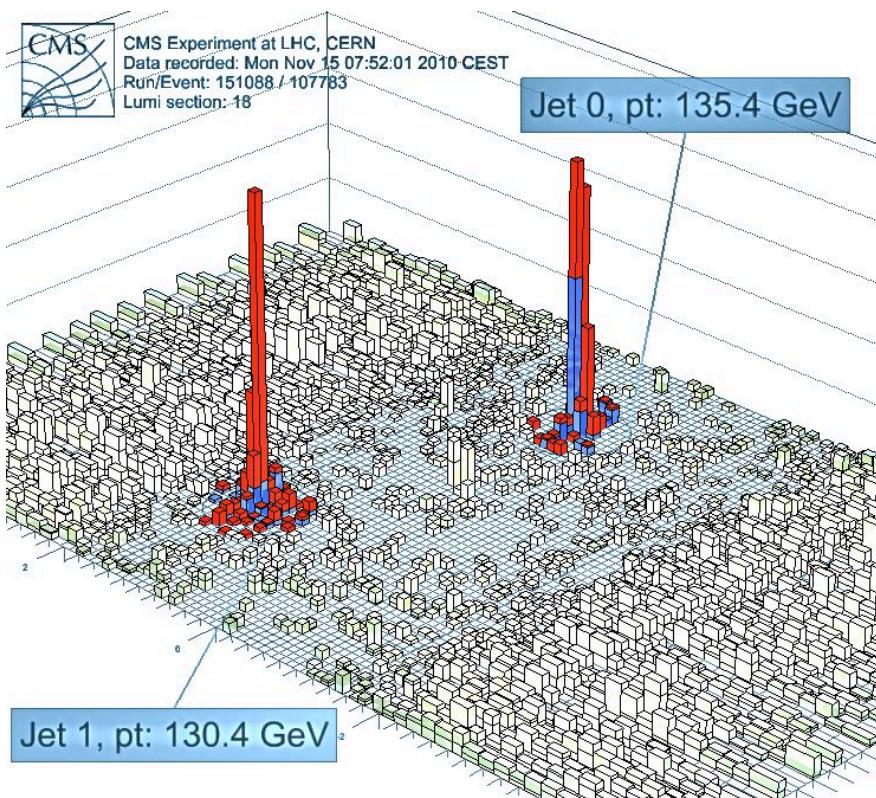


 $Z^0 \rightarrow \mu^+ \mu^-$ 



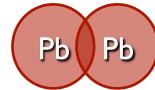
# Dijet event candidates in CMS

- First hours of LHC running
  - ◆ We see dijet events
  - ◆ We see dijets with unbalanced energy: is this real?





# Dijet energy imbalance



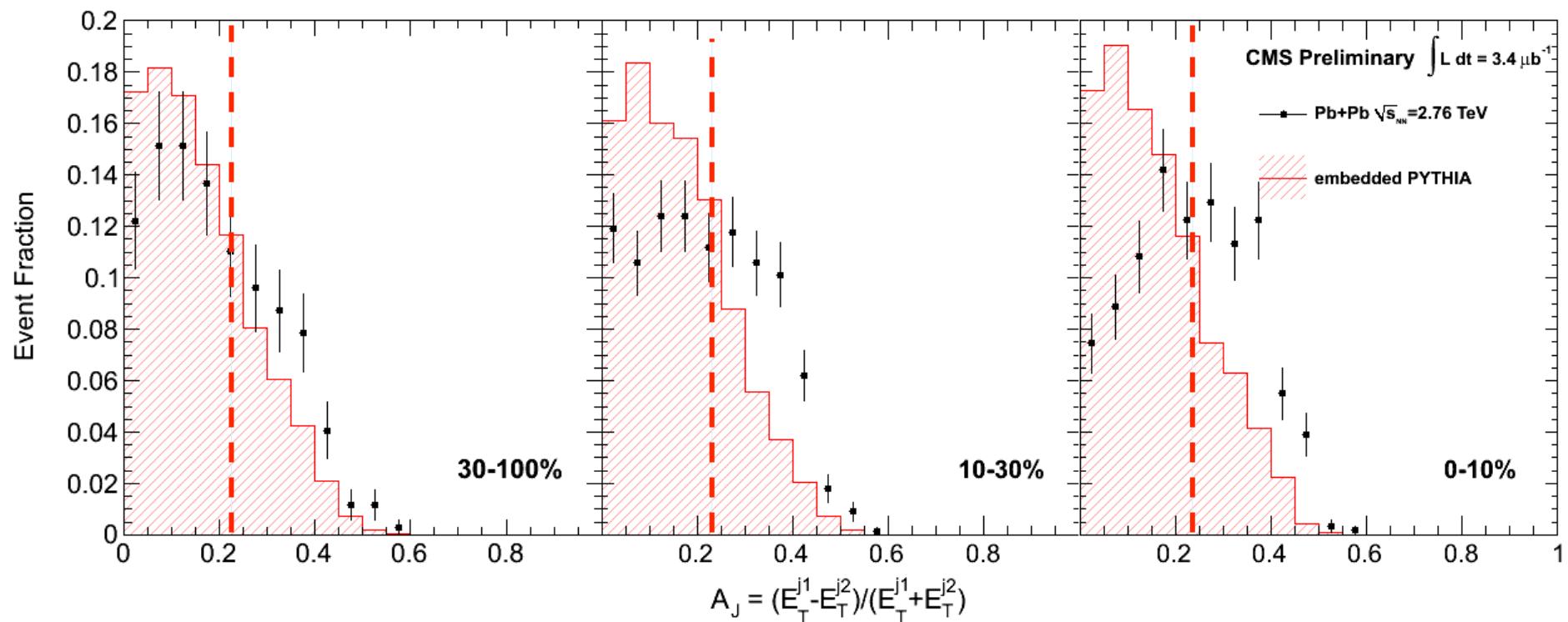
Semi-Peripheral



Semi-Central



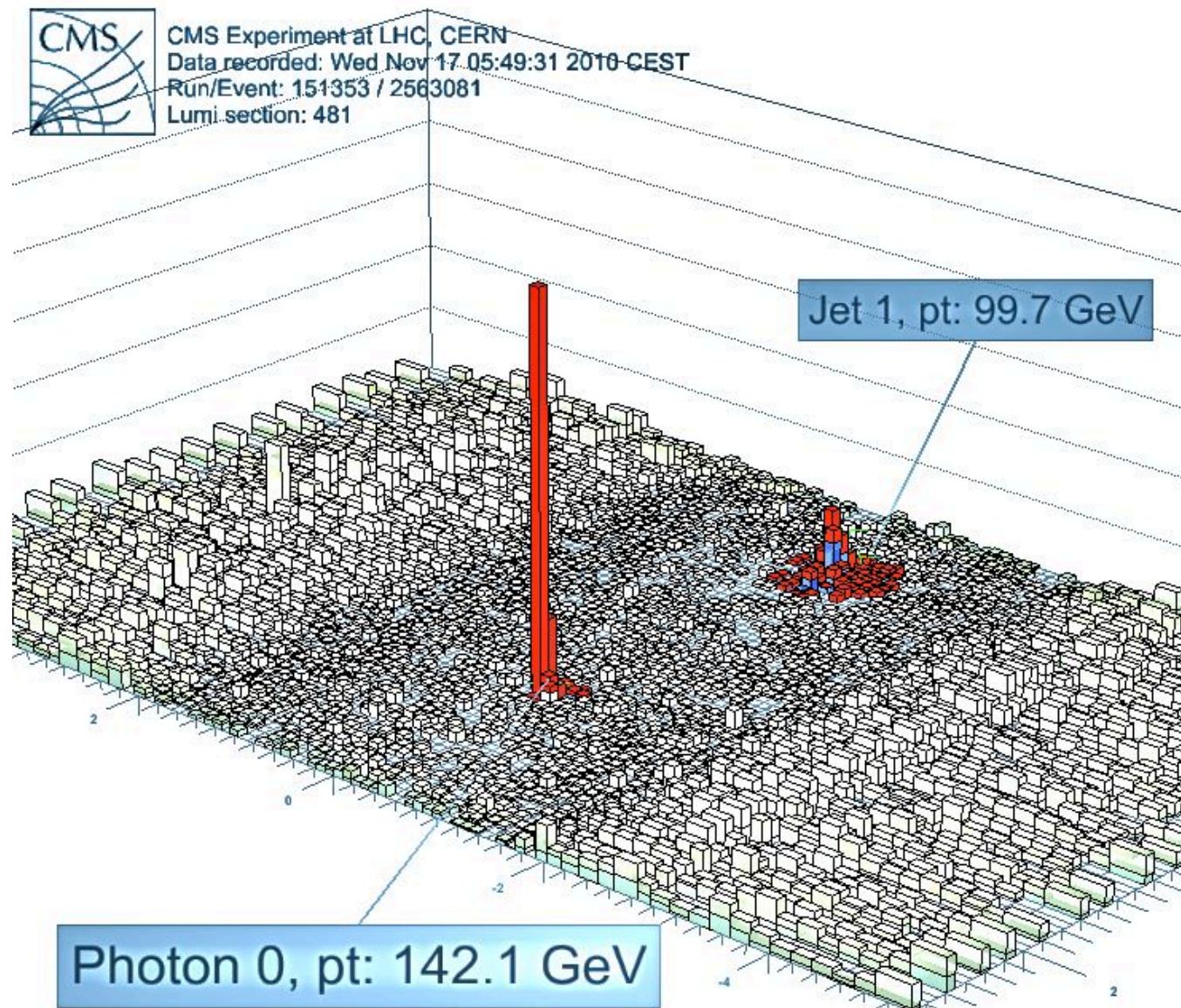
Central



A significant dijet imbalance, well beyond that expected from unquenched MC, appears with increasing collision centrality



# Future studies: $\gamma$ -jet ?





## Conclusions

- LHC is performing very well ; 50 pb-1 collected by the end of 2010 and > 1000 pb-1 expected by end 2011
- Very interesting search program: with few 10 pb-1 already exploring uncharted territory
- CMS - and the other experiments -is also performing very well

STAY TUNED

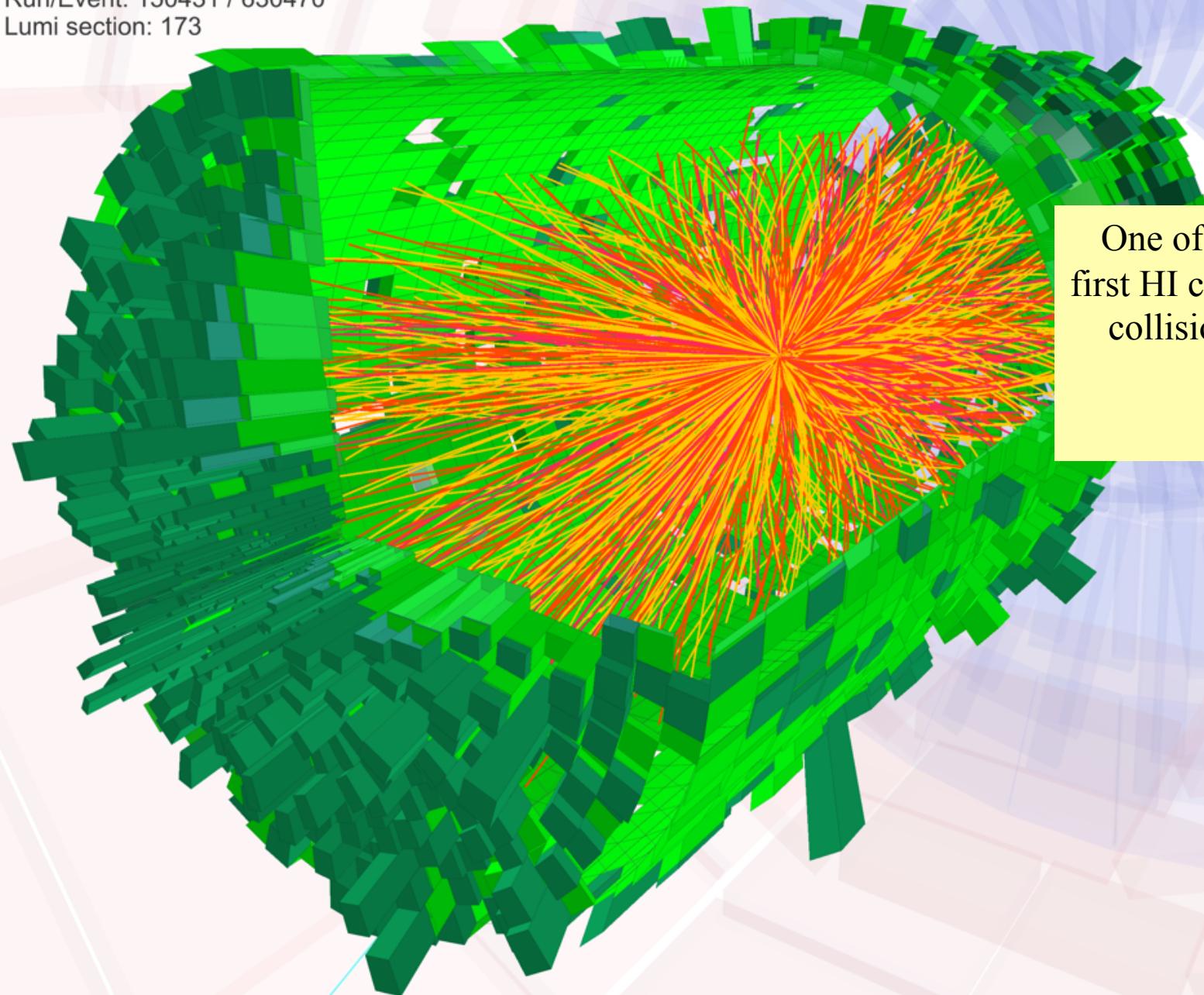


CMS Experiment at LHC, CERN

Data recorded: Mon Nov 8 11:30:53 2010 CEST

Run/Event: 150431 / 630470

Lumi section: 173



One of the  
first HI central  
collisions



# The CMS Collaboration

AACHEN-1, AACHEN-3A, AACHEN-3B, ADANA-CUKUROVA, ANKARA-METU, ANTWERPEN, ATHENS, ATOMKI, AUCKLAND, BARI, BEIJING-IHEP, BOGAZICI, BOLOGNA, BOSTON-UNIV, BRISTOL, BROWN-UNIV, BRUNEL, BRUSSEL-VUB, BRUXELLES-ULB, BUDAPEST, CALTECH, CANTERBURY, CARNEGIE-MELLON, CATANIA, CCCS-UWE, CERN, CHANDIGARH, CHEJU, ILLINOIS-CHICAGO, CHONNAM, CHUNGBUK, CHUNGLI-NCU, COLORADO, CORNELL, DEBRECEN-IEP, DELHI-UNIV, DEMOKRITOS, DESY, DONGSHIN, DUBLIN-UCD, DUBNA, EINDHOVEN, FAIRFIELD, FERMILAB, FIRENZE, FLORIDA-FIU, FLORIDA-STATE, FLORIDA-TECH, FLORIDA-UNIV, FRASCATI, GENOVA, GHENT, HAMBURG-UNIV, HEFEI-USTC, HELSINKI-HIP, HELSINKI-UNIV, HEPHY, IOANNINA, IOWA, IPM, ISLAMABAD-NCP, JOHNS-HOPKINS, KANGWON, KANSAS-STATE, KANSAS-UNIV, KARLSRUHE-IEKP, KHARKOV-ISC, KHARKOV-KIPT, KHARKOV-KSU, KONKUK-UNIV, KOREA-UNIV, KYUNGPOOK, LAPP, LAPPEENRANTA-LUT, LIP, LIVERMORE, LONDON-IC, LOUVAIN, LYON, MADRID-CIEMAT, MADRID-UNIV, MARYLAND, MEXICO-IBEROAM, MEXICO-IPN, MEXICO-PUEBLA, MEXICO-UASLP, MILANO-BICOCCA, MINNESOTA, MINSK-INP, MINSK-NCPHEP, MINSK-RIAPP, MINSK-UNIV, MISSISSIPPI, MIT, MONS, MOSCOW-INR, MOSCOW-ITEP, MOSCOW-LEBEDEV, MOSCOW-MSU, MOSCOW-RDIPE, MUMBAI-BARC, MYASISHCHEV, NAPOLI, NEBRASKA, NICOSIA-UNIV, NORTHEASTERN, NORTHWESTERN, NOTRE DAME, NUST, OHIO-STATE, OVIEDO, PADOVA, PAVIA, PEKING-UNIV, PERUGIA, PISA, POLYTECHNIQUE, PRINCETON, PROTVINO, PSI, PUERTO RICO, PURDUE, PURDUE-CALUMET, RAL, RICE, RIE, RIO-CBPF, RIO-UERJ, ROCHESTER, ROCKEFELLER, ROMA-1, RUTGERS, SACLAY, SANTANDER, SAO PAULO, SEONAM, SEOUL-EDU, SEOUL-SNU, SHANGHAI-IC, SKK-UNIV, SOFIA-CLMI, SOFIA-INRNE, SOFIA-UNIV, SPLIT-FESB, SPLIT-UNIV, ST-PETERSBURG, STRASBOURG, SUNY-BUFFALO, TAIPEI-NTU, TALLINN, TASHKENT, TBILISI-IHEPI, TBILISI-IPAS, TENNESSEE, TEXAS-TAMU, TEXAS-TECH, TIFR-EHEP, TIFR-HECR, TORINO, TRIESTE, UCDAVIS, UCLA, UC RIVERSIDE, UC SANTA BARBARA, UC SAN DIEGO, UNIANDES, VANDERBILT, VILNIUS-ACADEMY, VILNIUS-UNIV, VINCA, VIRGINIA-TECH, VIRGINIA-UNIV, WARSAW-IEP, WARSAW-INS, WARSAW-ISE, WAYNE, WISCONSIN, WONKWANG, YEREVAN, ZAGREB-RUDJER, ZURICH-ETH, ZURICH-UNIV

**182 Institutions >3000 scientists and engineers  
~ 2000 Authors (including students)**

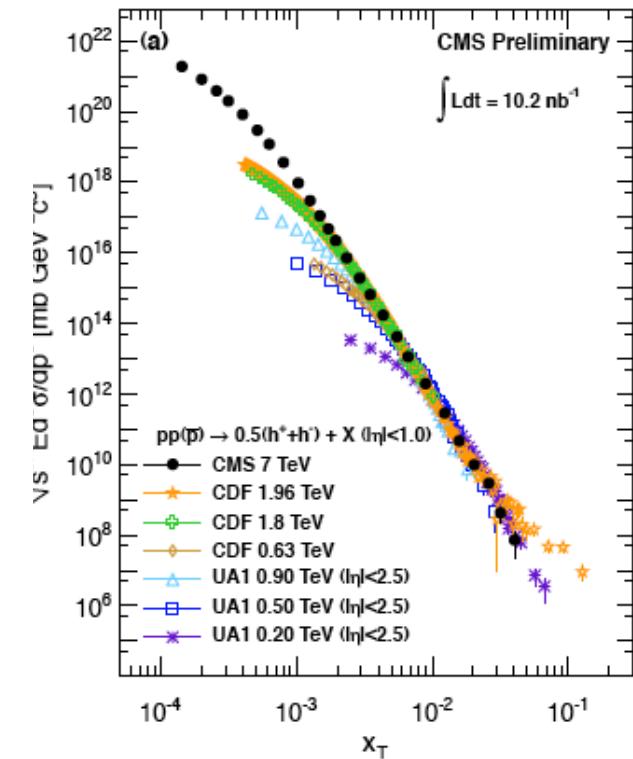
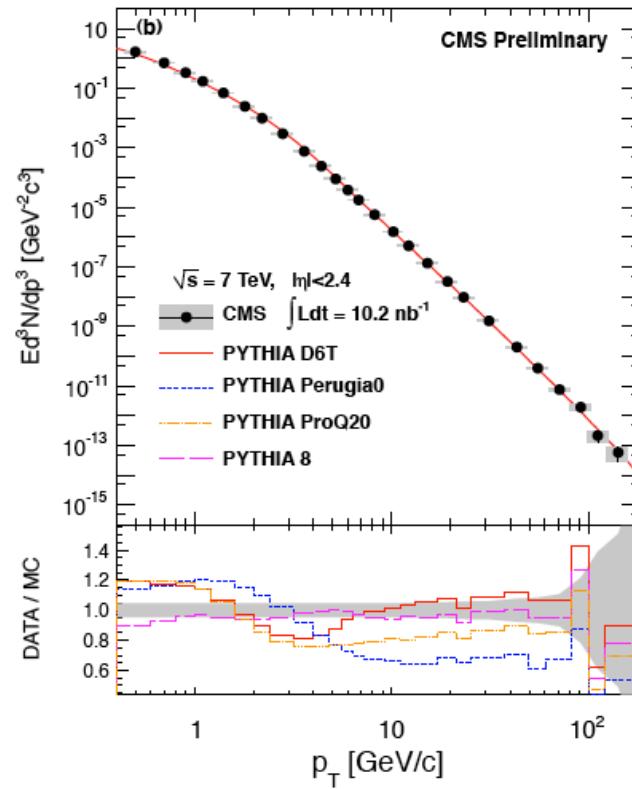
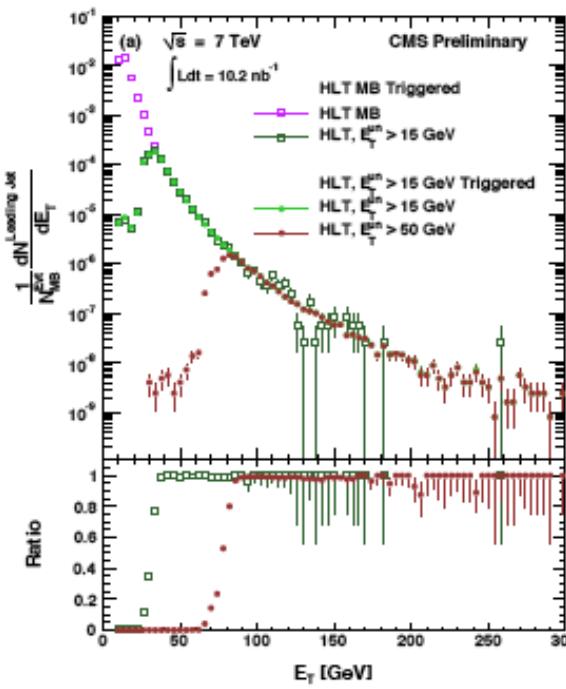


~ 1/4 of the people who made CMS possible



# Jet Triggered Charged particle Spectra

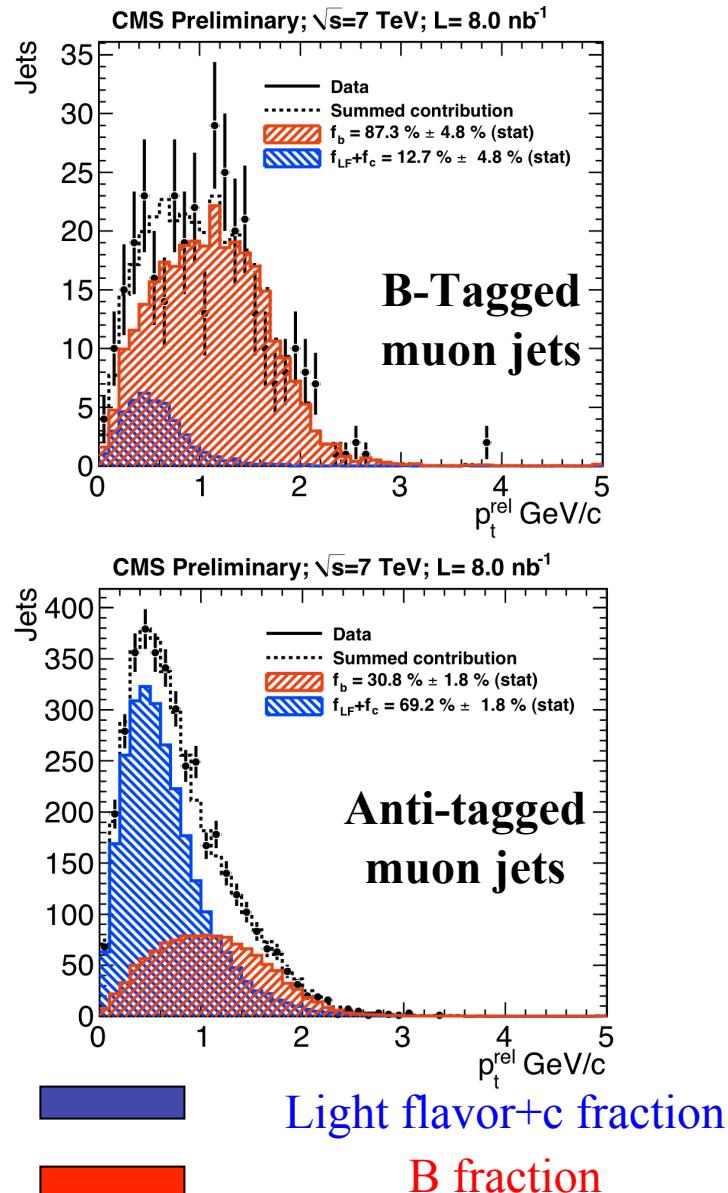
Using Jet trigger it is possible to extend the momentum range of charged particle spectra



Cross sections scaled  
empirically by  $(\sqrt{s})^{5.1}$



# Data driven b-tagging efficiency



Efficiency is estimated from data fitting the  $p_T^{\text{rel}}$  distribution of muons in muon jets.

B-fraction is extracted from the fit of data using distribution templates based on MC

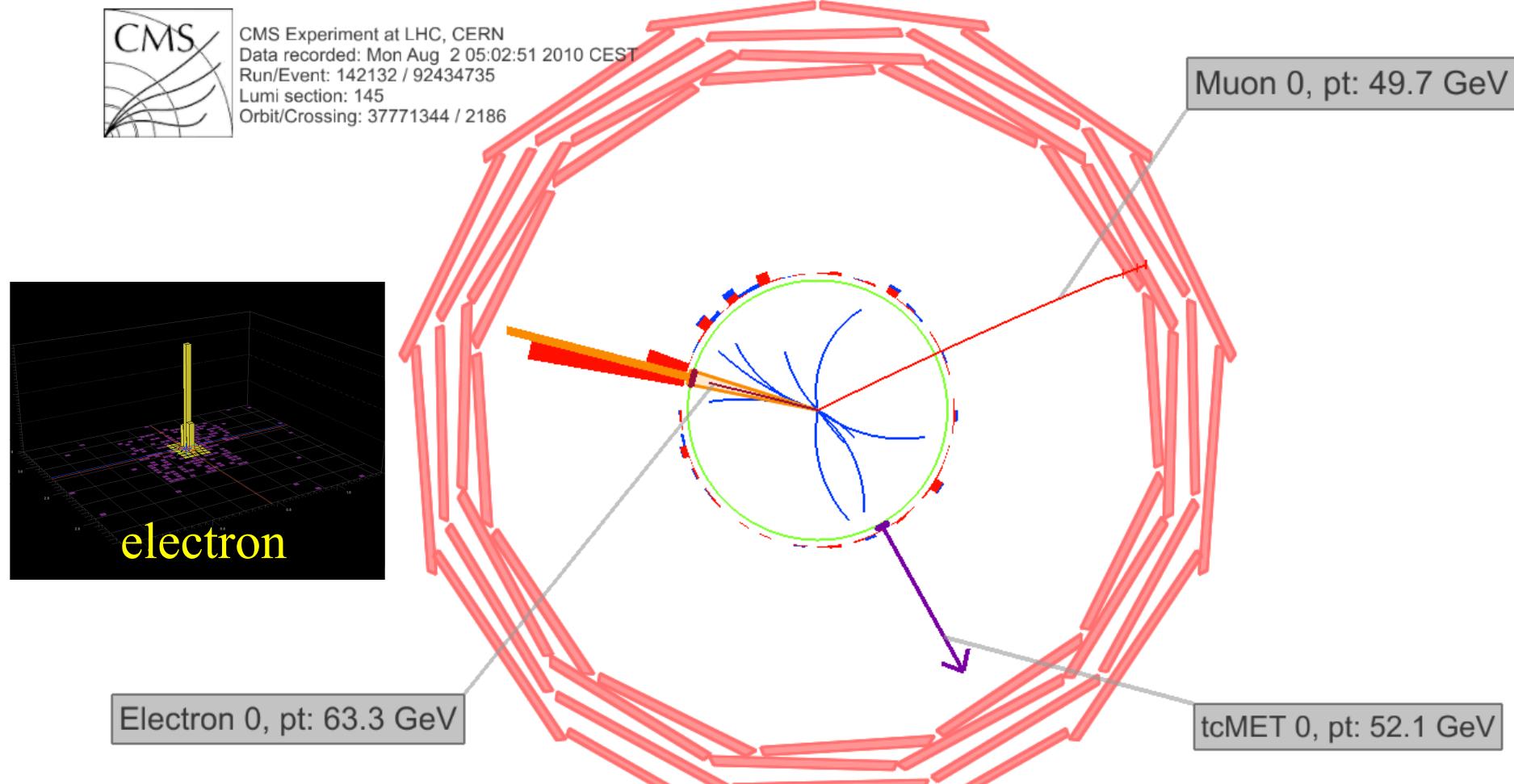
$$\epsilon_b^{\text{data}} = \frac{f_b^{\text{tag}} \cdot N_{\text{data}}^{\text{tag}}}{f_b^{\text{tag}} \cdot N_{\text{data}}^{\text{tag}} + f_b^{\text{untag}} \cdot N_{\text{data}}^{\text{untag}}}$$

Tagger+Operating Point	Scale factor
SSV algorithm High Purity configuration	$0.98 \pm 0.08 \pm 0.18$
Track Counting algorithm High Purity configuration	$0.95 \pm 0.06 \pm 0.19$

# Mid Mass Regime, $M_H \sim 160$ : $N_{\text{events}} = \sigma \times \text{BR} \times L$

Experimental signature		Signal events		Comments
		TeV Exp. $9 \text{ fb}^{-1}$	LHC Exp <b><math>0.5 \text{ fb}^{-1}</math></b>	
$H \rightarrow WW$	$H \rightarrow (l\nu)(l\nu) \text{ with } n=0,1 \text{ jets}$	222	236	<b>5 times better S/B</b>
	$qqH \rightarrow qq (l\nu)(l\nu)$	15	20	<b>S/B ~same</b>
	$qqH \rightarrow qq (l\nu)(jj)$	93	120	<b>S/B ~same</b>
	$WH \rightarrow (l\nu)(l\nu)(jj), \text{ same-sign dilepton}$	27	7	
	$ZH \rightarrow (ll)(l\nu)(jj)$	5	1	

# A $p\bar{p} \rightarrow WW$ Candidate



Very Clean Signature !

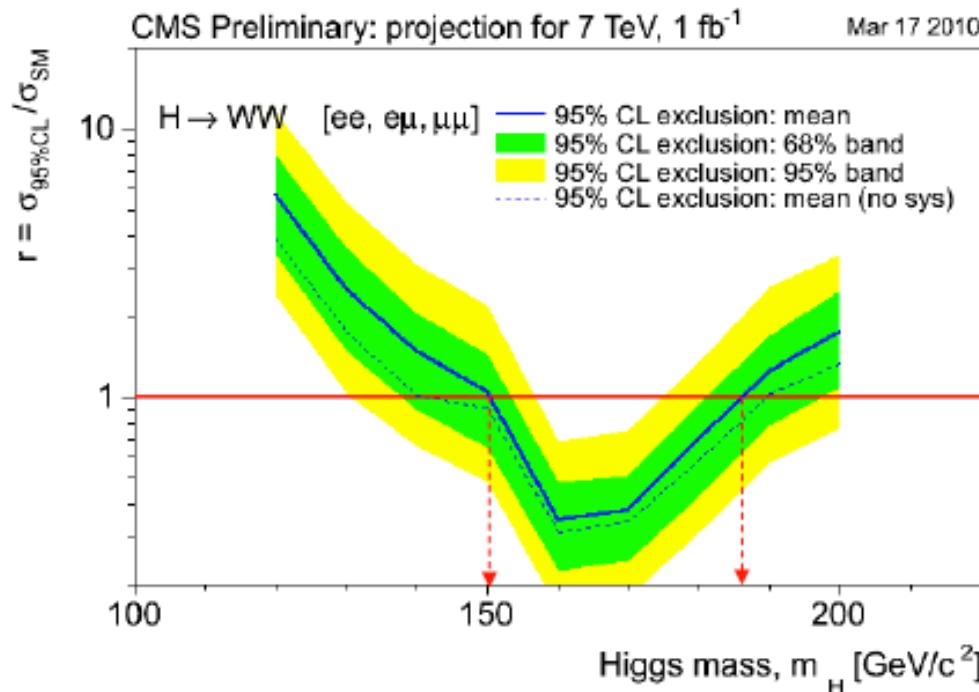


## #2 SM $H \rightarrow WW \rightarrow 2l2v$

Reference: HIG-2008/006

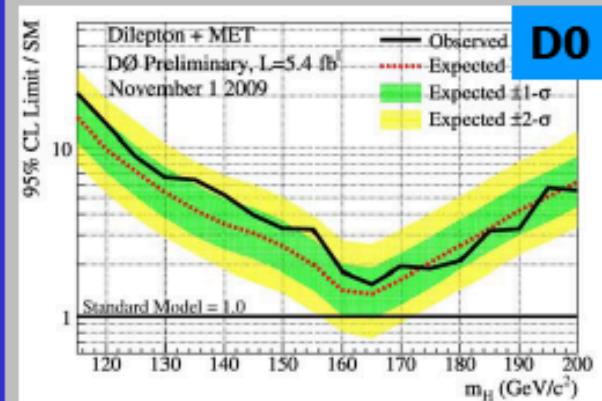
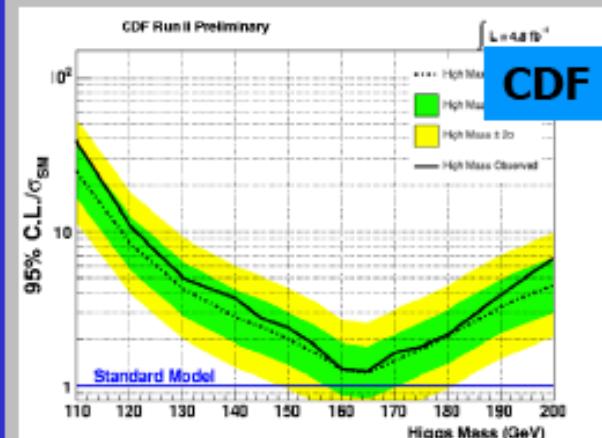
Method: Counting above a MVA-output cut

Three sub-channels:  $2e$ ,  $2\mu$ ,  $e\mu$



SM Higgs expected excluded range: **150-185 GeV**  
(dashed lines are superimposed in ppt, they are not part of the plot)

TEVATRON



# Low Mass Higgs $M_H \sim 120$ : $N_{\text{events}} = \sigma \times \text{BR} \times L$

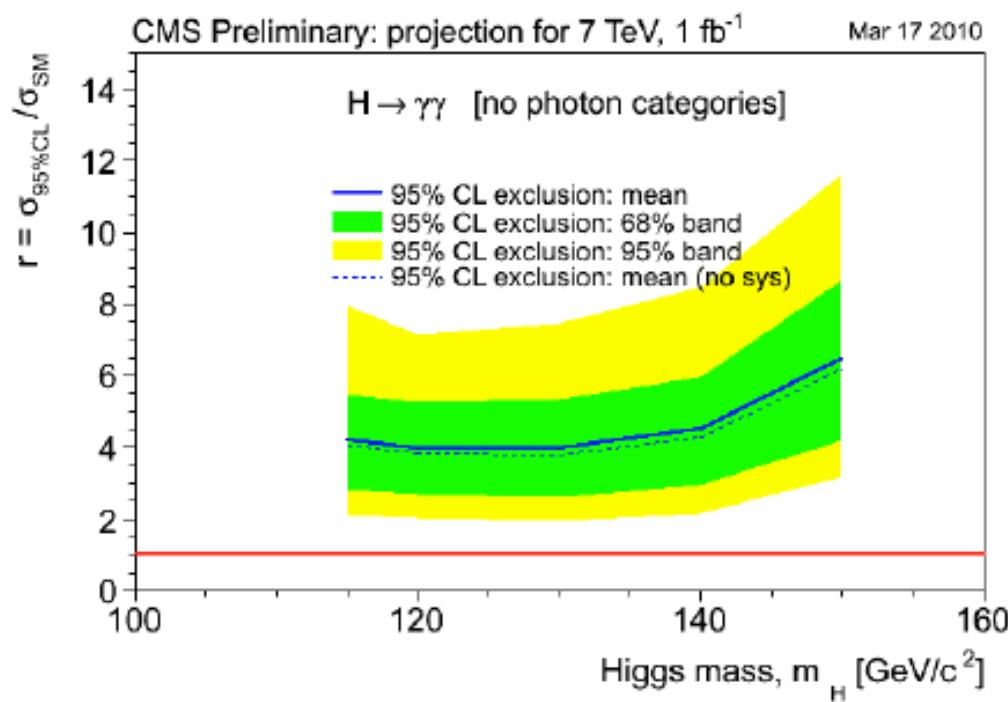
Experimental signatures		Signal events		Comments
		TeV Exp 9 fb <sup>-1</sup>	LHC Exp 0.5 fb <sup>-1</sup>	
H → γγ		28	22	x4 better $m_{\gamma\gamma}$ res
H → bb	qqH → qq(bb) <b>with n b-tags</b>	430	440	
	WH → lv(bb) <b>with n b-tags</b>	208	49	x5 worse S/B
	ZH → 2v(bb) <b>with n b-tags</b>	114	23	
	ZH → (ll)(bb) <b>with n b-tags</b>	38	8	
	VH → (2l/2v/1v) (bb) <b>[highly boosted]</b>	?	?	1 (after all cuts)
H → WW	H → (lv)(lv) <b>with n=0,1 jets</b>	85	65	X5 better S/B
	qqH → qq (lv)(lv)	4	4	
	qqH → qq (lv)(jj)	26	26	
	WH → (lv)(lv)(jj), same-sign dilepton	6	1.5	
	ZH → (vv)(lv)(jj)	7	1.4	
	ZH → (ll)(lv)(jj)	2	0.5	
H → ττ	qqH → qq (ττ)	23	22	



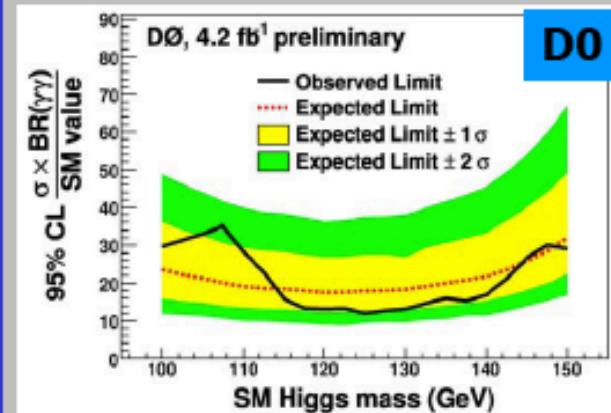
# #1 SM $H \rightarrow \gamma\gamma$

**Reference:** NOTE-2006/112

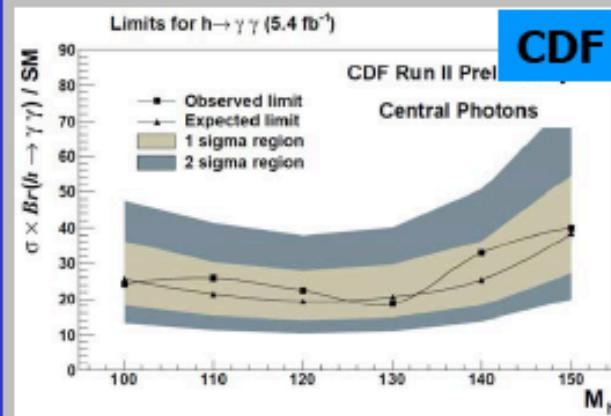
**Method:** Counting in a mass window  
No photon categories



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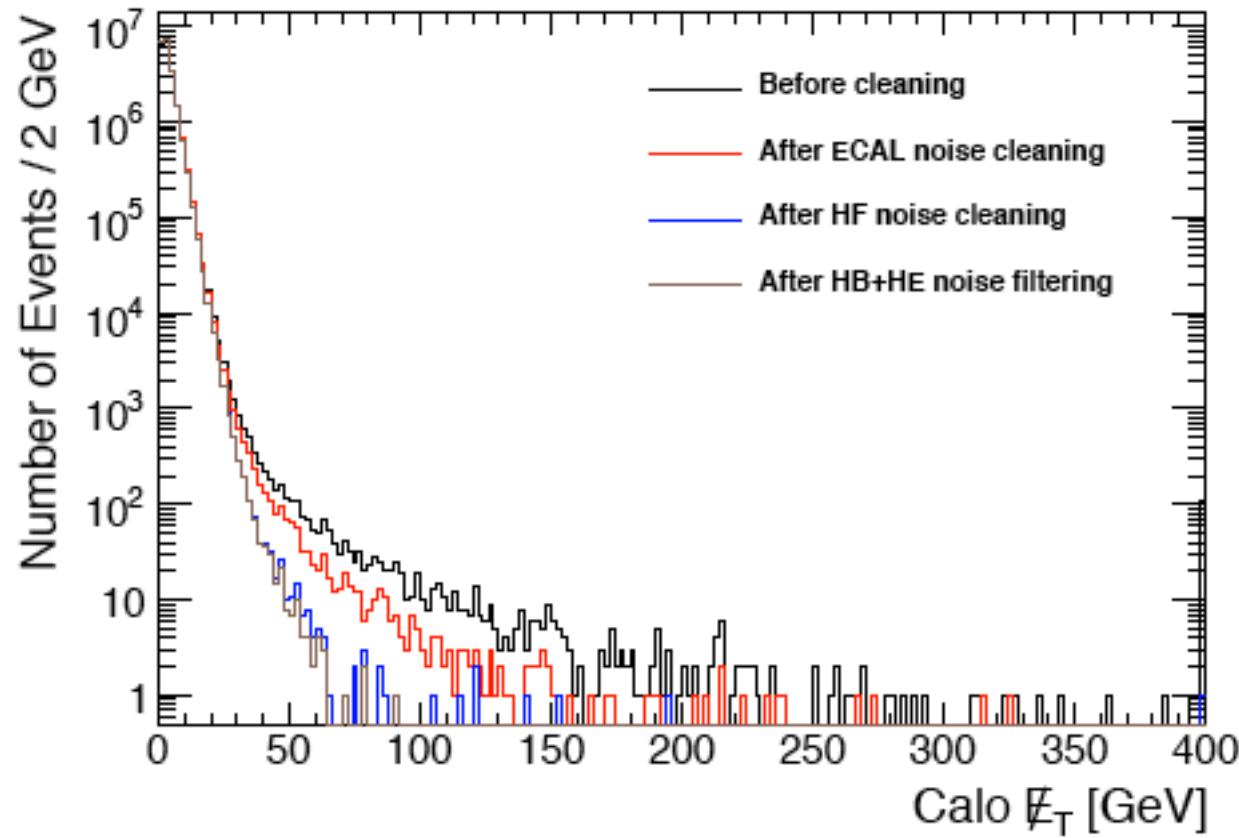


Limits for  $h \rightarrow \gamma\gamma$  (5.4  $\text{fb}^{-1}$ )





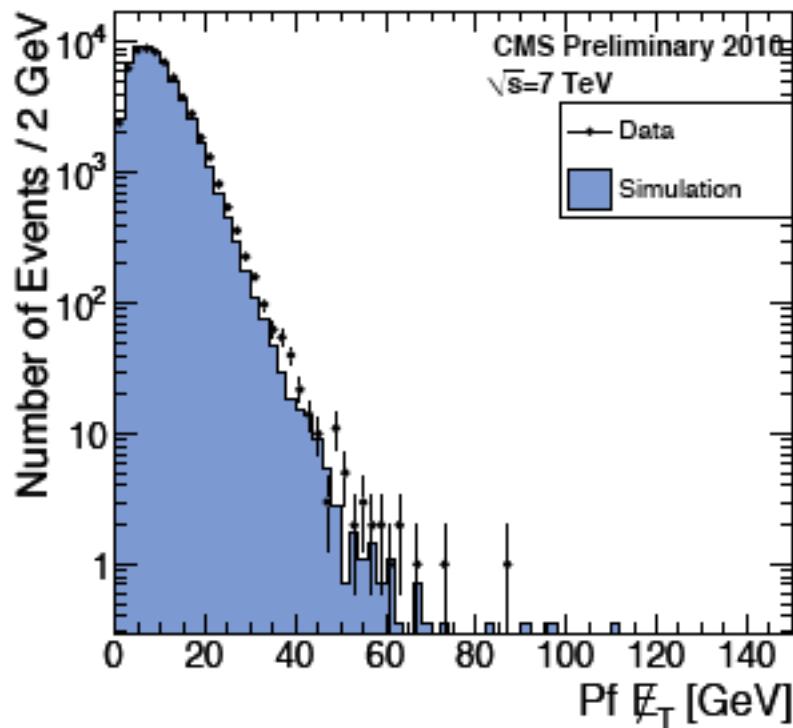
# Looking at Missing Energy Tails



Requires a very performing detector since all instrumental anomalies mimic missing energy



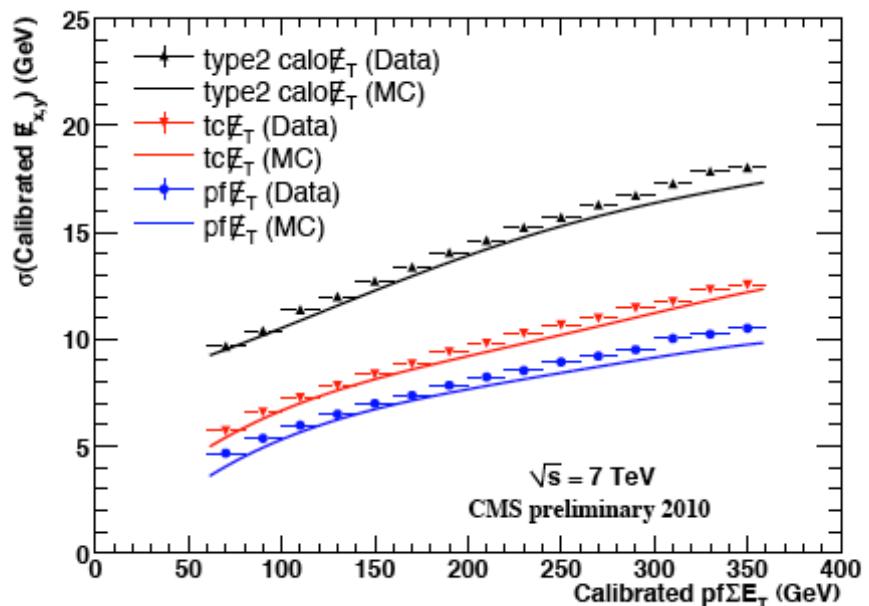
# Missing energy in multi jets events



(d)  $\text{pf}\cancel{E}_T$  distribution

missing energy distribution

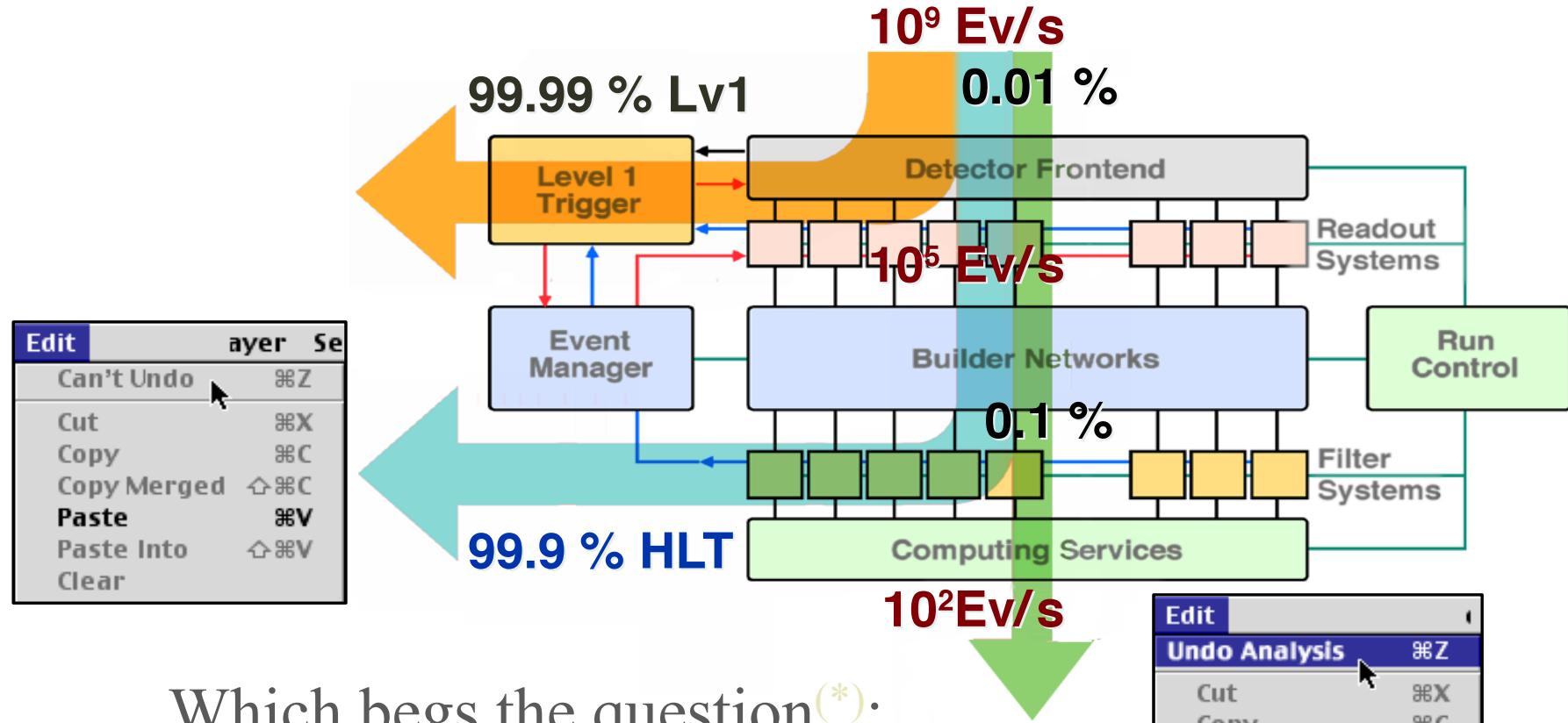
Low luminosity – NO tails expected



missing energy resolution



# Trigger: A tricky business

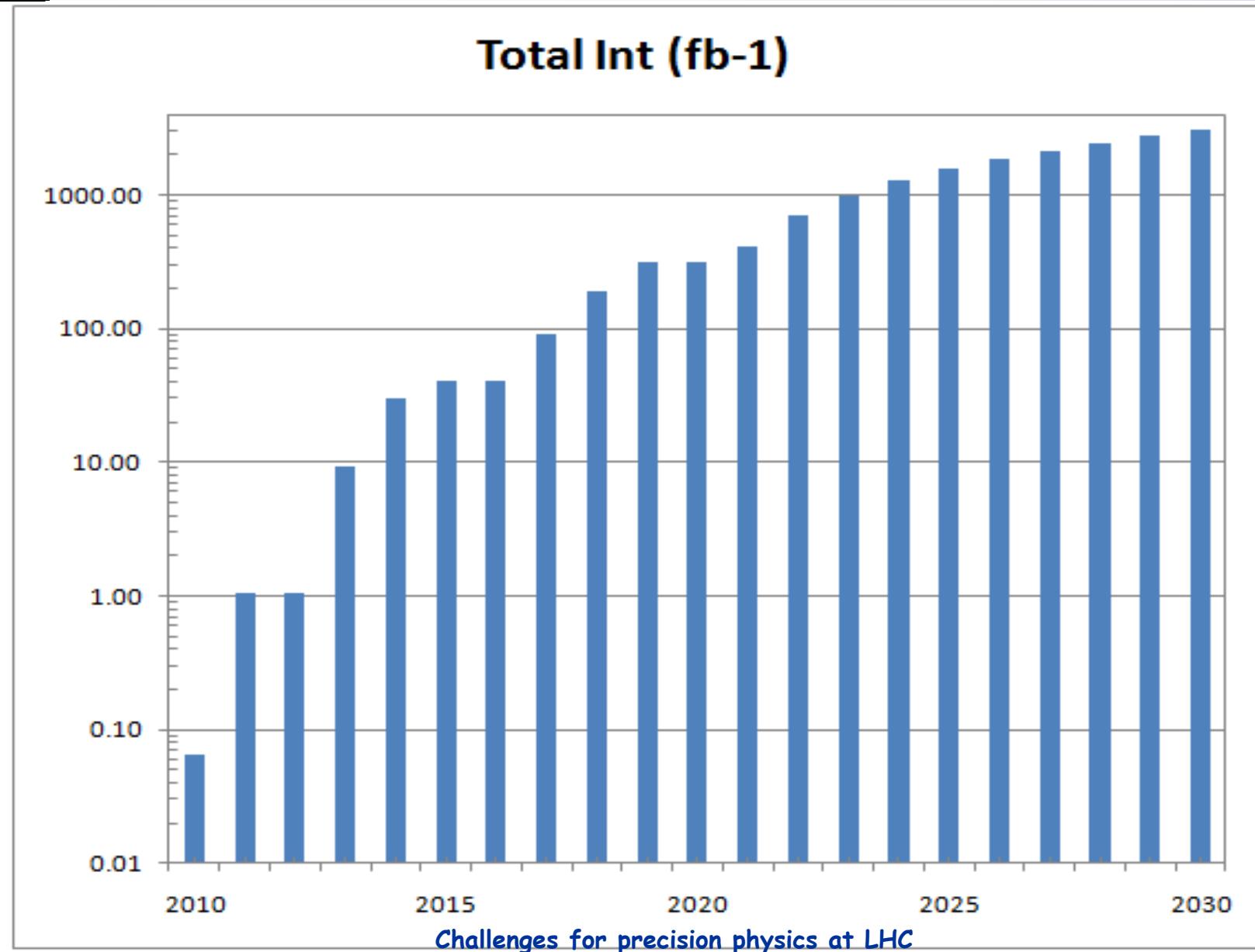


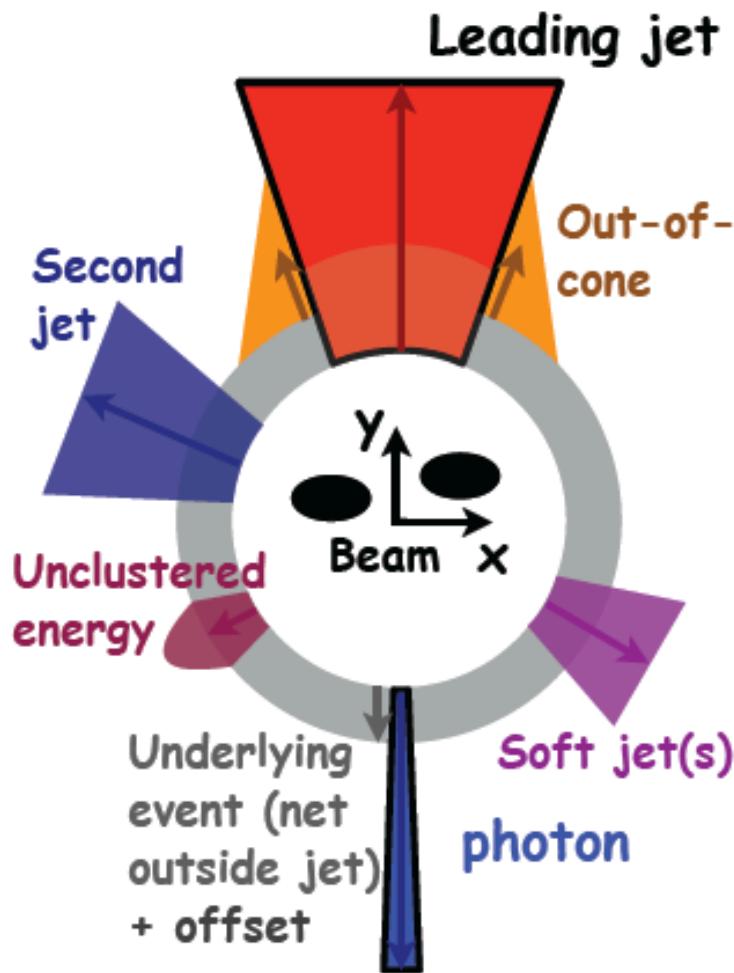
Which begs the question<sup>(\*)</sup>:  
Will your favorite new physics signal  
be included in the small fraction  
of selected events?



# Preliminary Long Term Predictions

Steve Myers ICHEP JULY 2010





$$\vec{p}_{T,\gamma} + \vec{p}_{T,recoil} = \vec{0}$$

$$R_\gamma \vec{p}_{T,\gamma} + R_{recoil} \vec{p}_{T,recoil} = -\vec{E}_T^{miss}$$

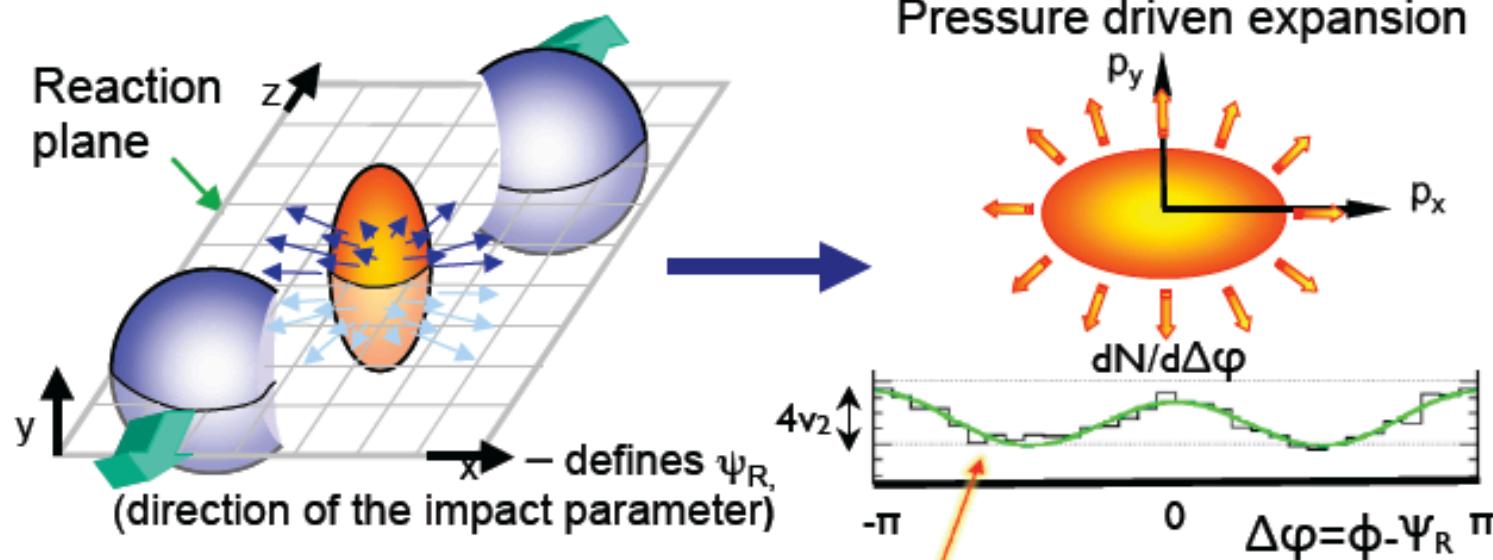
$$R_{MPF} \equiv \frac{R_{recoil}}{R_\gamma} = 1 + \frac{\vec{E}_T^{miss} \cdot \vec{p}_{T,\gamma}}{(p_{T,\gamma})^2}$$

$$R_{recoil} = R_{lead\,jet} (1 + \Delta R_{recoil} \cdot \hat{p}_{T,recoil})$$

- ◆ no real missing  $E_T$ : balances the photon with the full recoil
  - ▶ the MPF response is interpreted as the leading jet response if the different parts of the topology have similar response (ideally suited to PFJets)
- ◆ generally less sensitive to systematics than the classical  $p_T$  balance for PFJets

# Correlation in Heavy Ions

Collective flow phenomena:



$$\sim \cos(2\Delta\varphi) \text{ (long-range in } \eta\text{)}$$

Extracted shear viscosity of the medium found to be close to theoretical lower bound  $1/4\pi$