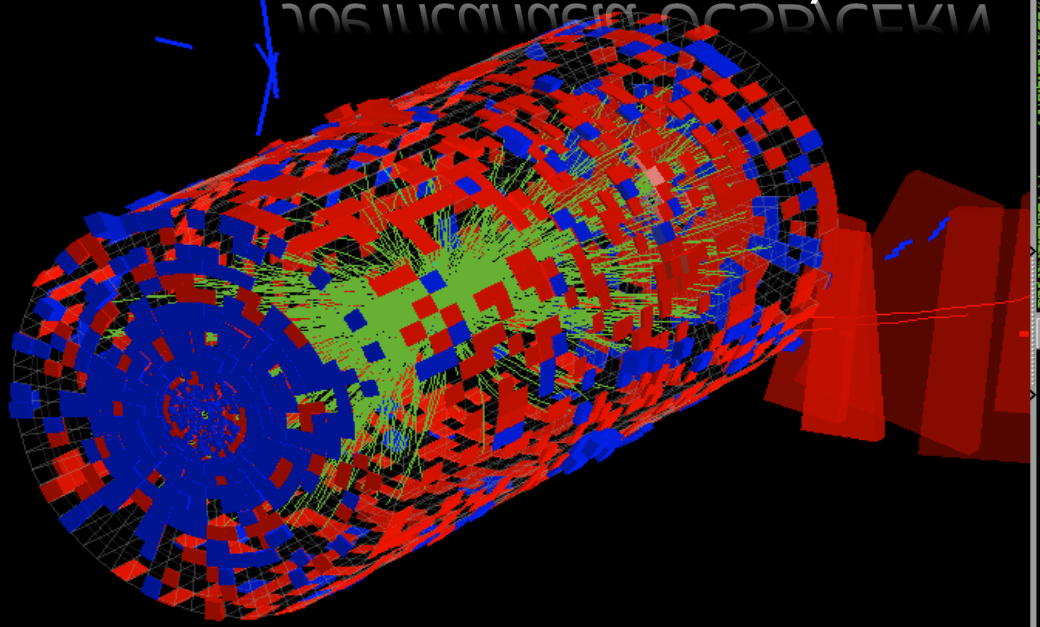
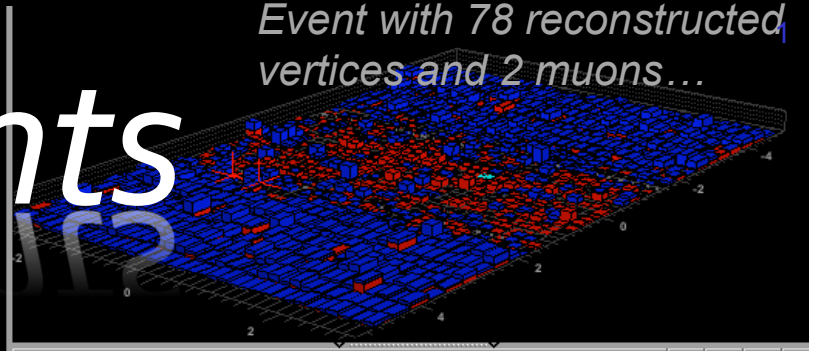
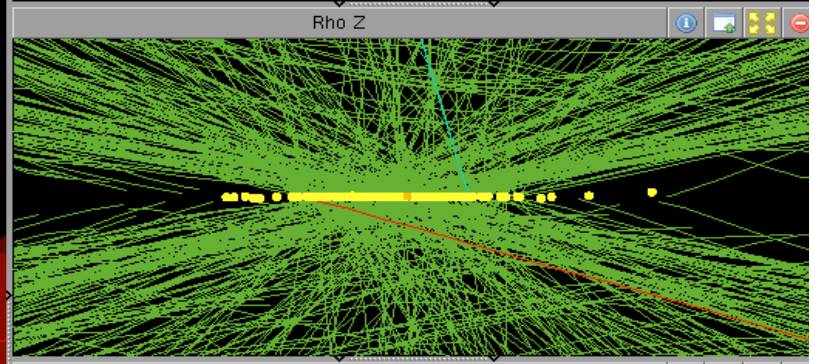
CMS Highlights

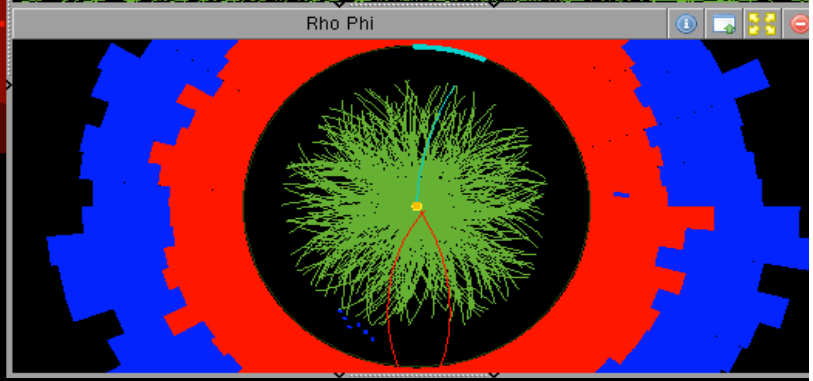
October 1, 2012

Joe Incandela UCSB/CERN

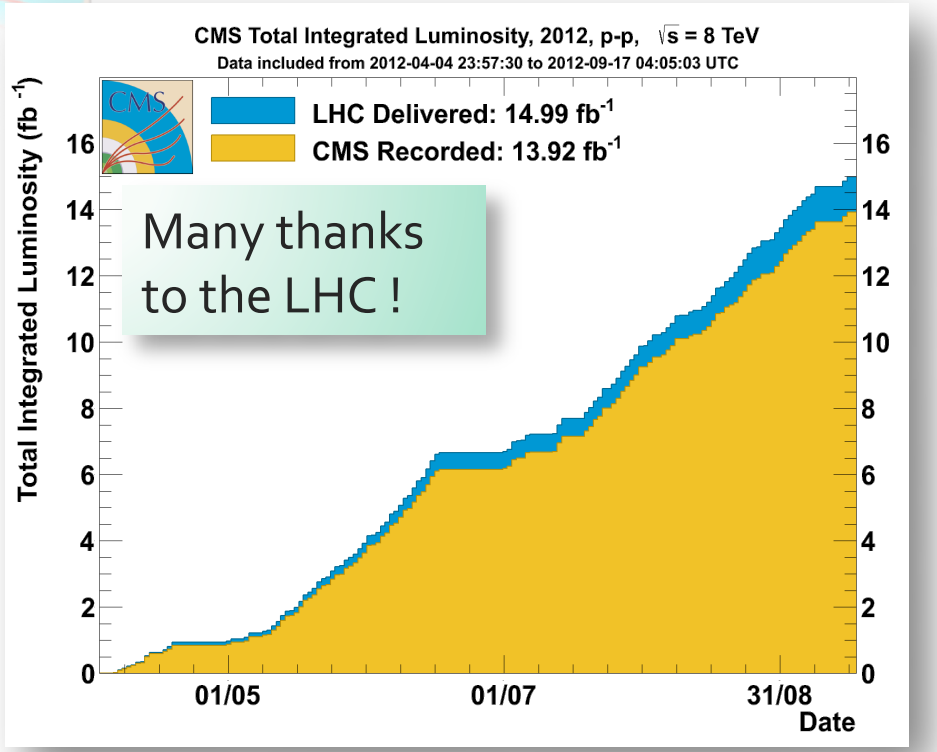






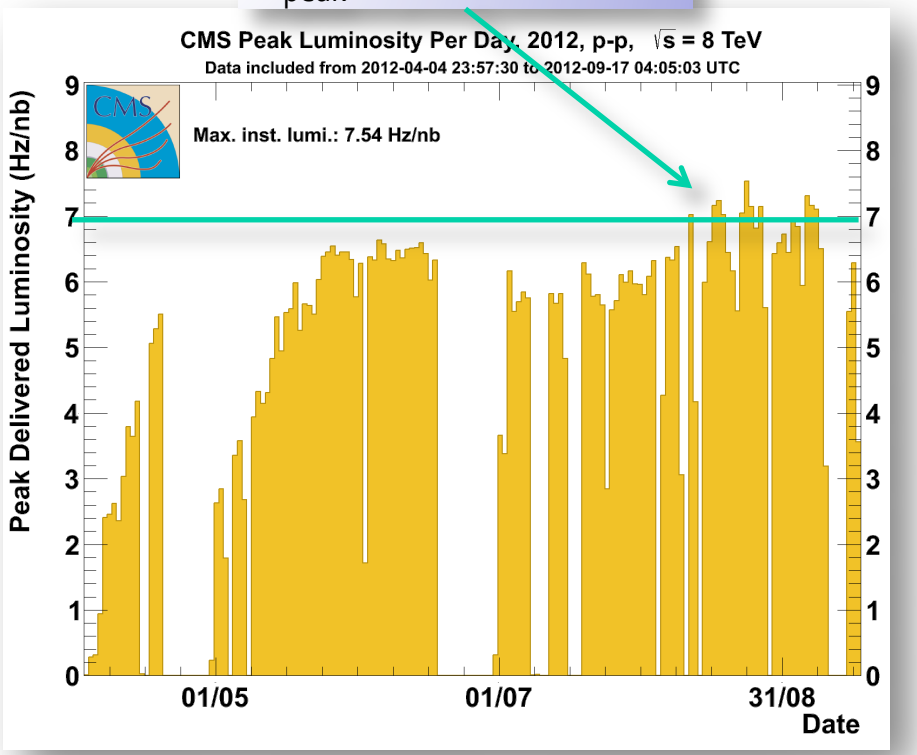


CMS data-taking 2012



Many thanks to the LHC !

$L_{peak} > 7x10^{33} Hz/cm^2$!



- Detector Status and Operational Efficiency are very good
- Recent fills 96-99% efficiency
  - More than doubled the 2012 dataset from that used on July 4th
- We were not so lucky with infrastructure in a few periods
  - 0.5 /fb at B-0 for instance

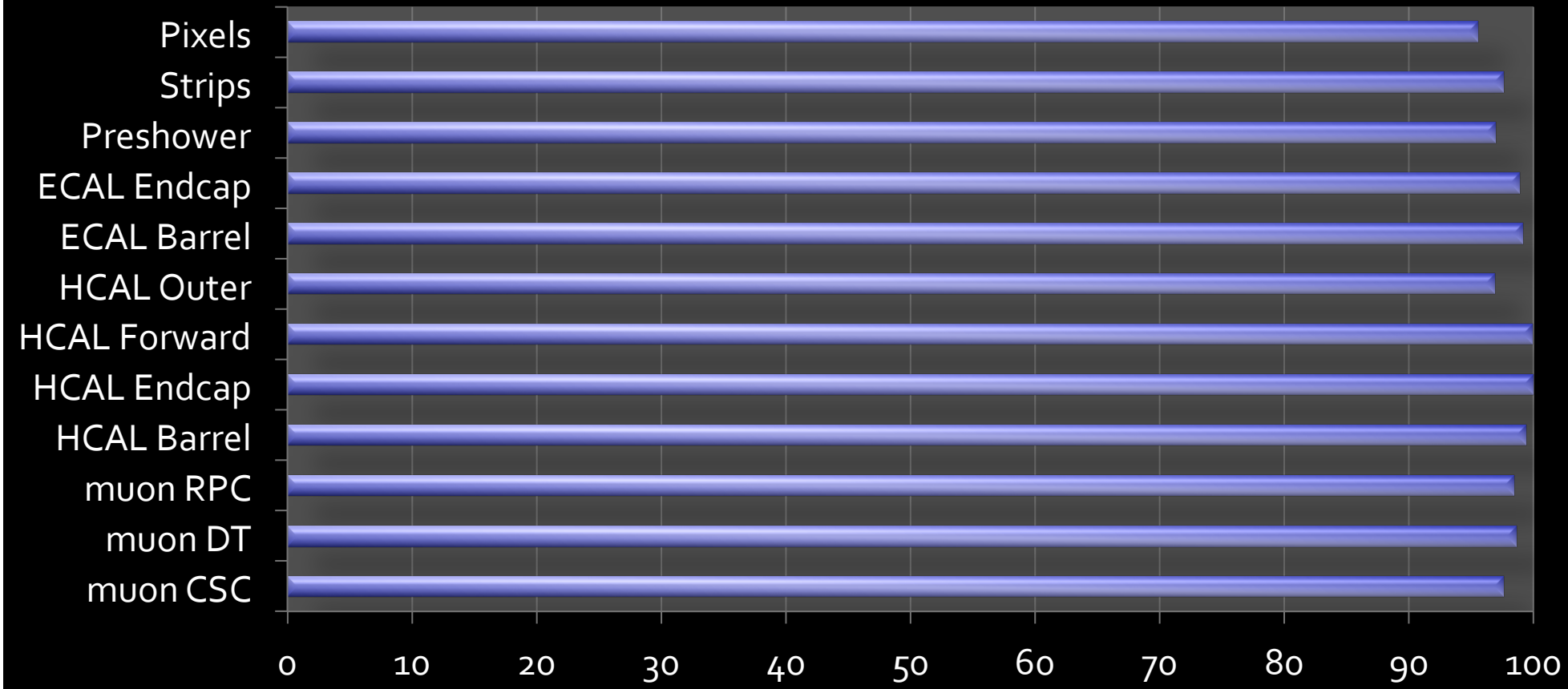
Last 2 fills before the recent technical stop

Delivered: 142.8 pb^{-1}

Recorded: 140.5 pb^{-1} 98.4%

Delivered: 153.1 pb^{-1} Recorded: 150.8 pb^{-1} 98.5%

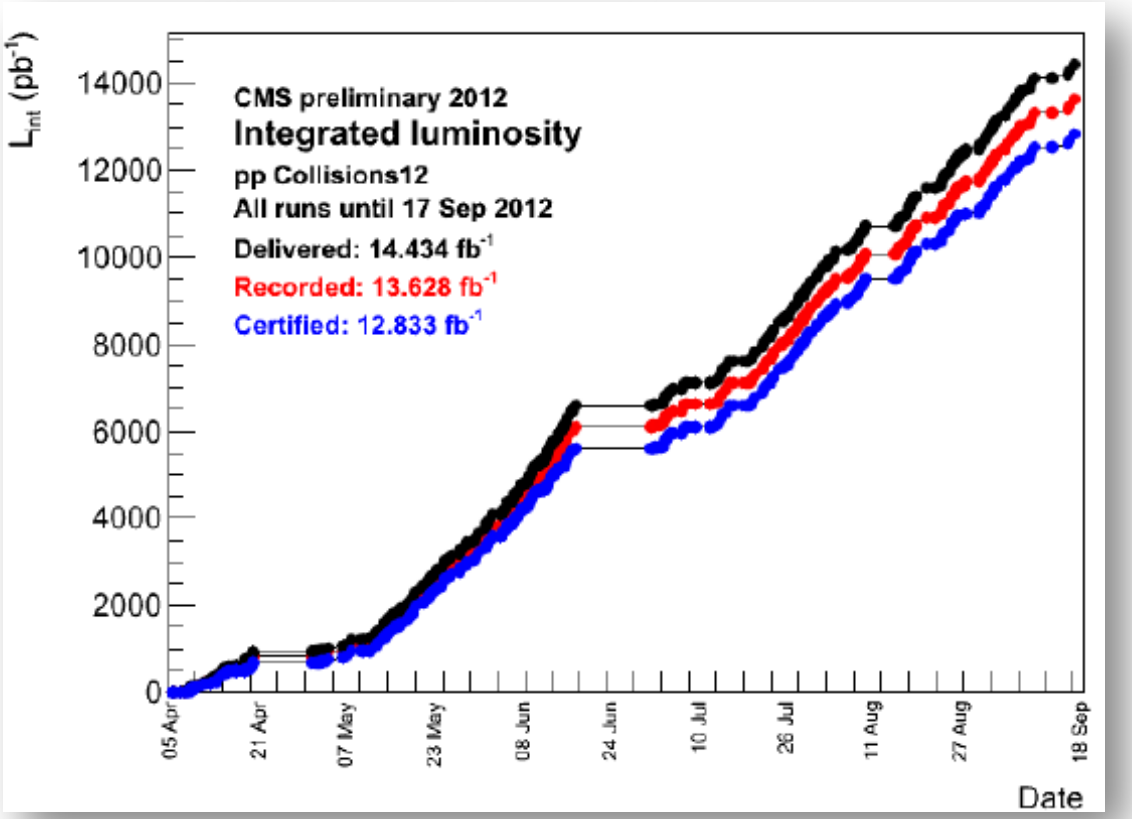
Detector Performance



CMS Subsystem	muon CSC	muon DT	muon RPC	HCAL Barrel	HCAL Endcap	HCAL Forward	HCAL Outer	ECAL Barrel	ECAL Endcap	Preshower	Strips	Pixels
%Operational	97.55	98.6	98.4	99.4	99.96	99.88	96.88	99.11	98.89	96.9	97.61	95.5

2012 Data Certification

- Delivered 14.4 fb^{-1}
- Recorded 13.6 fb^{-1} (94.4%)
- Certified
  - Golden 12.1 fb^{-1} (84%)
  - Muon 12.8 fb^{-1} (89%)



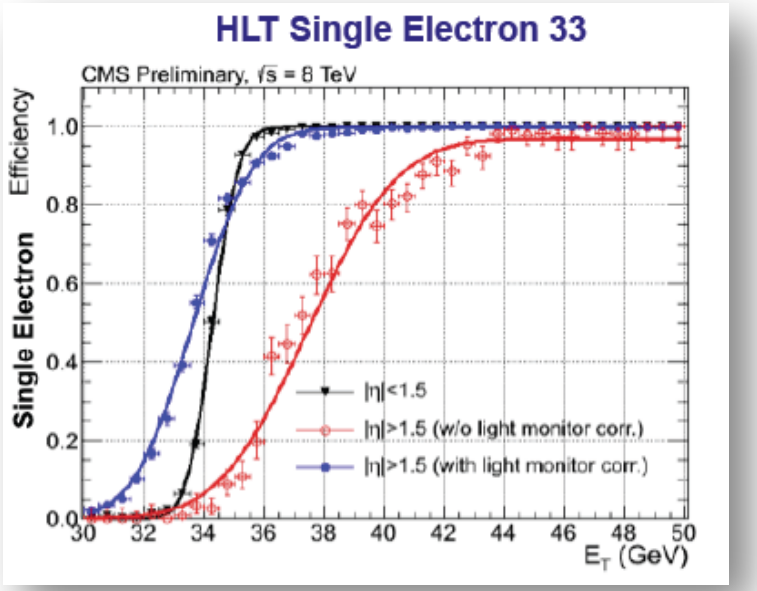
88-89% of data delivered is used for physics

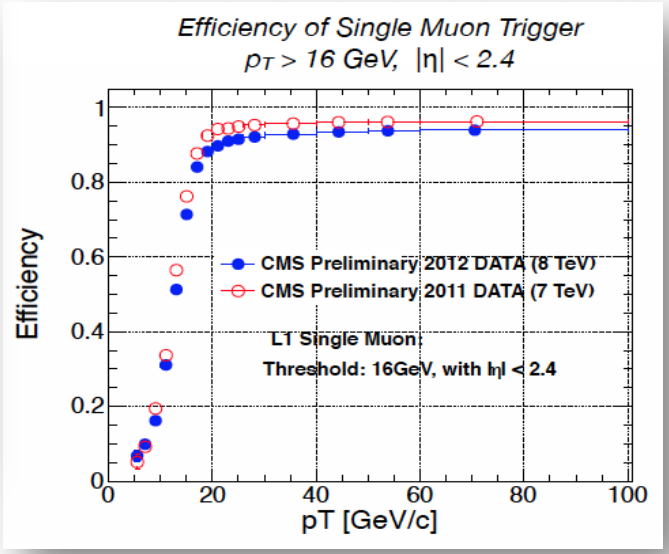
2011 final numbers: Delivered 5.602 fb^{-1}

- Recorded 5.189 fb^{-1} (93%)
- Certified
  - Golden 4.699 fb^{-1} (84%)
  - Muon 4.965 fb^{-1} (89%)

Trigger Performance

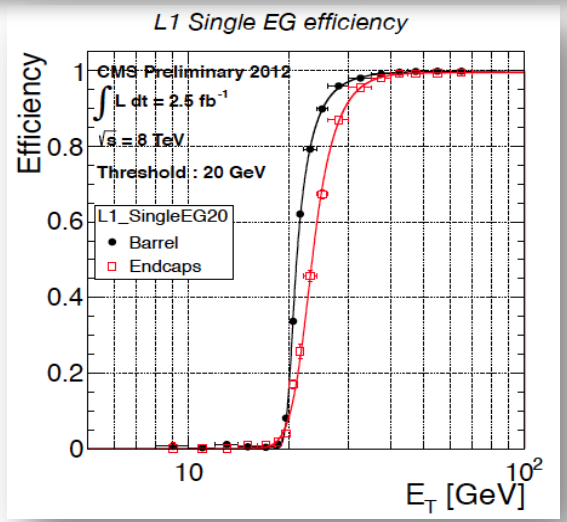
8E33 menu deployed last week



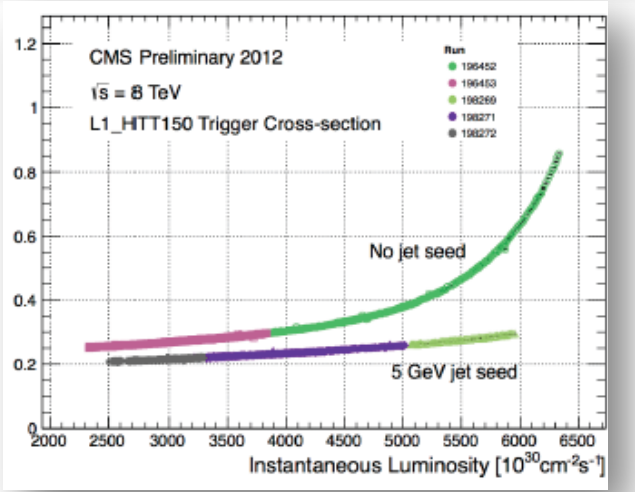


μ rate cut 50% for few % loss in efficiency
- And re-scoped to |η| =2.4

- e/γ Triggers in 2012
  - ECAL transparency corrections implemented -> sharper turn-ons

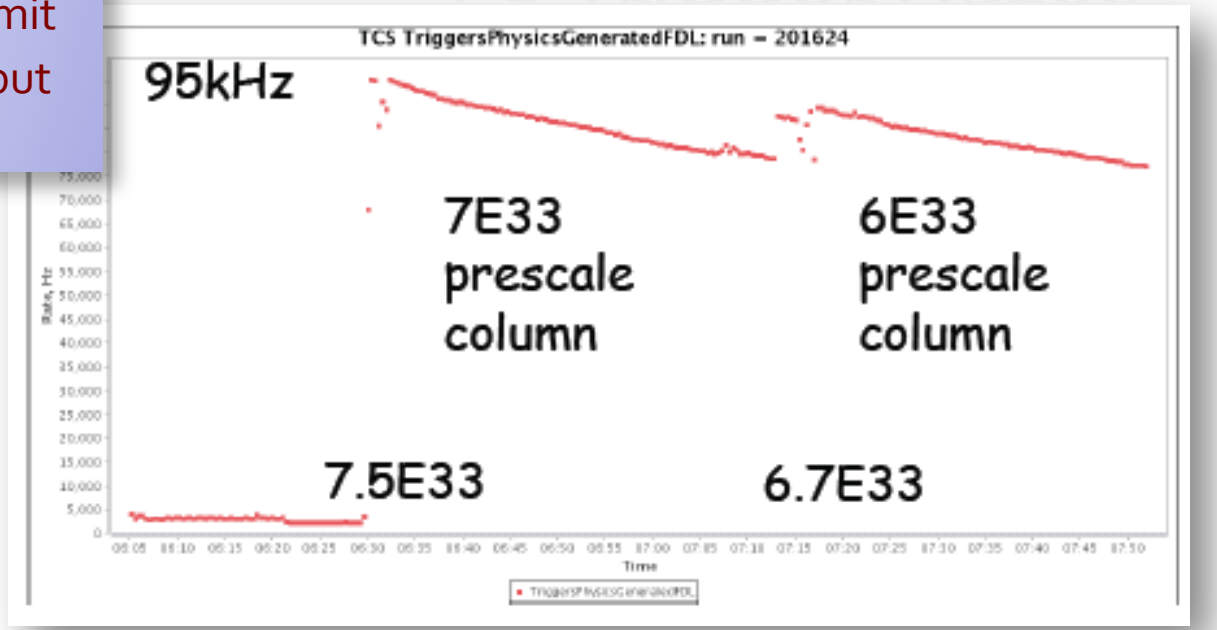


- Jets: Added a 5 GeV jet seed threshold.
  - Greatly improves linearity, no loss in physics



L1 Trigger Rates

- Record Lumi Fill (7.5E33)
  - Steady near 100 kHz limit
  - Deadtime 5% initially but very quickly drops



8E33 column has not yet been used.

- At this luminosity we start to impact Higgs and other key physics channels.

L1 Trigger / Column	6E33	7E33	8E33
Single EG	20	20	22
Single MU (η<2.1)	12	12	14
Double MU	10, Open	10, Open	10, 3.5
Double MU HighQ (BPH)	0,0	0,0	3, 0
HT	150	150	175
MET	36	40	40
Double-Jet (central)	56	64	64
Quad-Jet (central)	36	40	40

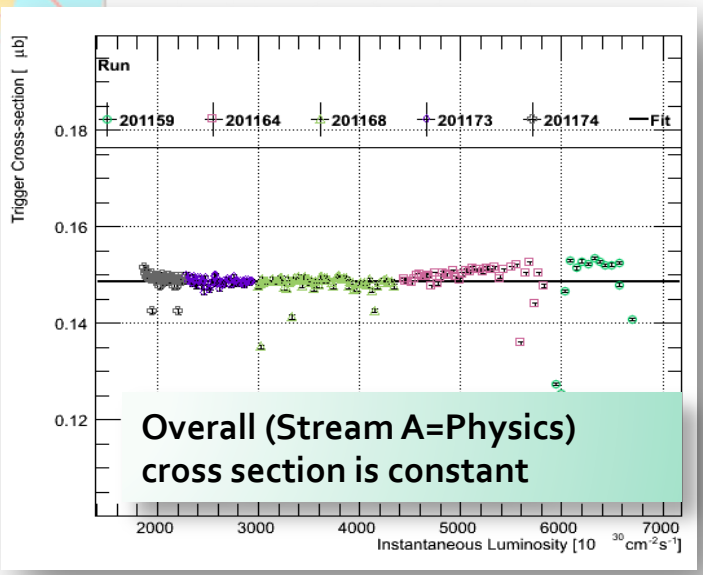
thresholds

9E33 Failsafe column

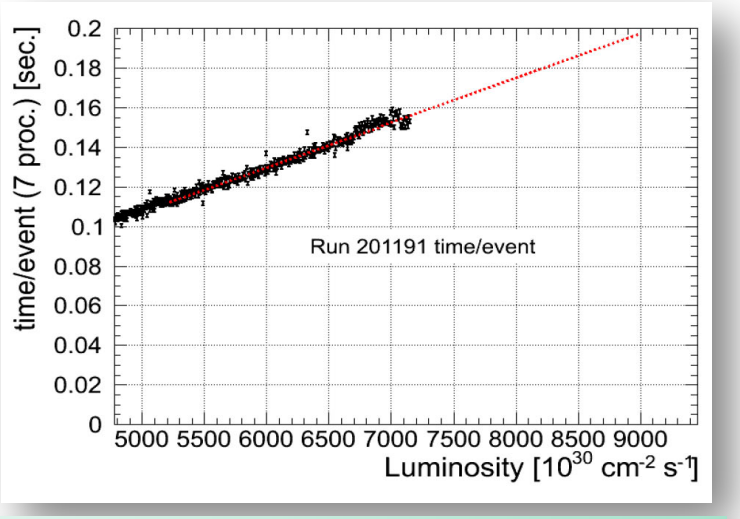
22	Single EG
14	Single Mu (central)
10, 3.5	Double Mu
xxx	Double Mu HighQ (BPH)
xxx	HT
50	MET
64	Double Jet (central)
xxx	Quad Jet (central)

HLT Status

HLT is working fine, up to the recent record luminosity of 7.5nb^{-1}/s



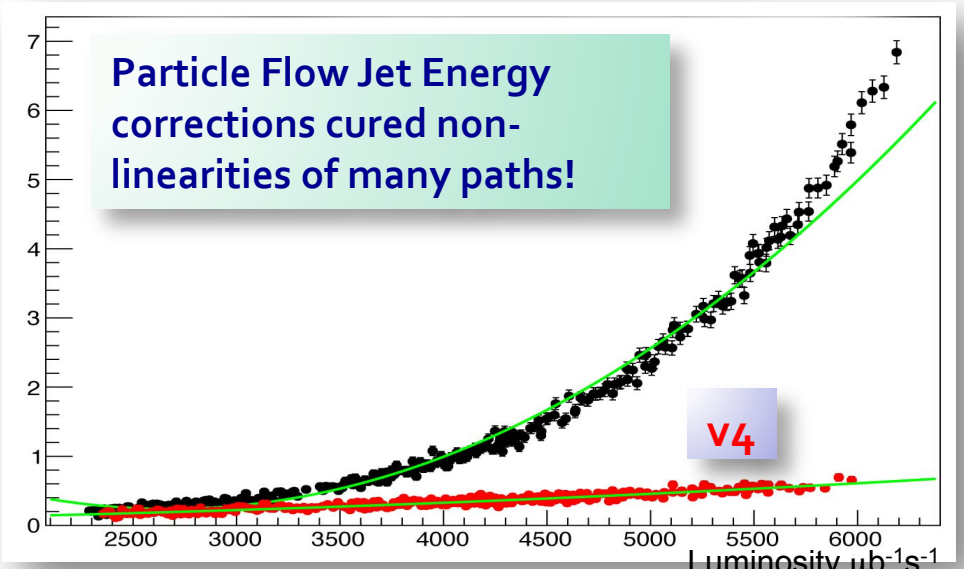
Overall (Stream A=Physics) cross section is constant

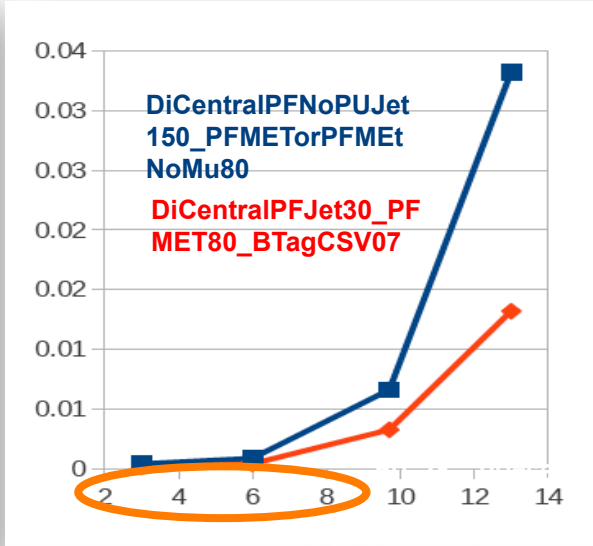


CPU time linear with PU, no sign of runaway

Our limit ~ 190 ms ➔ ~8.5 E33 (at ~100kHz L1 input)

- **Ranking CPU-intensive paths is ongoing**



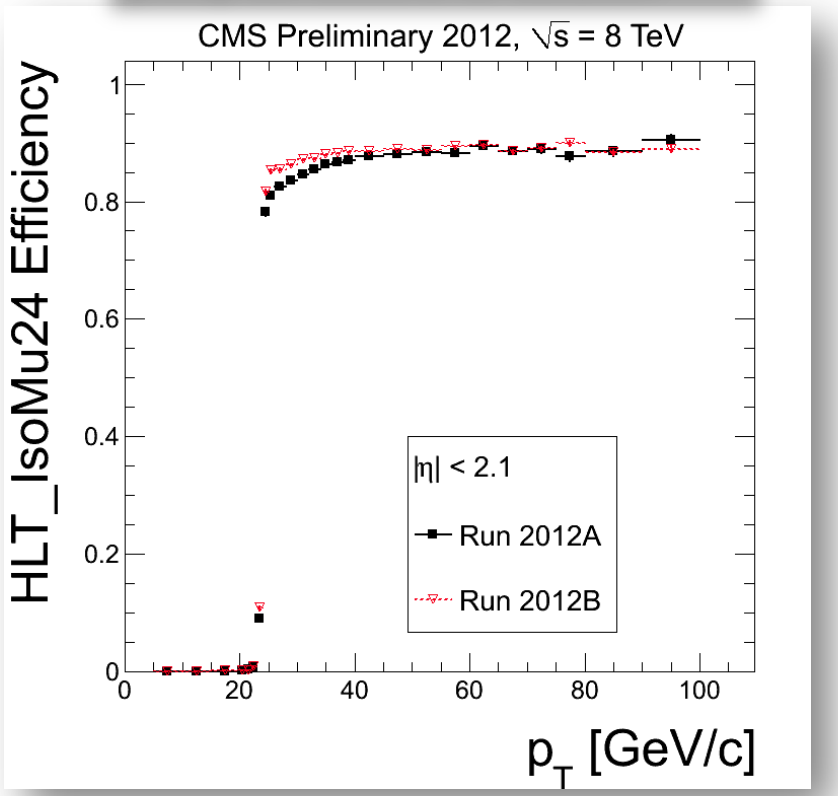


Some paths (mostly MET related) are still non-linear

- Evident in High-PU test runs

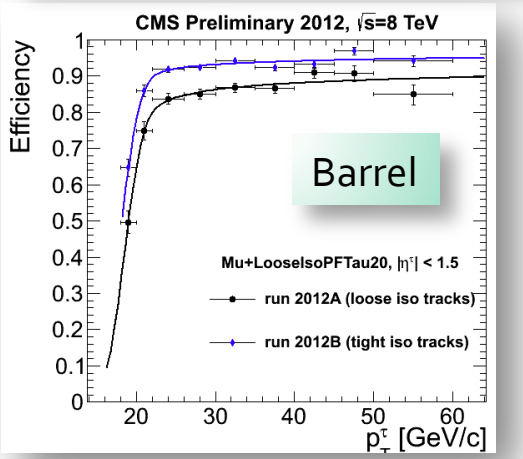
HLT Performance

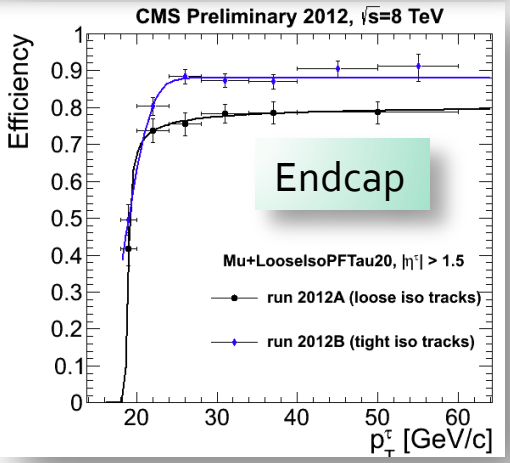
HLT μ efficiency increased in 2nd half of 2012 via introduction of pileup corrections for isolation



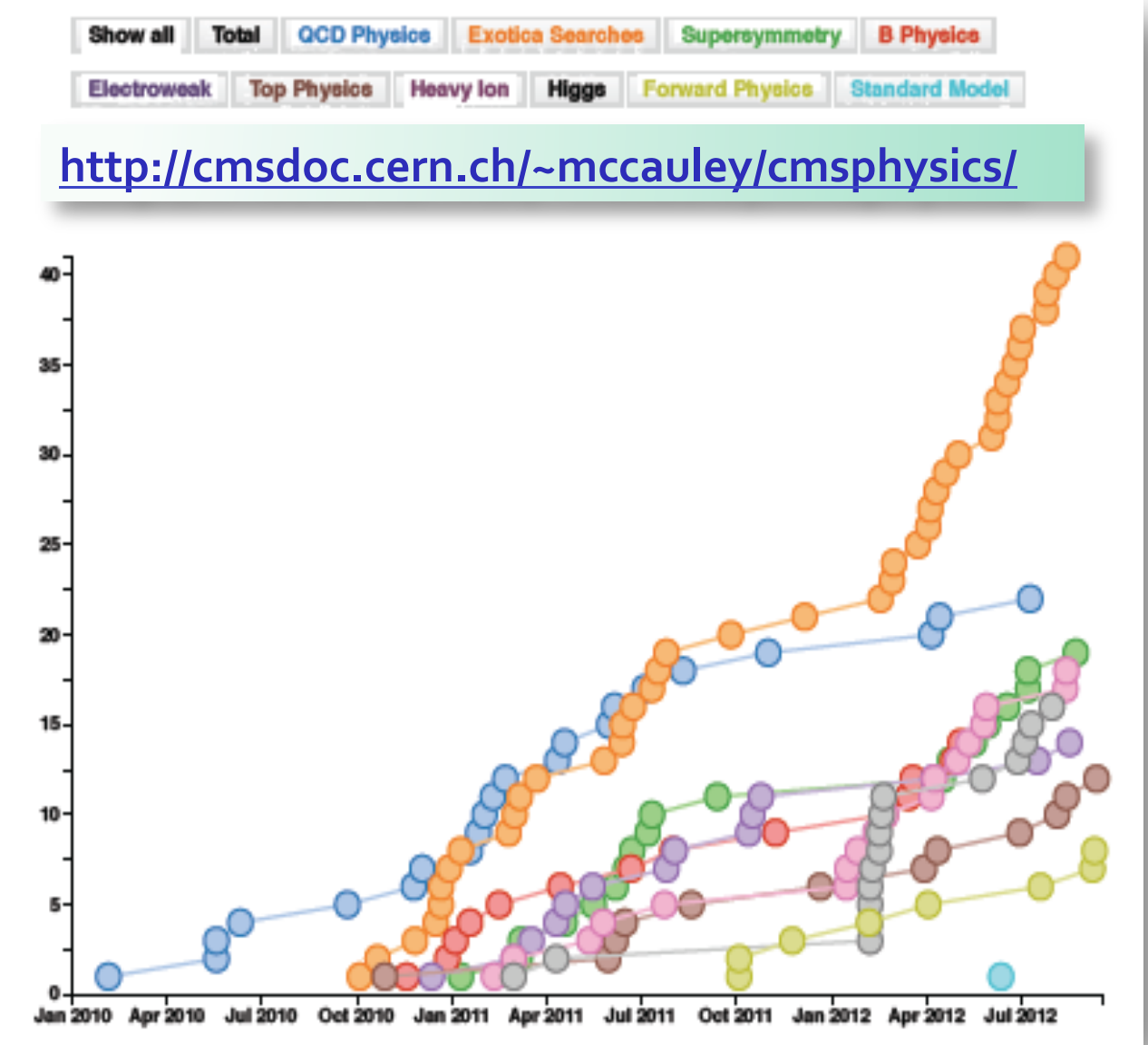
Tau trigger: changed quality criteria on isolation tracks

- 60% improvement in H → ττ efficiency



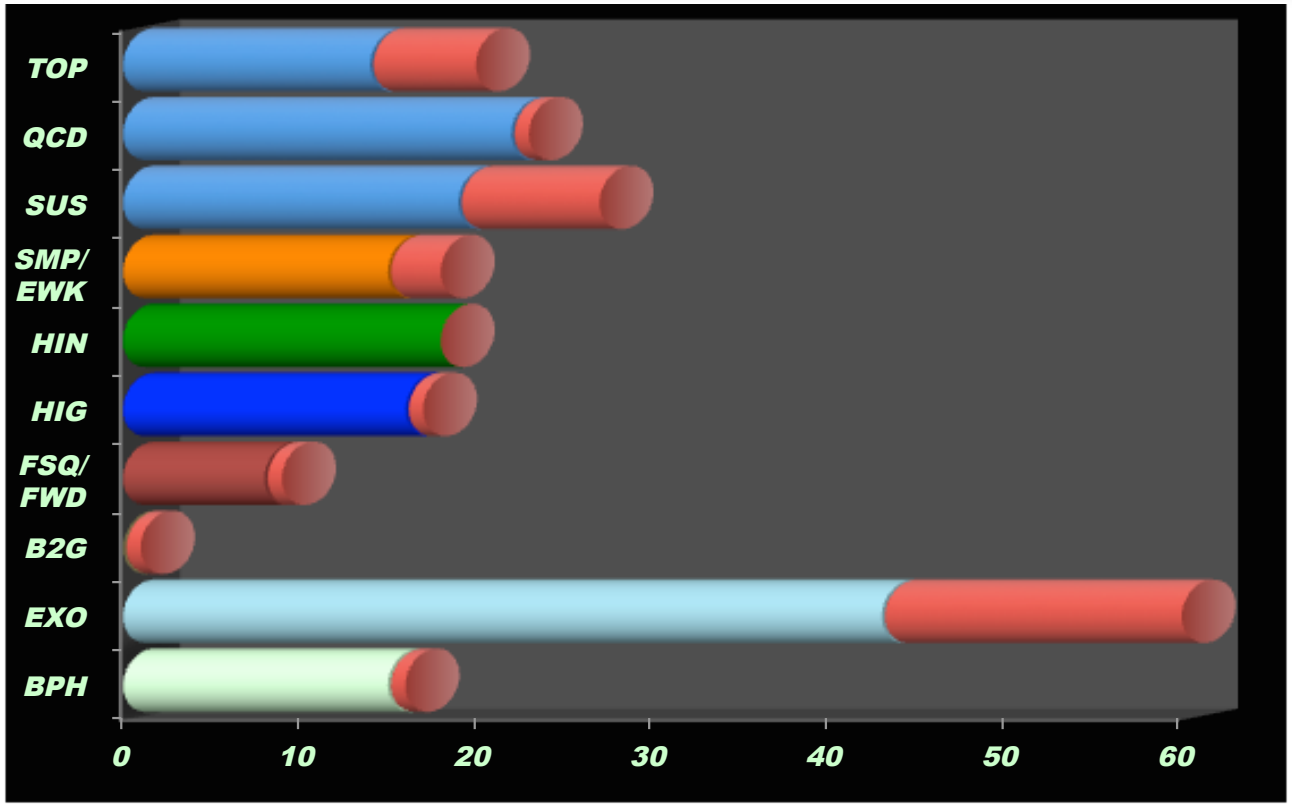


CMS publications



CMS publications

170 Collision data papers published or submitted
40 now in final stages of preparation for submission



Remaining (planned) pubs with 2011 data

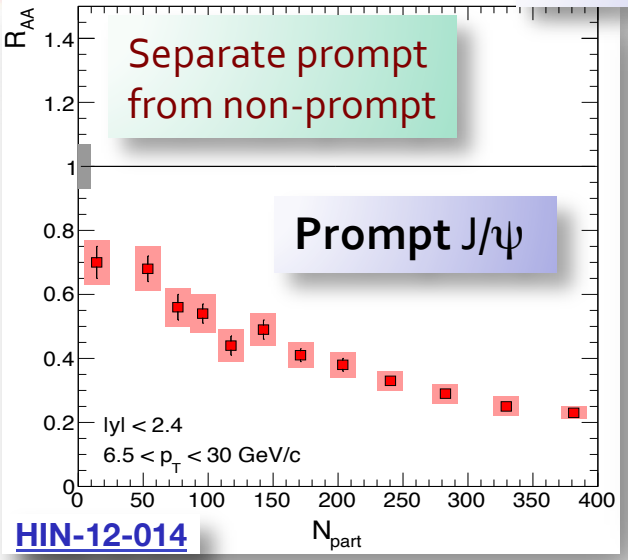
Physics Group	Planned
B2G	10
BPH	19
SMP	22
EXO	1
FWD/FSQ	15
HIG	6
HIN	3
SUS	3
TOP	5
	72

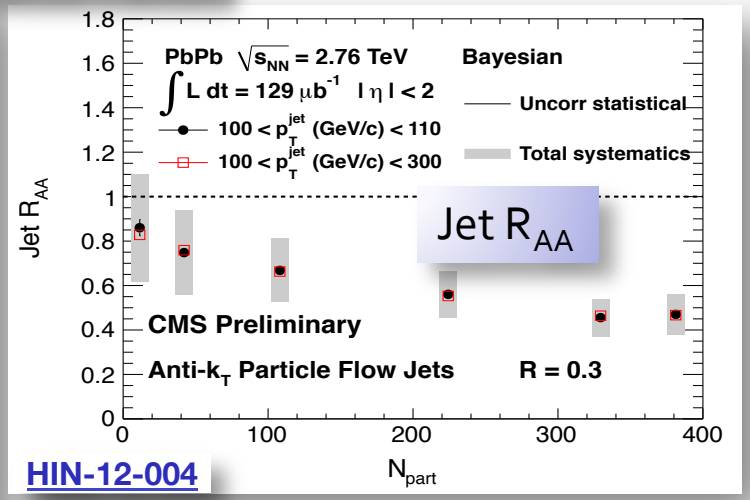
Publications with 2012 data: planning underway

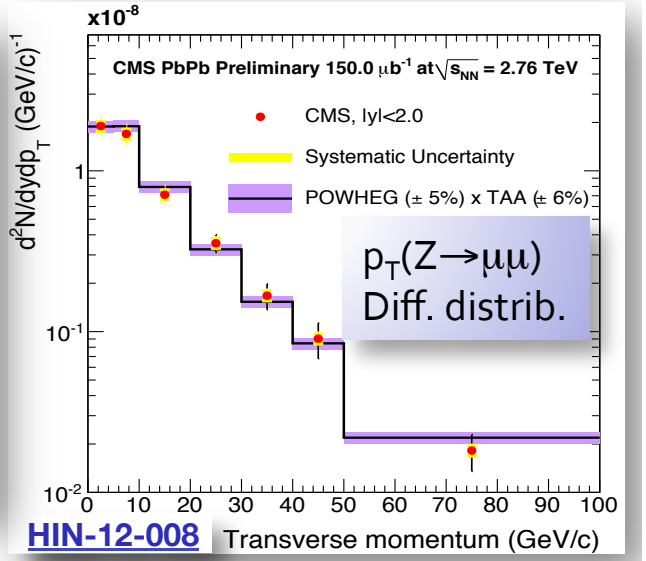
Some recent results

Heavy-Ion Highlights

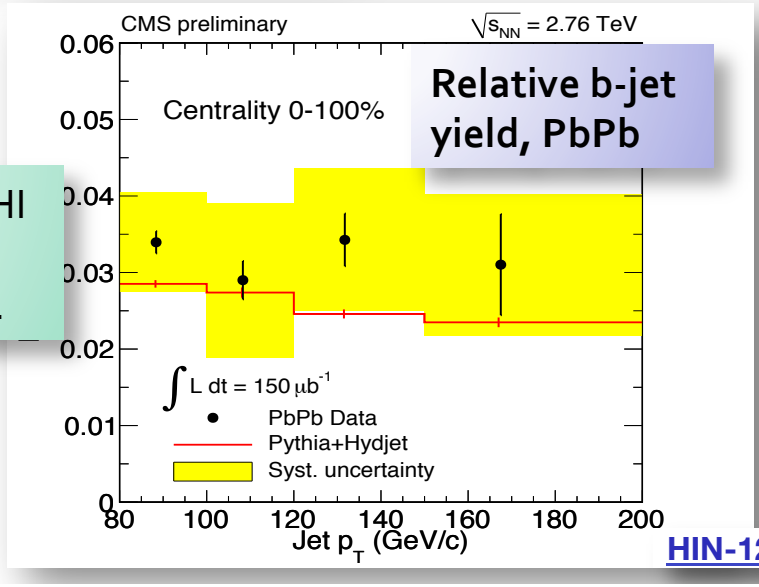
Nucl. Mod. Factors

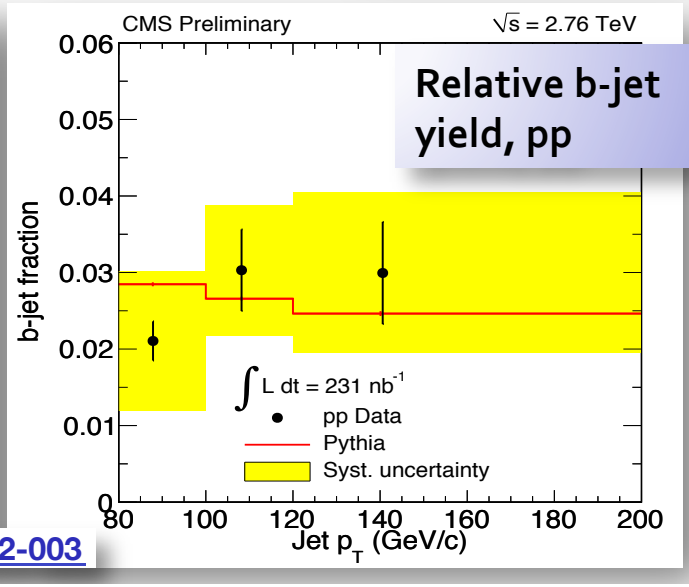






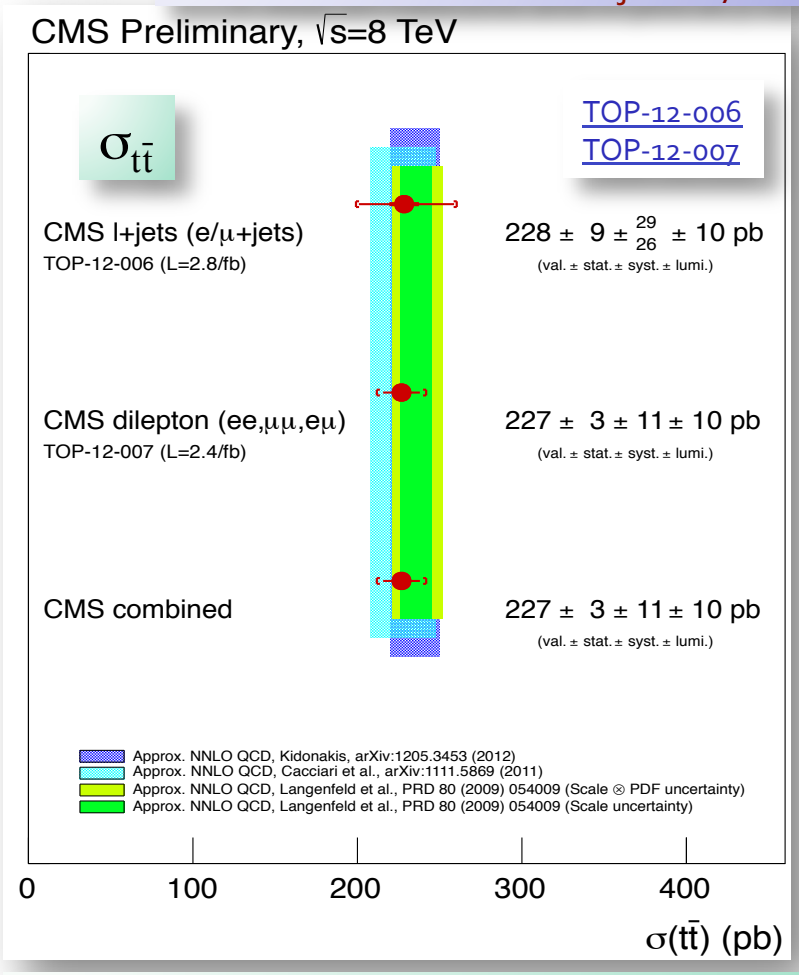
First bjet ID in HI collisions.
Also quenched.



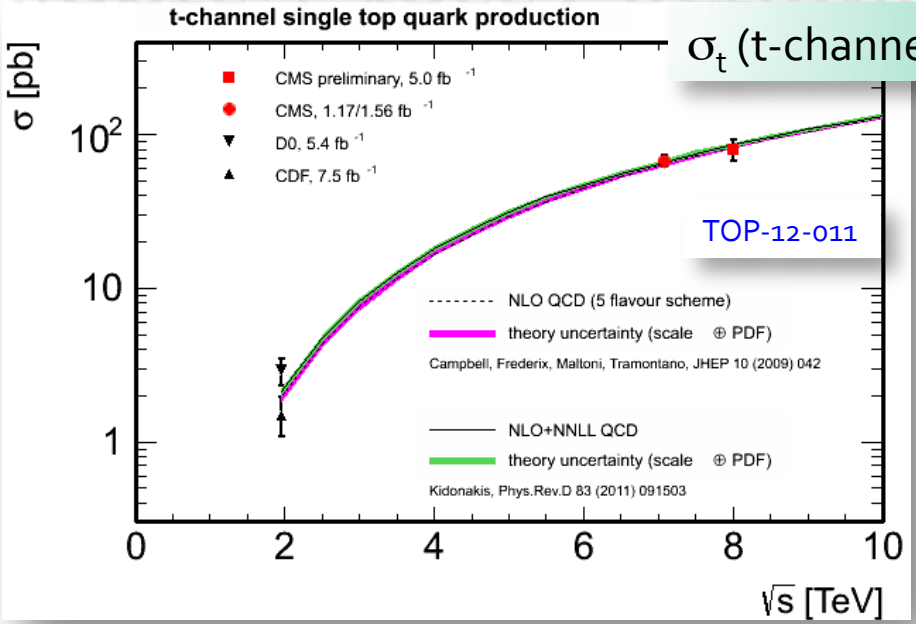


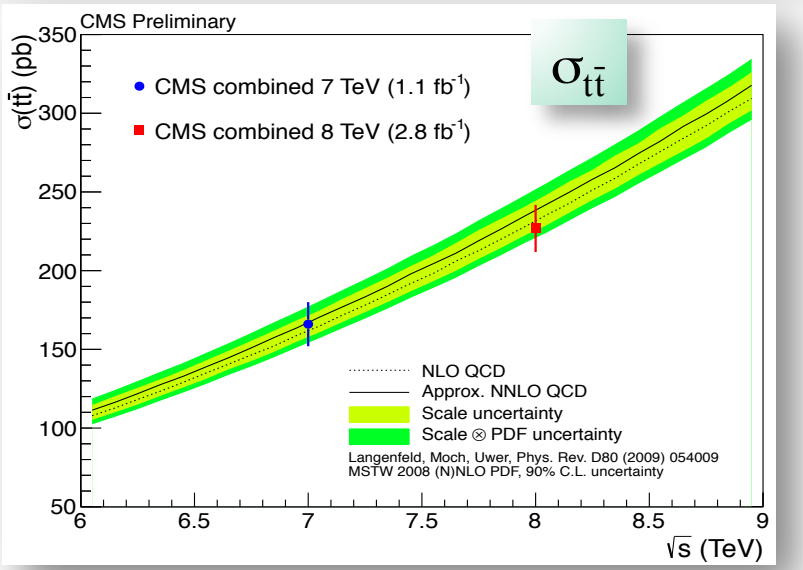
Top Highlights: Cross Sections

- σ_t (t-channel) at 8 and 7 TeV
- $\sigma_{t\bar{t}}$ in the dilepton and lepton +jets channels at 8 TeV
  - Also all-hadronic and τ+jets at 7 TeV



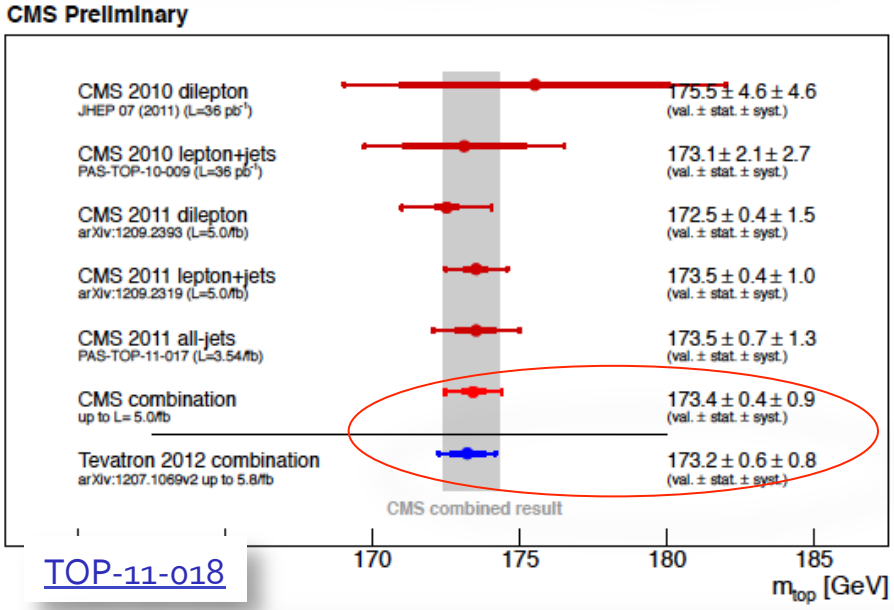
σ_{tt}(NLO) = 225.2 pb calculated using MCFM





Top Highlights: Properties

$m_t = 173.36 \pm 0.38\,(\text{stat.}) \pm 0.91\,(\text{syst.})\,\text{GeV}$

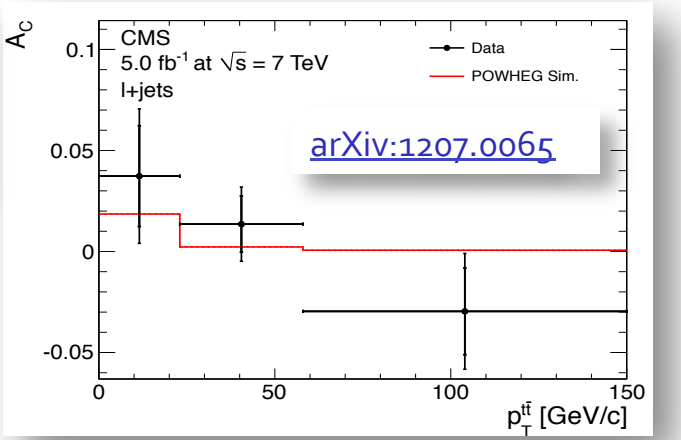


TOP-11-018

Table 2: Correlation coefficients between the input measurements

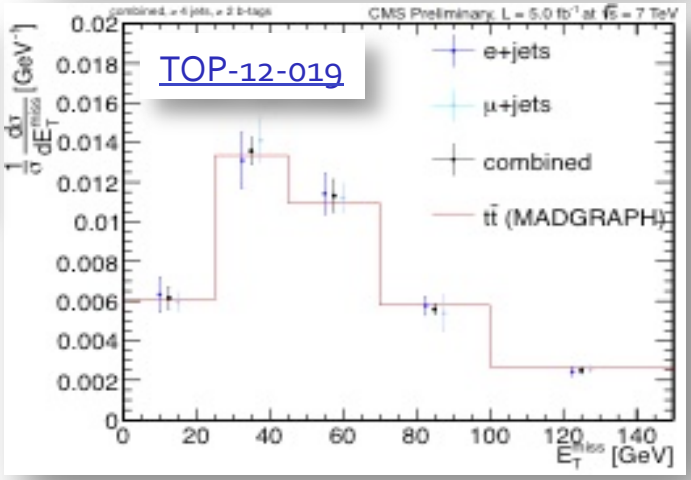
	Di-lepton 2010	Lepton+jets 2010	Di-lepton 2011	Lepton+jets 2011	All-jets 2011
Di-lepton 2010	1.00				
Lepton+jets 2010	0.30	1.00			
Di-lepton 2011	0.35	0.67	1.00		
Lepton+jets 2011	0.26	0.44	0.64	1.00	
All-jets 2011	0.36	0.59	0.71	0.56	1.00

- $t\bar{t}$ differential measurements:
  - e.g. Q asymmetry



arXiv:1207.0065

Associated production $t\bar{t}$+ME_T



TOP-12-019

Associated production $t\bar{t}b\bar{b}$

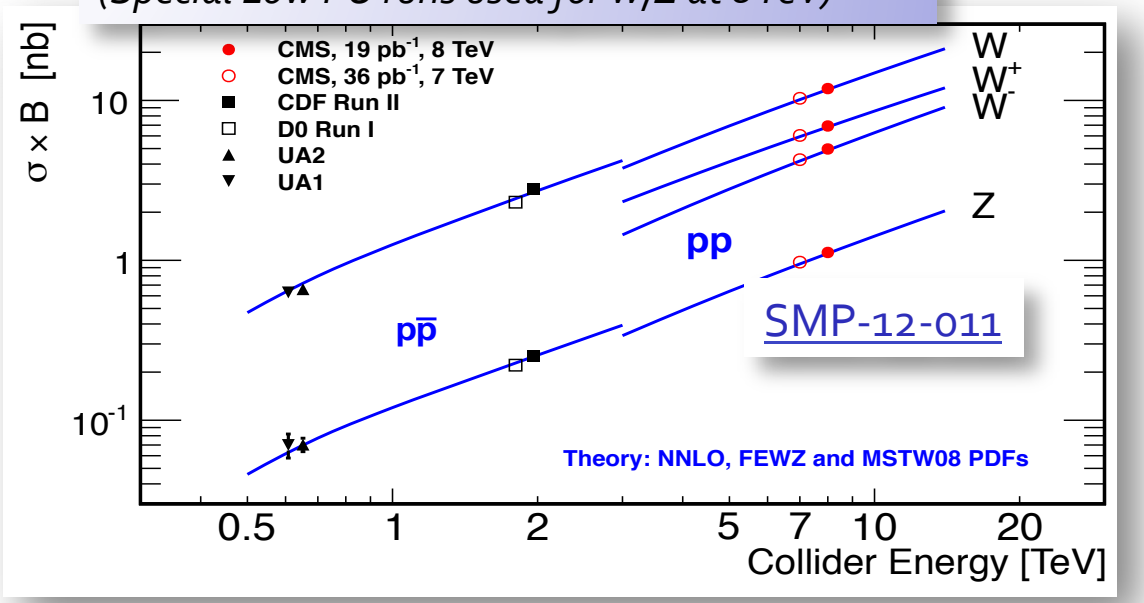
$\sigma(t\bar{t}b\bar{b})/\sigma(t\bar{t}jj) = 3.6 \pm 1.1(stat.) \pm 0.9(sys.)\%$

FCNC top decay limit: arXiv:1208.0957

B(t → Zq) < 0.24% @ 95% CL

Electroweak Highlights

W, Z, WW, and ZZ **cross sections at 8 TeV**
(Special Low PU runs used for W,Z at 8 TeV)

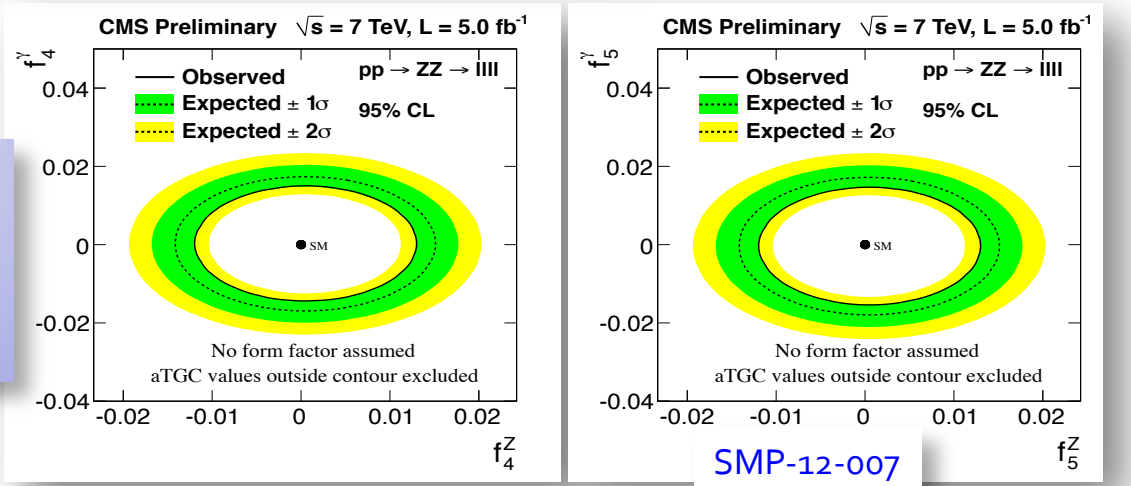


SMP-12-011

Measured σ (ZZ) = 8.4 ± 1.3 pb
SM (NLO) σ (ZZ) = 7.7 ± 0.4 pb
Measured σ (WW) =69.9 ± 7.0 pb
SM (NLO) σ (WW) = 57.3 ± 2.0 pb

SMP-12-013
SMP-12-014

- **Limits** on anomalous ZZZ/ZZγ couplings:



SMP-12-007

B and Forward Physics

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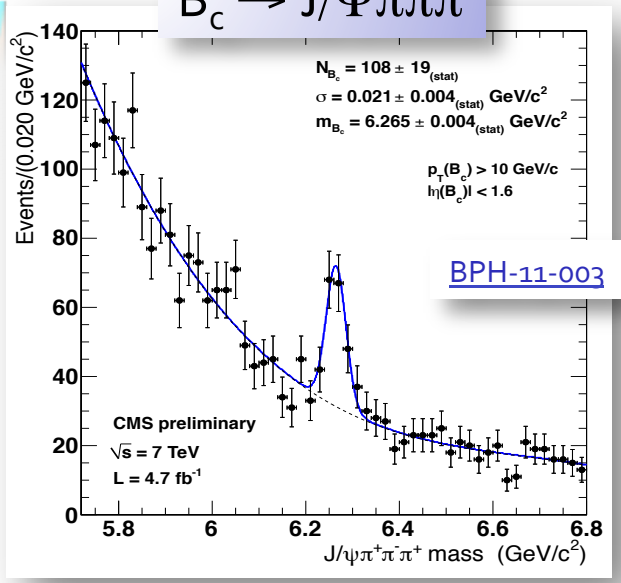
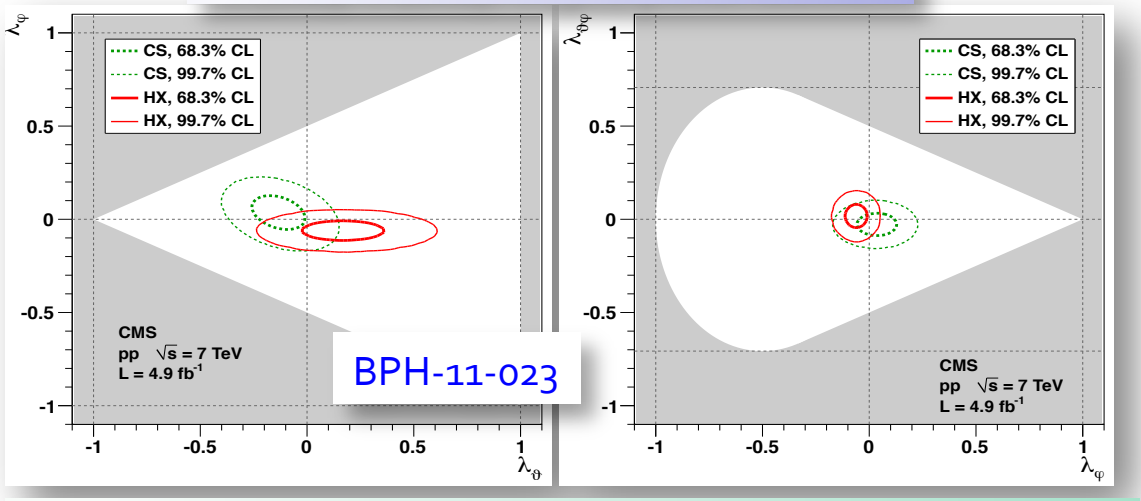
$B_c \rightarrow J/\Psi\pi\pi\pi$



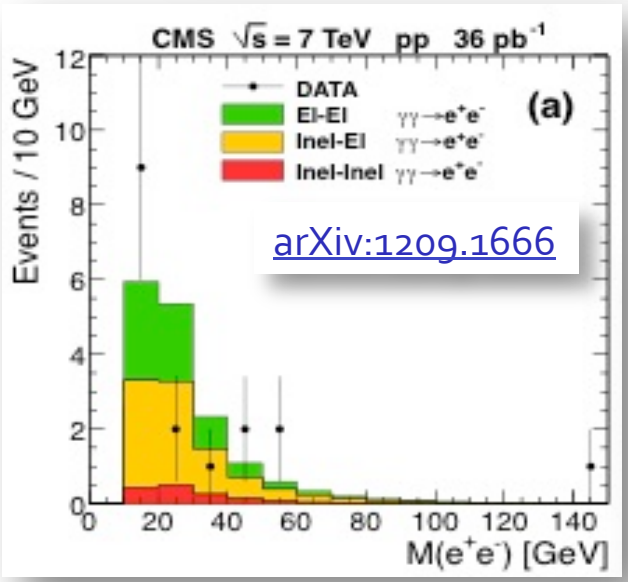
BPH-11-003

$\Upsilon(1S)$, $\Upsilon(2S)$, $\Upsilon(3S)$ polarization



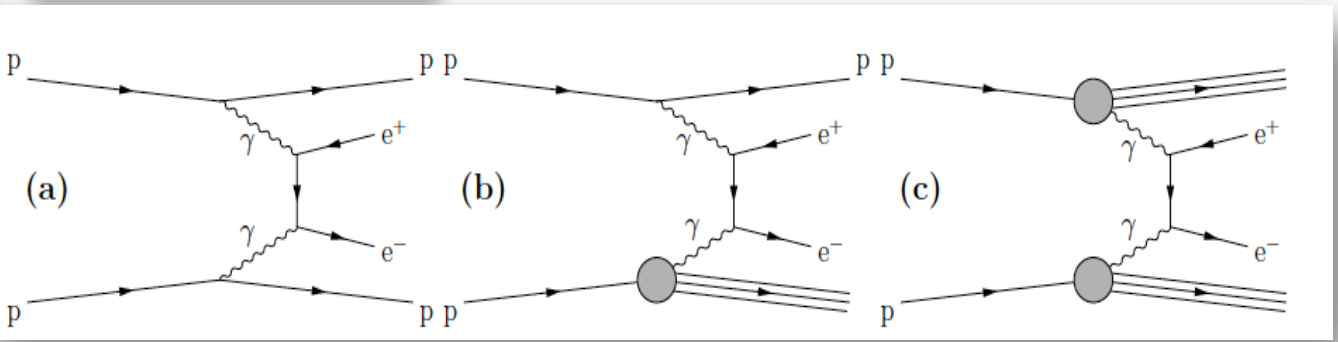
BPH-11-023

No evidence for large transverse or longitudinal polarizations



arXiv:1209.1666

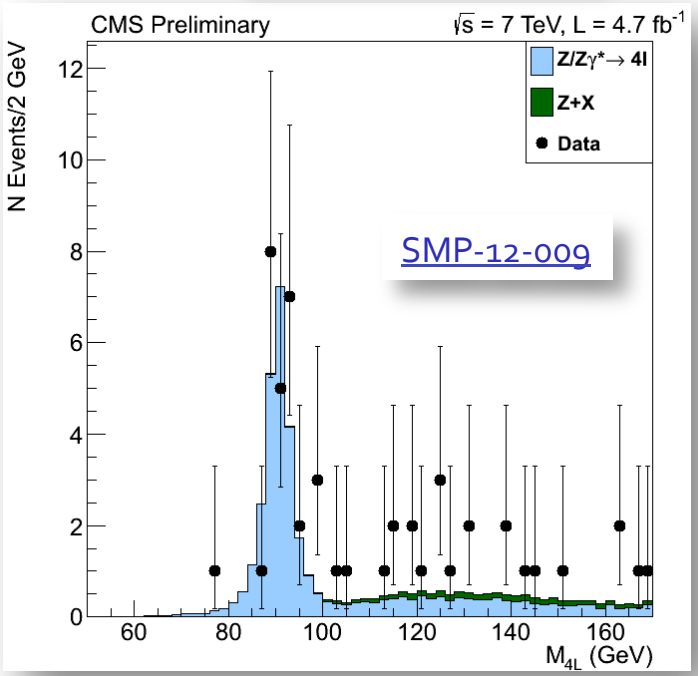
Observation of elastic e^+e^- production



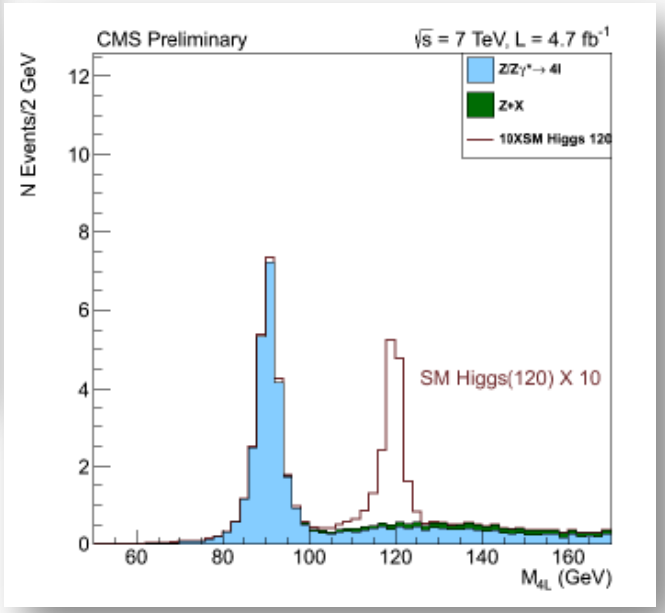
Electroweak Highlights

Z→ 4l decay
8.9 σ **observation**

Final state channels	$4e$	4μ	$2e2\mu$	4ℓ
Irreducible background ($pp \to Z\gamma^* \to 4\ell$)	0.04	0.16	0.08	0.3 ± 0.03
Other reducible backgrounds	0.01	0.01	0.05	0.1 ± 0.13
Expected signal ($pp \to Z \to 4\ell$)	3.1	12.3	9.2	24.6 ± 2.2
Total expected (MC)	3.2	12.5	9.3	25.0 ± 2.2
Observed events	2	14	10	26
Rate from the fit of the observed mass distribution		13.6	9.7	25.4



SMP-12-009

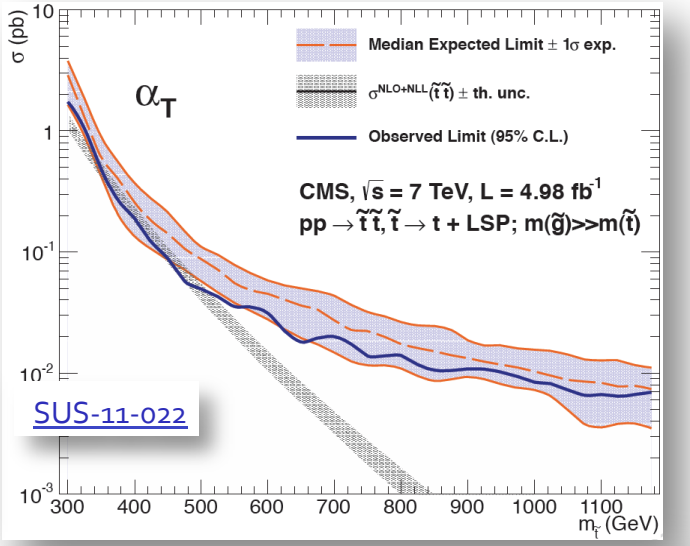


- Standard candle
  - H →ZZ→ 4l
  - 10x more events
- Current statistics
  ±0.5% on m_{4l} scale

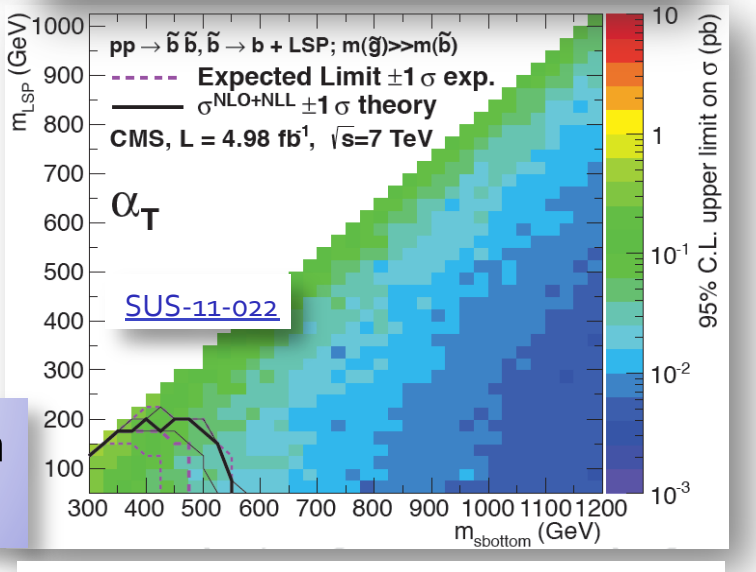
Requirement	Quantity of interest	$4e$	4μ	$2e2\mu$	4ℓ
$m_{\ell\ell} > 4$ GeV	partial width, Γ_i (keV)	2.95	2.95	5.21	11.12
	branching fractions, Γ_i/Γ_{tot}	$1.18 \cdot 10^{-6}$	$1.18 \cdot 10^{-6}$	$2.09 \cdot 10^{-6}$	$4.45 \cdot 10^{-6}$
	relative fractions, $f_i = \Gamma_i/\Gamma_{4\ell}$	0.2655	0.2655	0.4690	

Light stops, sbottoms and EWKinos

Stop via α_T

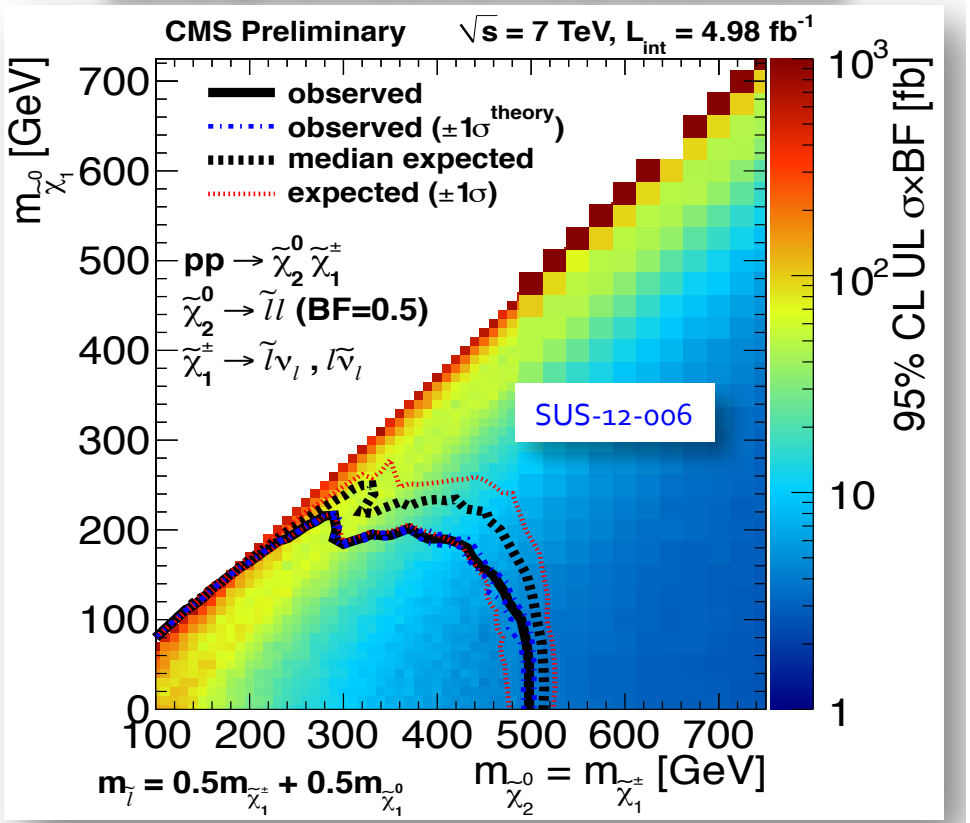


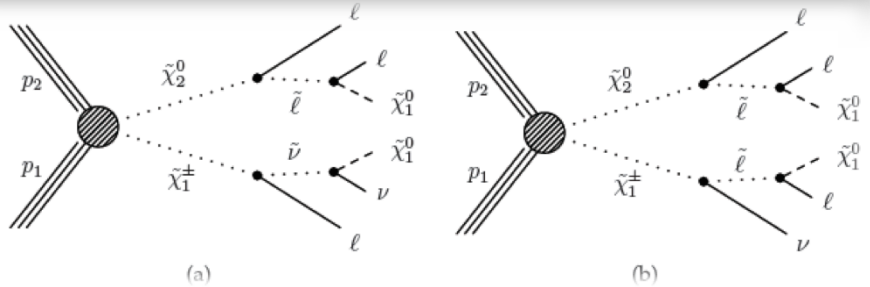
Sbottom via α_T



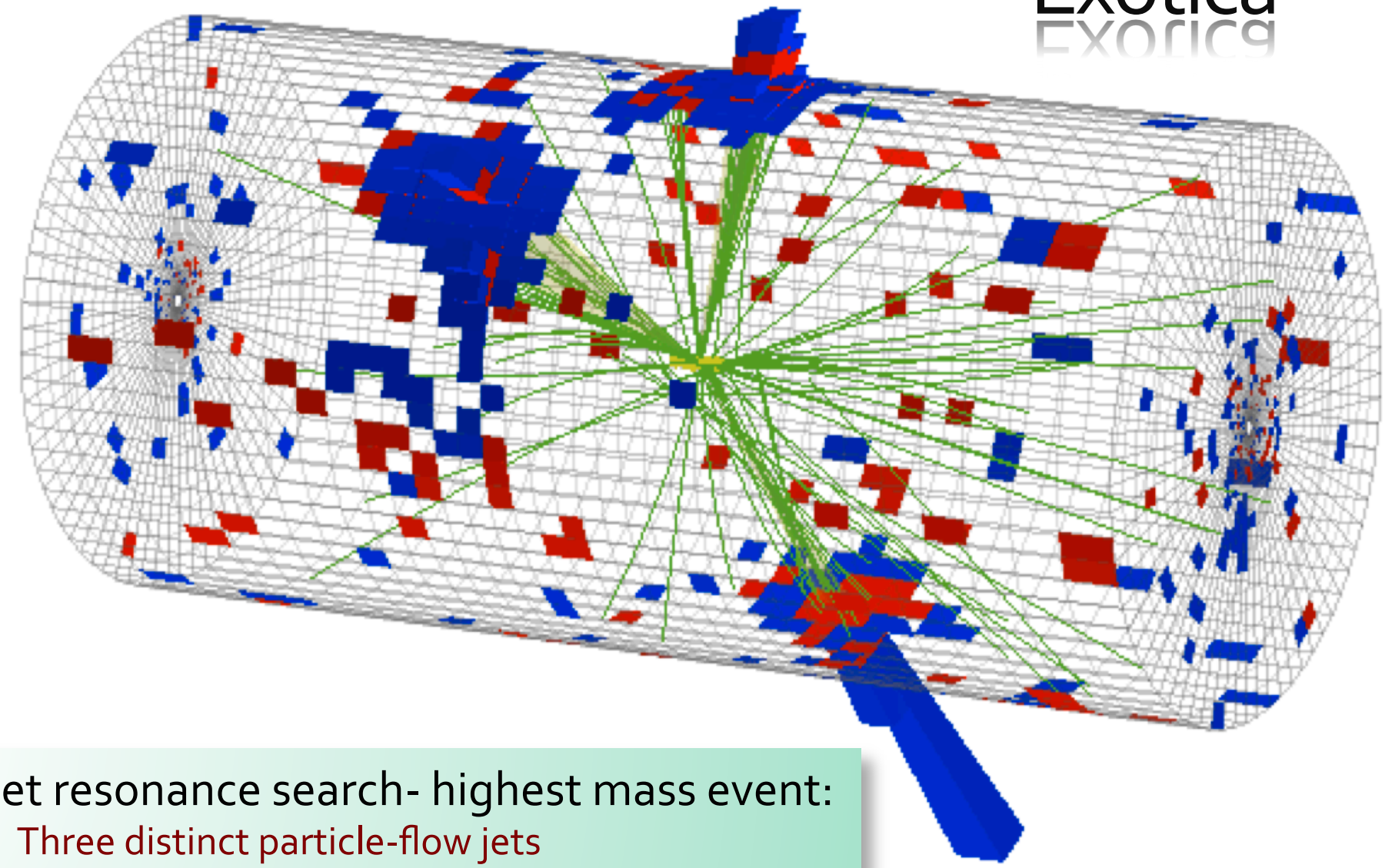
$$\alpha_T = \frac{E_T^{j_2}}{M_T} \quad , \quad M_T = \sqrt{\left(\sum_{i=1}^{2} E_T^{j_i}\right)^2 - \left(\sum_{i=1}^{2} p_x^{j_i}\right)^2 - \left(\sum_{i=1}^{2} p_y^{j_i}\right)^2}$$

Chargino-neutralino production





Exotica



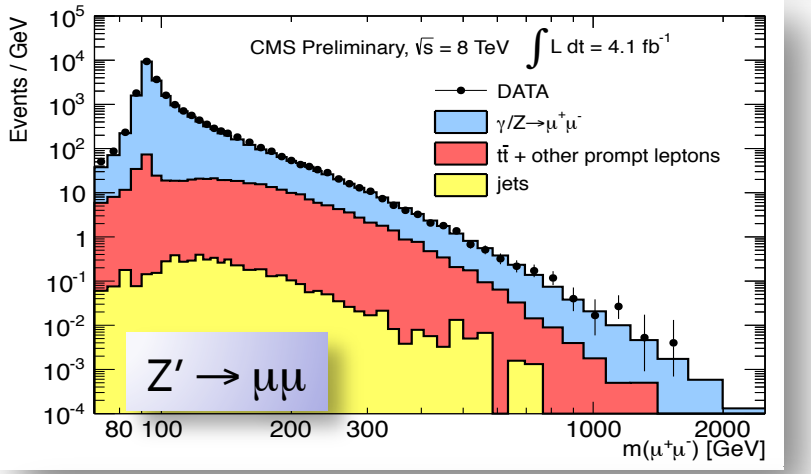
- Dijet resonance search- highest mass event:
  - Three distinct particle-flow jets
  - 2 lowest p_T jets combined by wide jet algorithm.
- Invariant mass of the two wide jets is 4.5 TeV

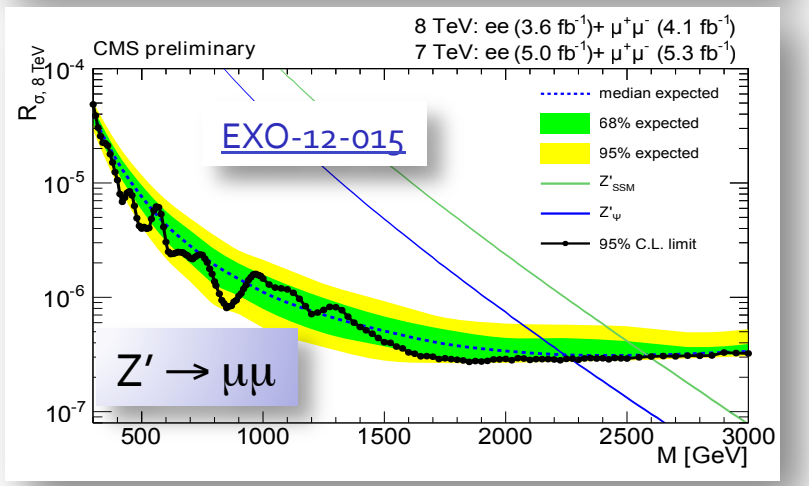
Data recorded: Sat May 26 13:25:29 2012 CEST
Run/Event: 195016 / 425646417
Lumi section: 384

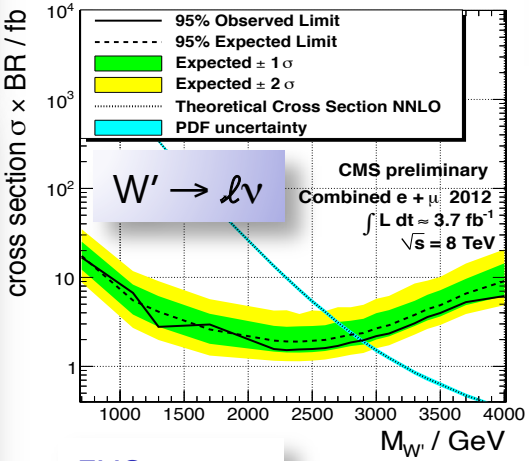
Exotica at √s= 8 TeV

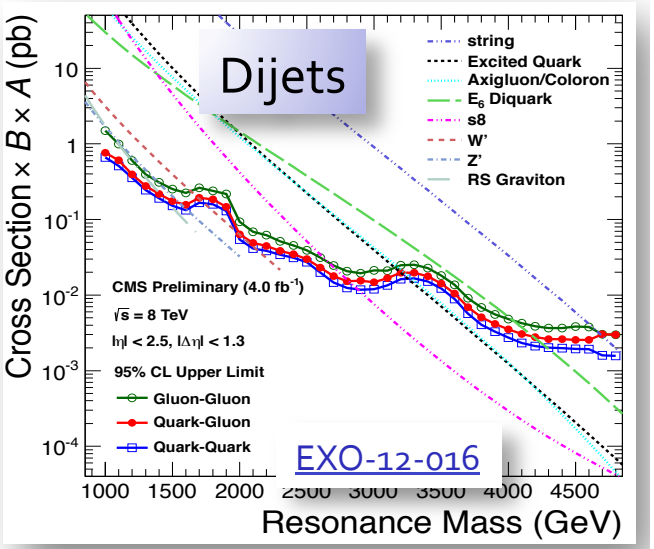
Higher √s translates directly into higher mass scales: Z′, W′, Black holes, …

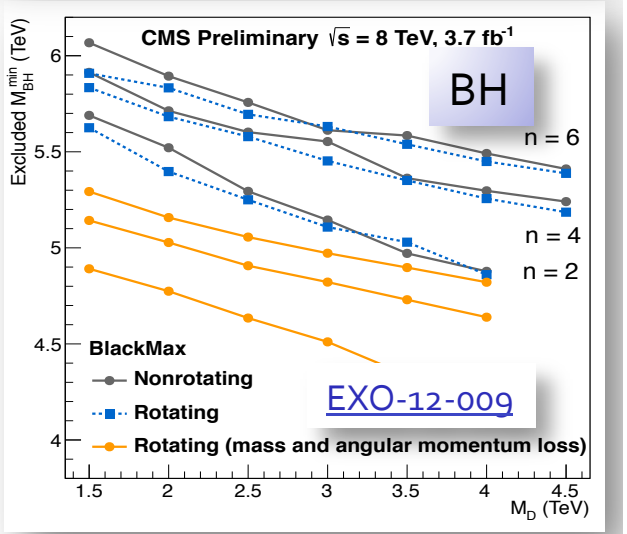
Z′: M > 2.6 TeV
W′: M > 2.9 TeV
BH: M > 5-6 TeV
q*: M > 3.2 TeV





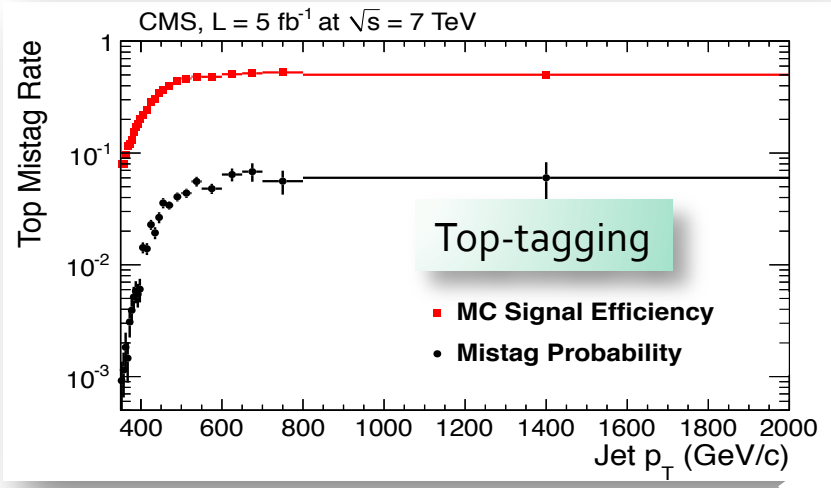


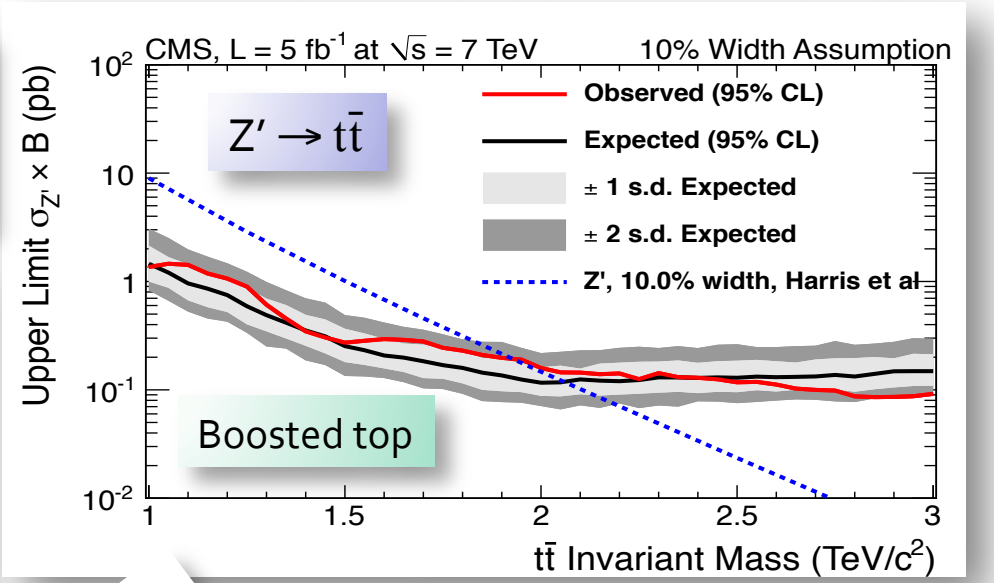




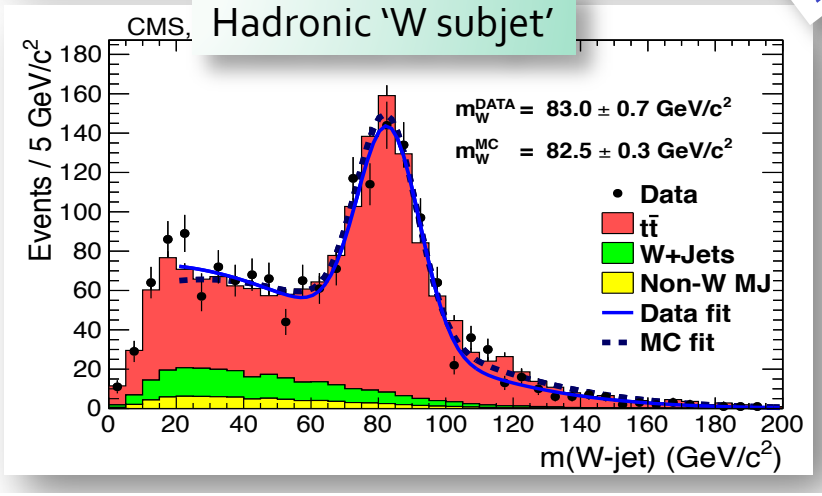
Beyond 2nd Generation (B2G): Boosted Objects

Search for $Z' \rightarrow t\bar{t}$ with merged jets from boosted top, W as reconstructed with algorithms developed by CMS

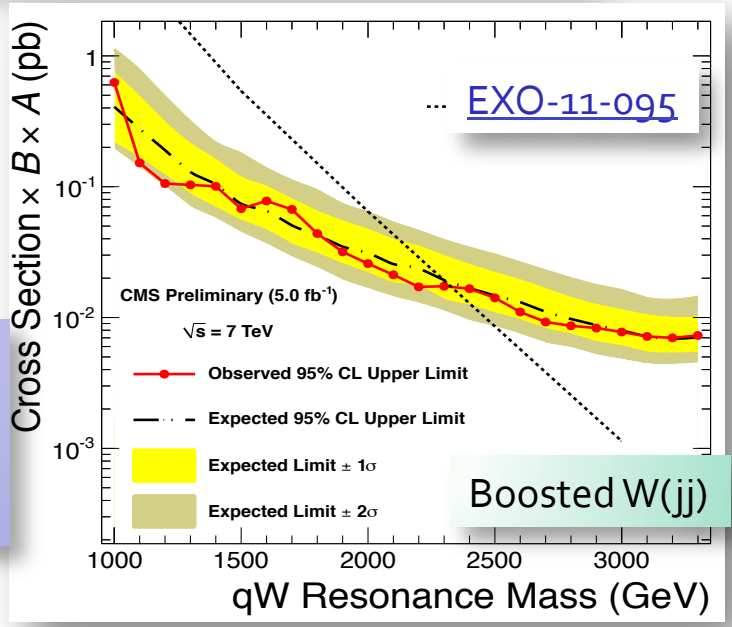




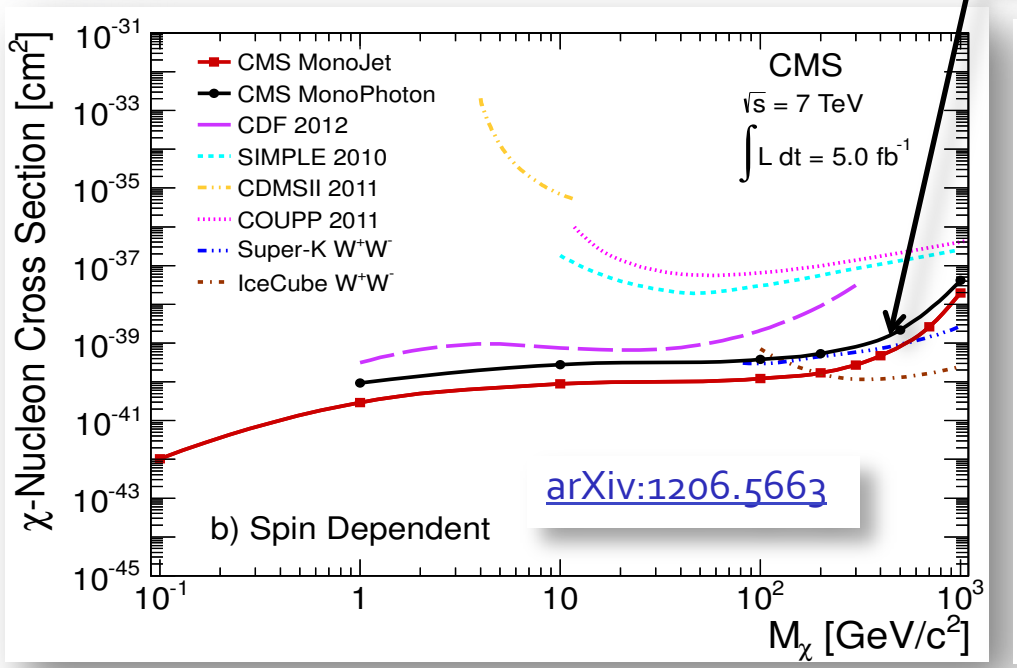
arXiv:1204.2488

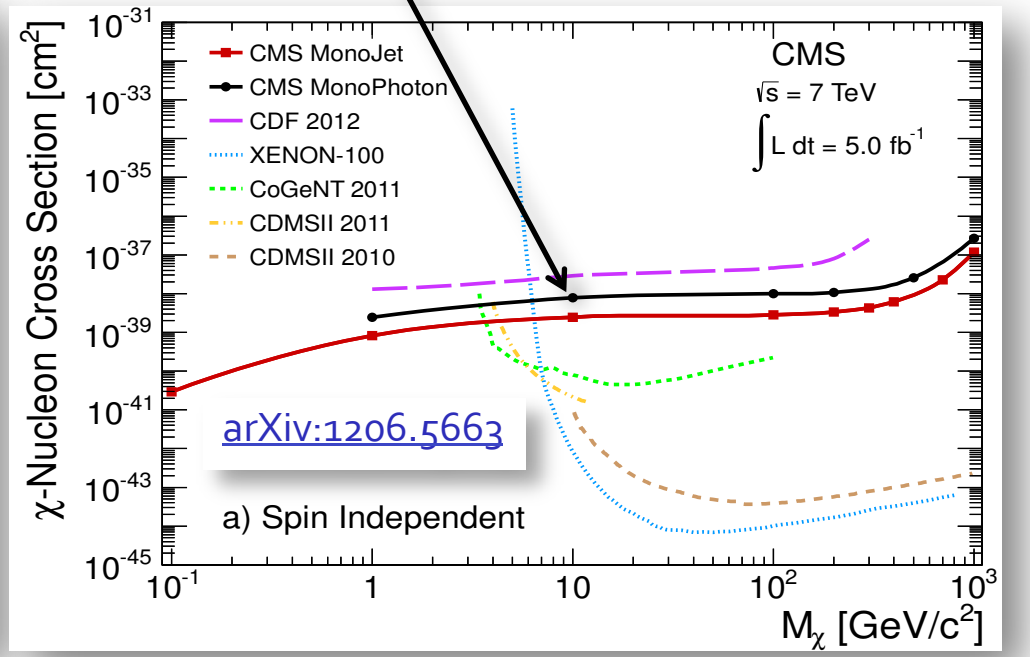


qW,qZ,WW,WZ,ZZ-resonances in the W or Z-tagged Dijet Mass Spectrum



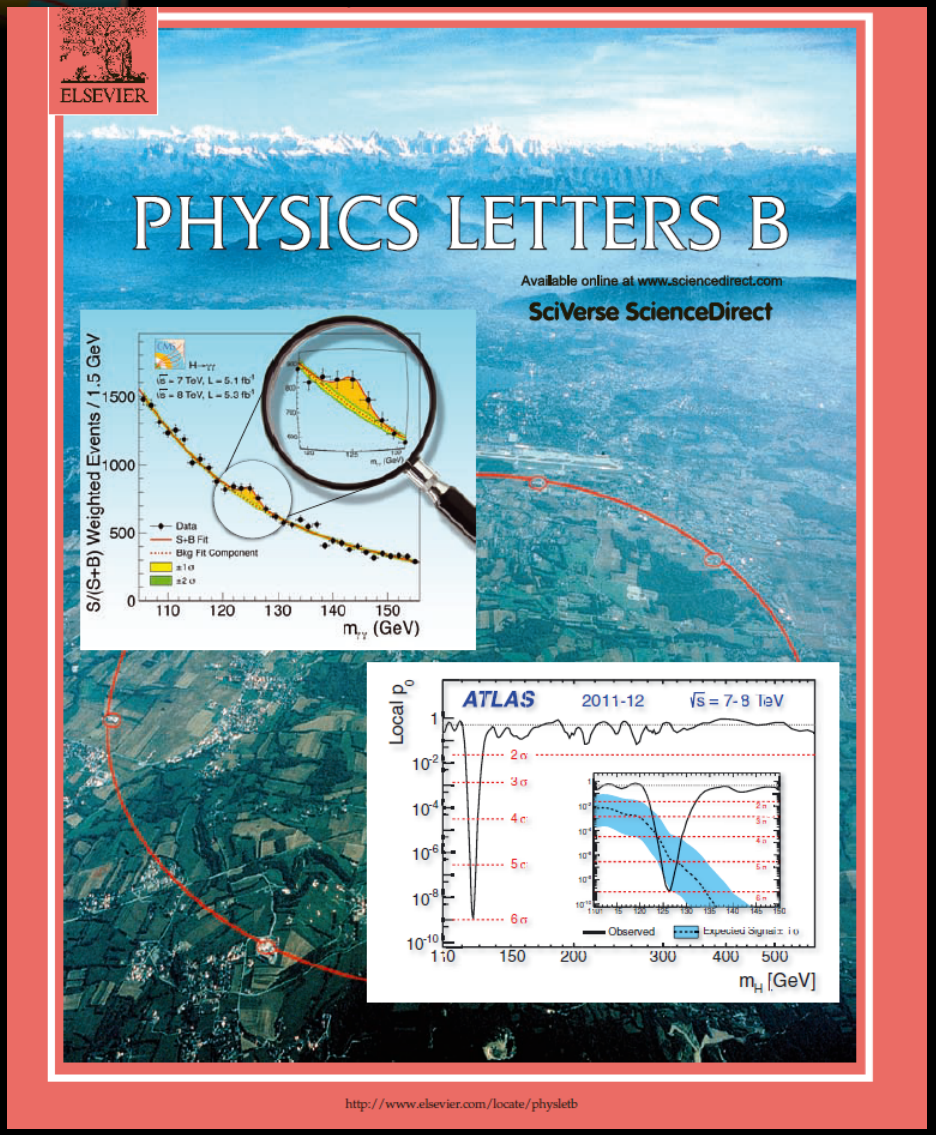
Exotica: Search for Dark Matter





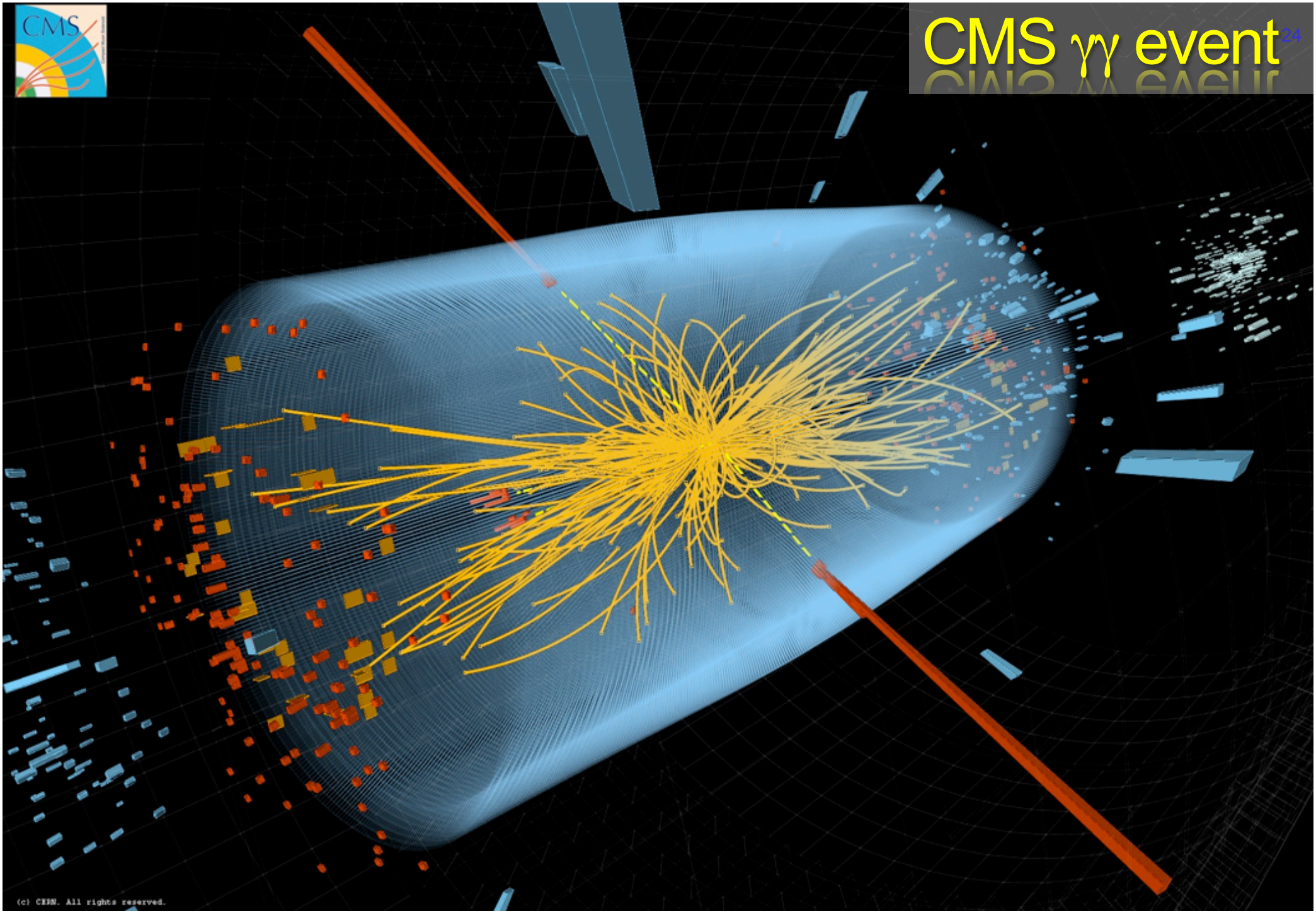
- Use photon or jet ISR to tag production of DM particles
  - Process very similar to that assumed in direct detection experiments
  - Exceeds sensitivity of cryogenic searches for DM for spin-dependent DM couplings
  - Adds sensitivity to light (M < 10 GeV) DM also for spin-independent couplings (where direct searches are most sensitive due to coherent scattering ~A^2)

Higgs



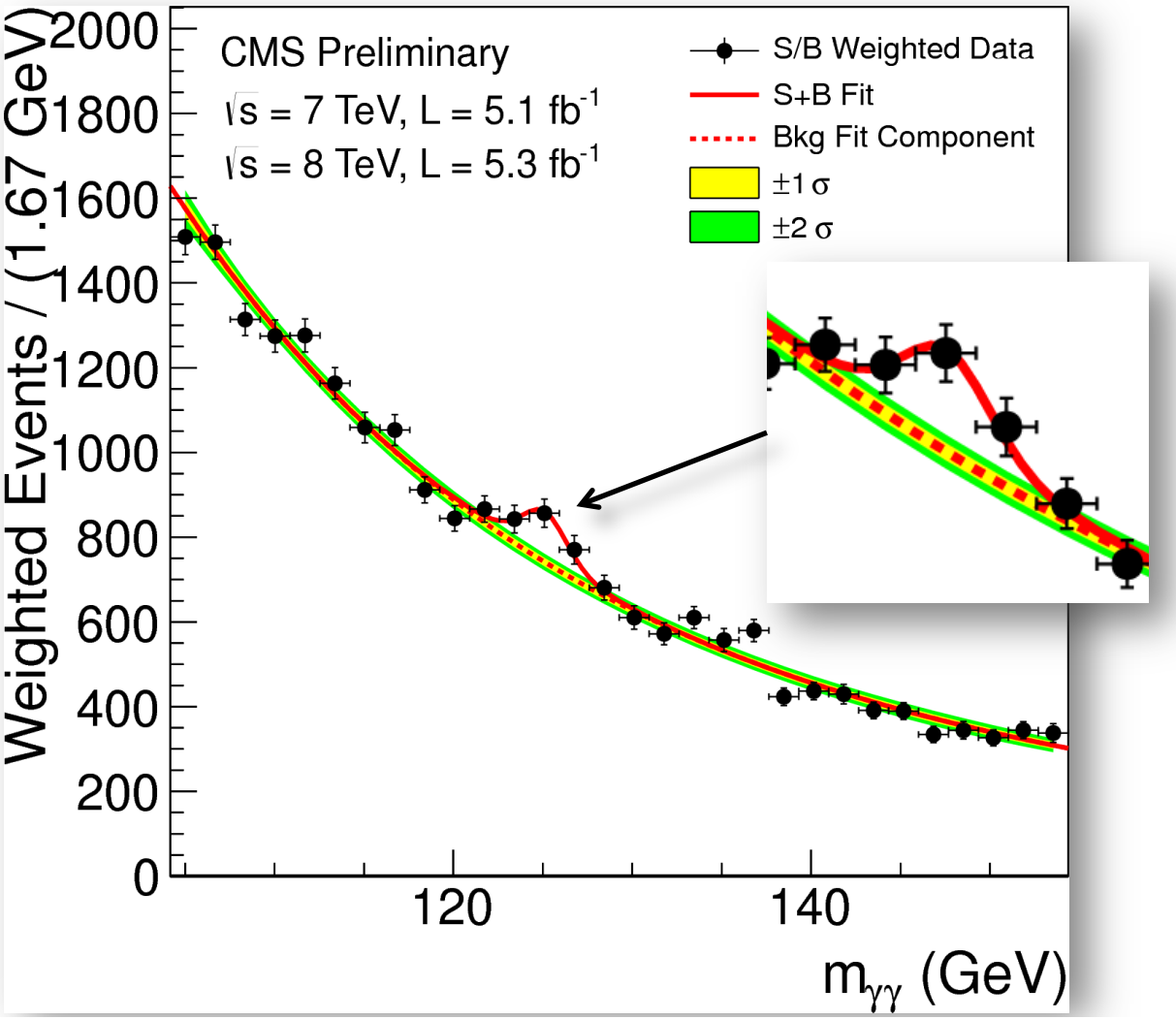
- Publication
  - No significant changes from 4th of July
- New
  - H →WW (Diff. Flavours)
    - Shape- based analysis
    - Stronger signal

CMS $\gamma\gamma$ event

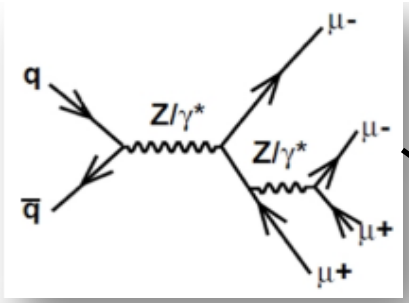


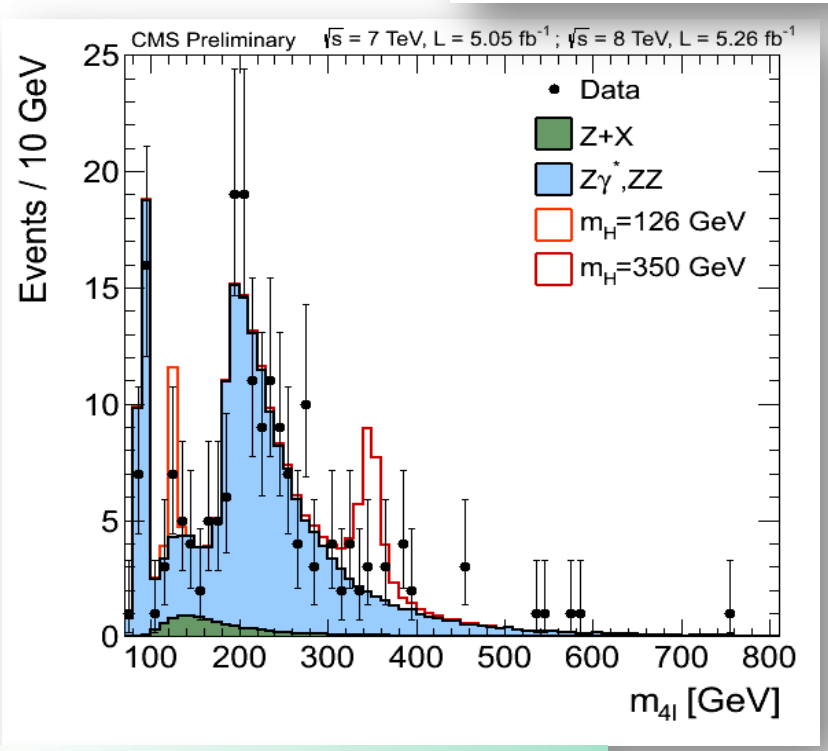
CMS γγ Mass Distribution

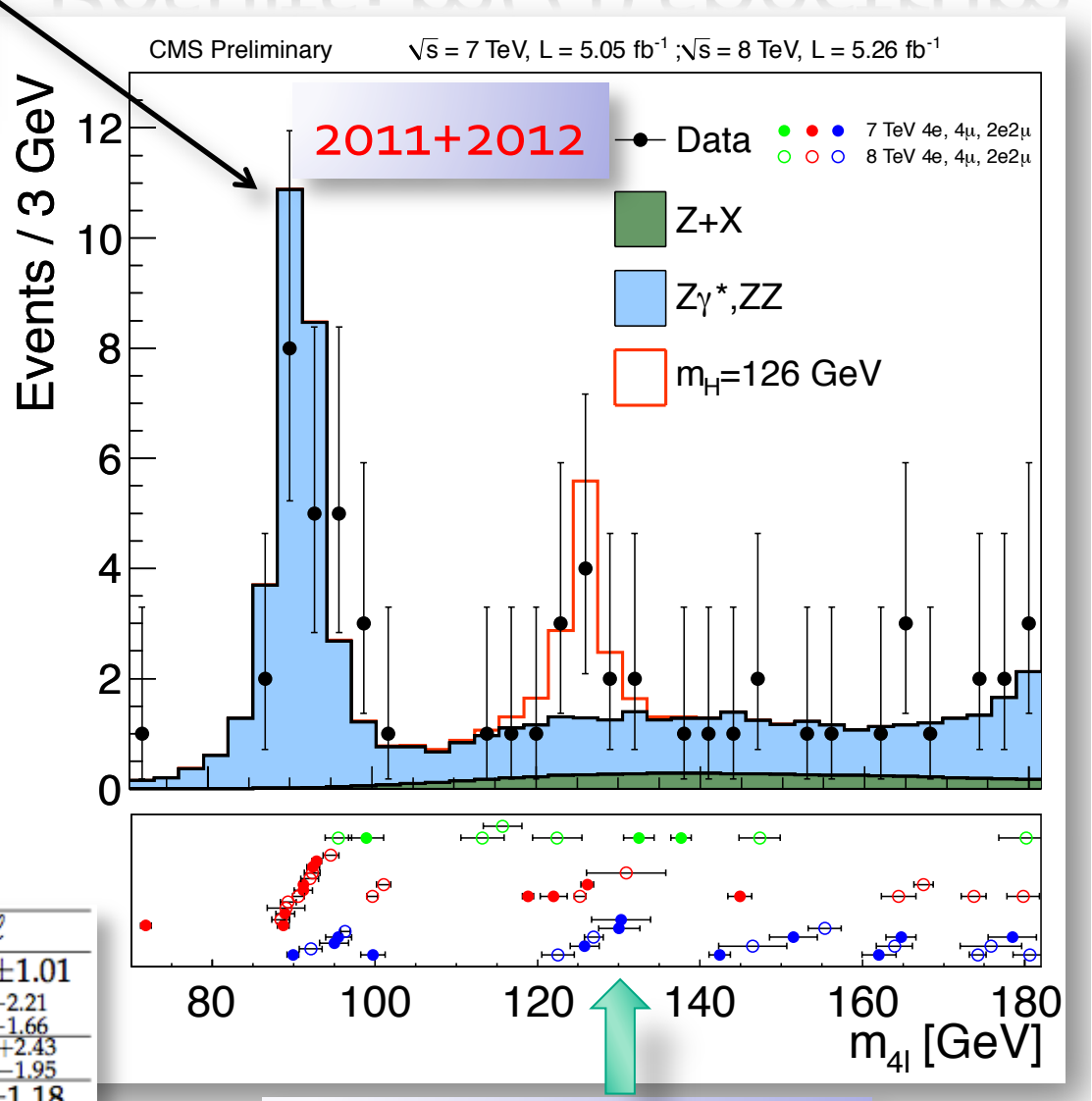
- Sum of mass distributions for each event class, weighted by S/B
  - B is integral of background model over a constant signal fraction interval



Results: m(4l) spectrum







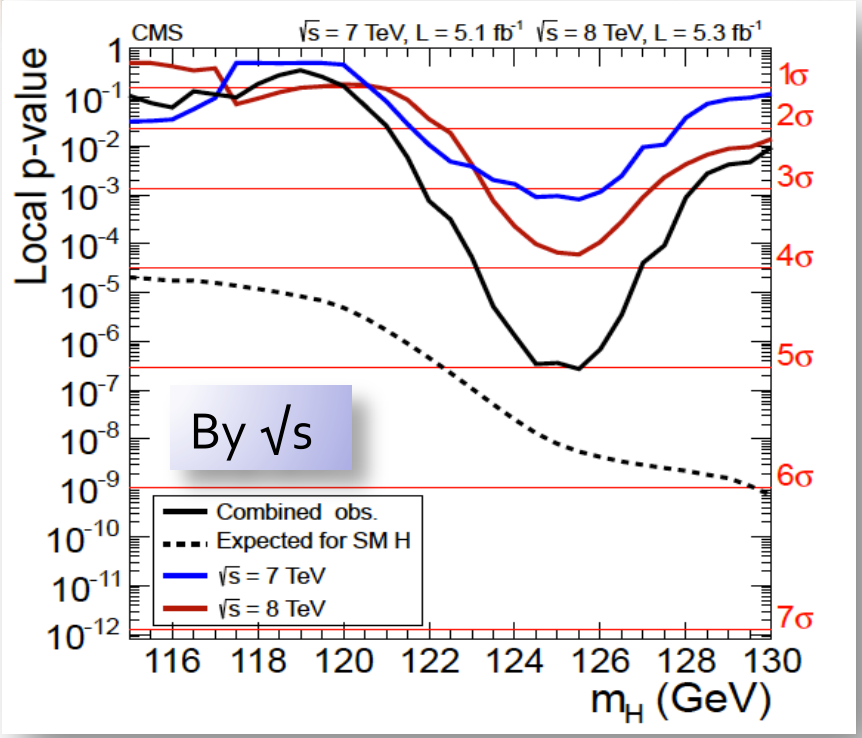
Yields for m(4l)=110..160 GeV

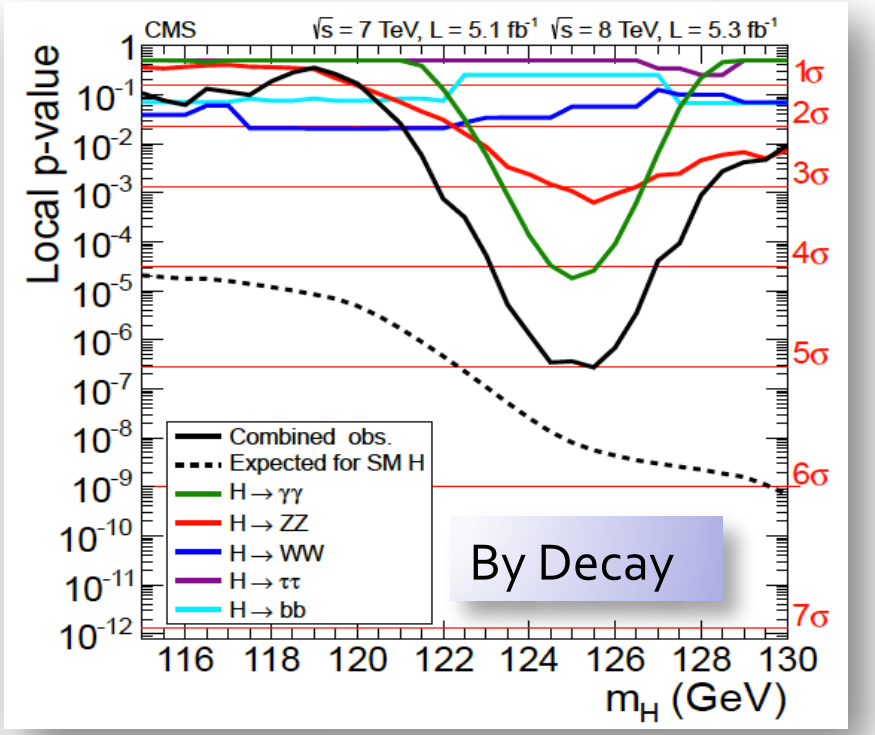
Channel	4e	4μ	2e2μ	4ℓ
ZZ background	2.65 $\pm$0.31	5.65 $\pm$0.59	7.17 $\pm$0.76	15.48 $\pm$1.01
Z+X	$1.20^{+1.08}_{-0.78}$	$0.92^{+0.65}_{-0.55}$	$2.29^{+1.81}_{-1.36}$	$4.41^{+2.21}_{-1.66}$
All backgrounds	$3.85^{+1.12}_{-0.84}$	$6.58^{+0.88}_{-0.81}$	$9.46^{+1.96}_{-1.56}$	$19.88^{+2.43}_{-1.95}$
$m_H = 126$ GeV	1.51 $\pm$0.48	2.99 $\pm$0.60	3.81 $\pm$0.89	8.31 $\pm$1.18

164 events expected in [100, 800 GeV]
172 events observed in [100, 800 GeV]

Event-by-event errors

PLB: Combined Results

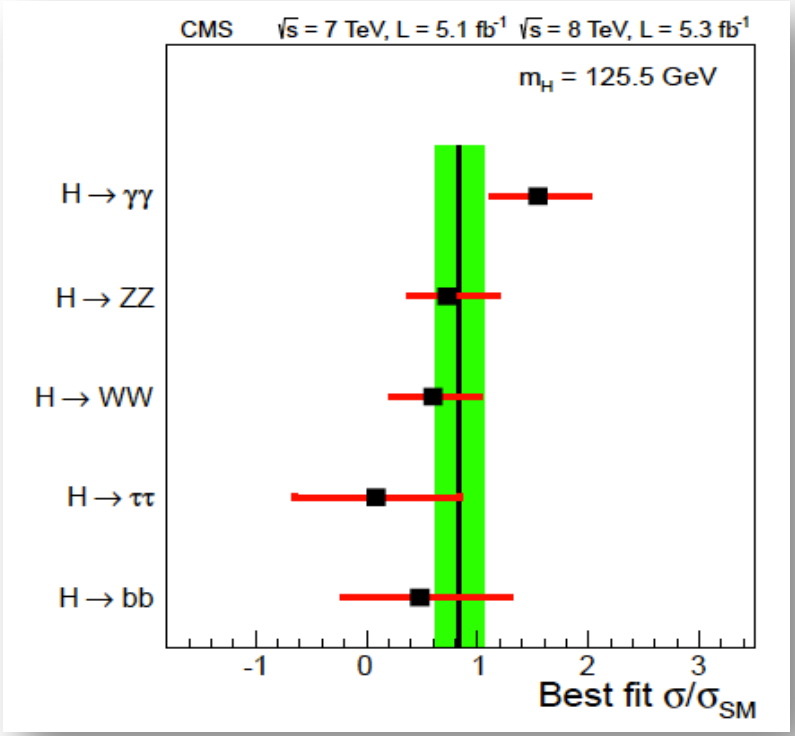




Decay mode/combination	Expected (σ)	Observed (σ)
$\gamma\gamma$	2.8	4.1
ZZ	3.6	3.1
$\tau\tau$ + bb	2.4	0.4
$\gamma\gamma$ + ZZ	4.7	5.0
$\gamma\gamma$ + ZZ + WW	5.2	5.1
$\gamma\gamma$ + ZZ + WW + $\tau\tau$ + bb	5.8	5.0

5.0σ versus
5.8σ expected

Signal Strengths

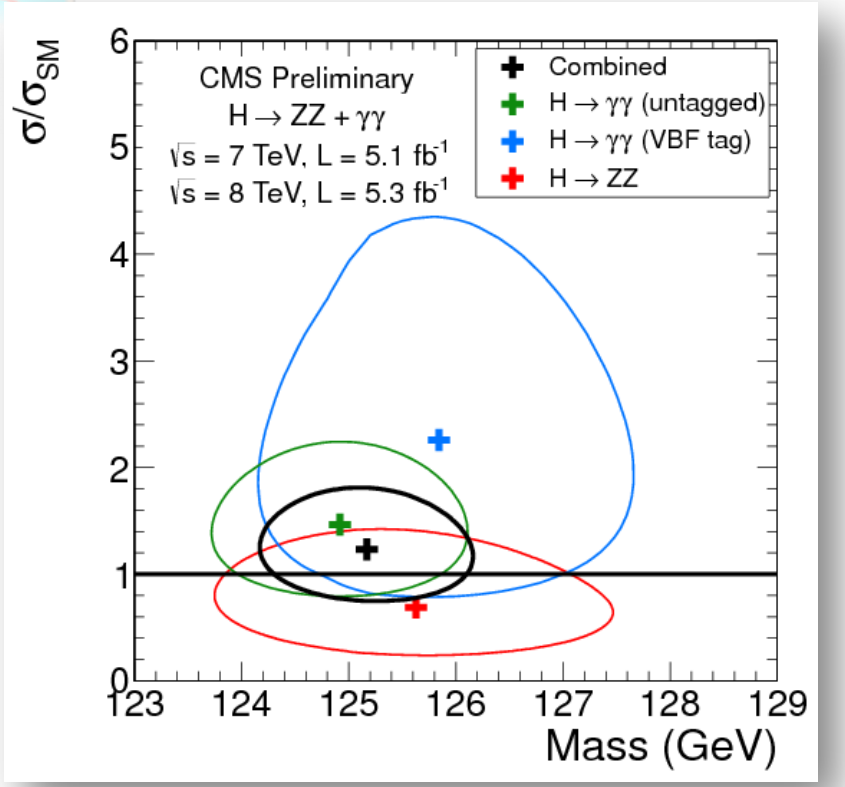


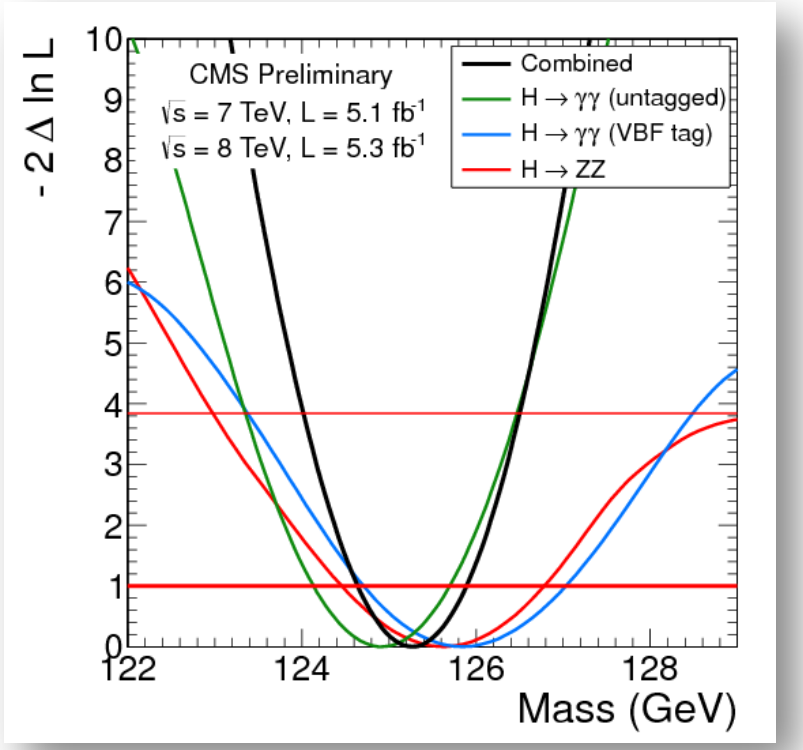
- Best-fit signal strength to combined data

$$\frac{\sigma}{\sigma_{SM}} = 0.87 \pm 0.23$$

- Spin-parity
  - Spin one ruled out by 2γ decay
  - Assuming S=0, one can use H→ZZ to distinguish between parity states

Characterization of the excess: mass





- Likelihood scan for mass and signal strength in three high mass resolution channels
  - results are self-consistent and can be combined

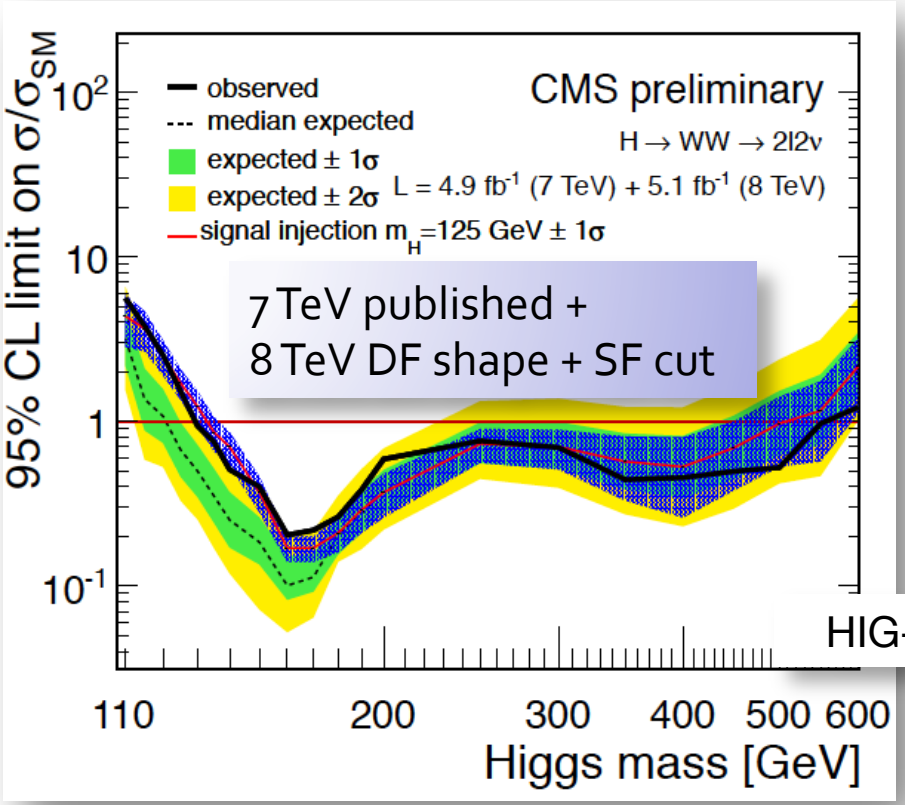
- To reduce model dependence, allow for free cross sections in three channels and fit for the common mass:

$m = 125.3 \pm 0.4\ (stat) \pm 0.5\ (syst)$

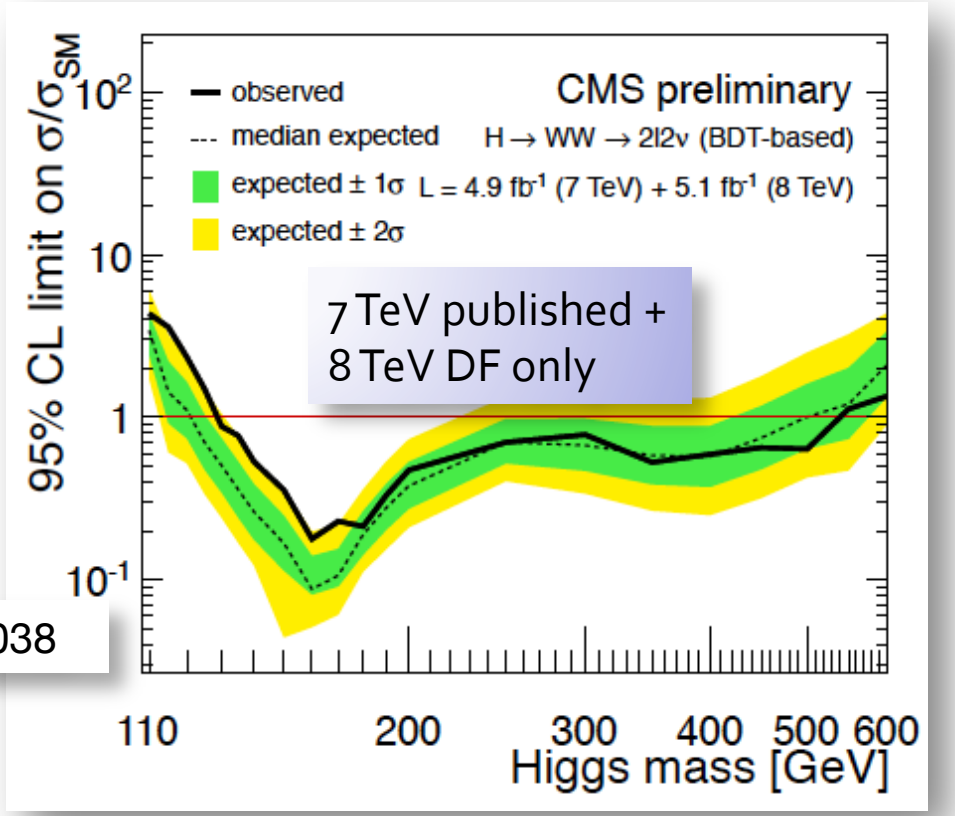
LHC ultimate precision: < 100 MeV

New H→WW Shape-Based Analysis

- Discovery result was based on SF (ee, μμ) and DF (eμ) cut-based analysis
  - Understanding of the SF background dominated by DY+MET is very non-trivial in the presence of large PU
  - Moving away from SF in the future (sensitivity is marginal)
- The shape-based DF analysis will be the basis of future updates



HIG-12-038

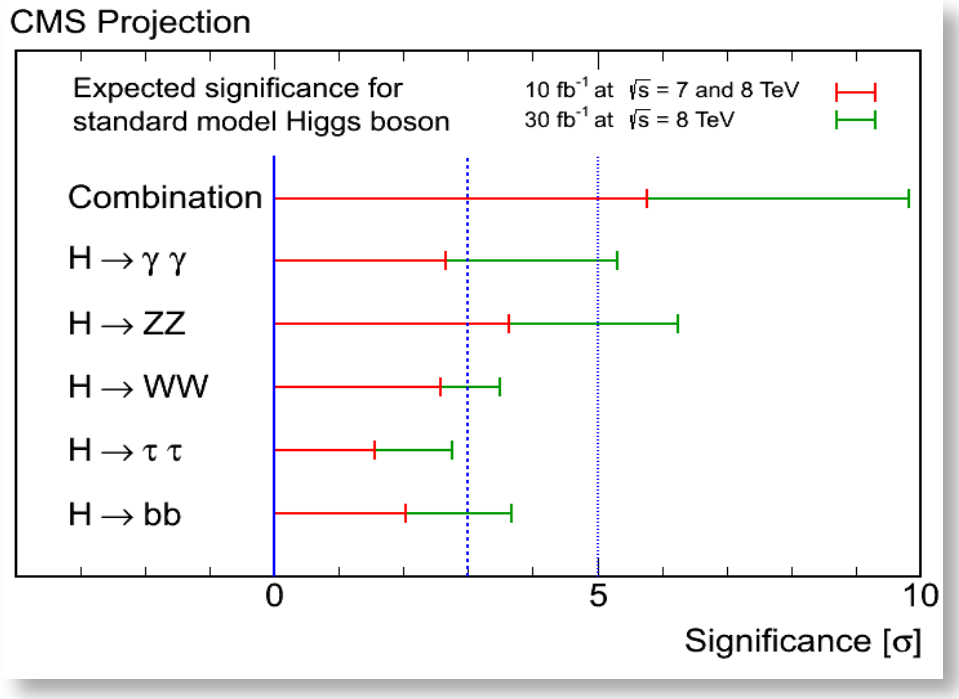


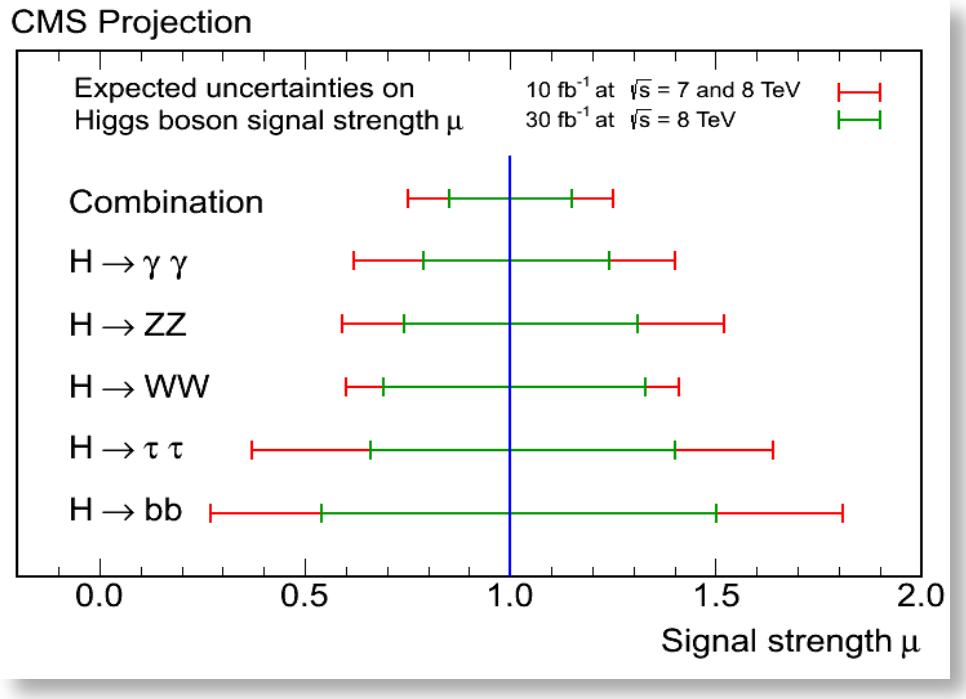
Some Projections

2011+2012 datasets

Higgs Projections

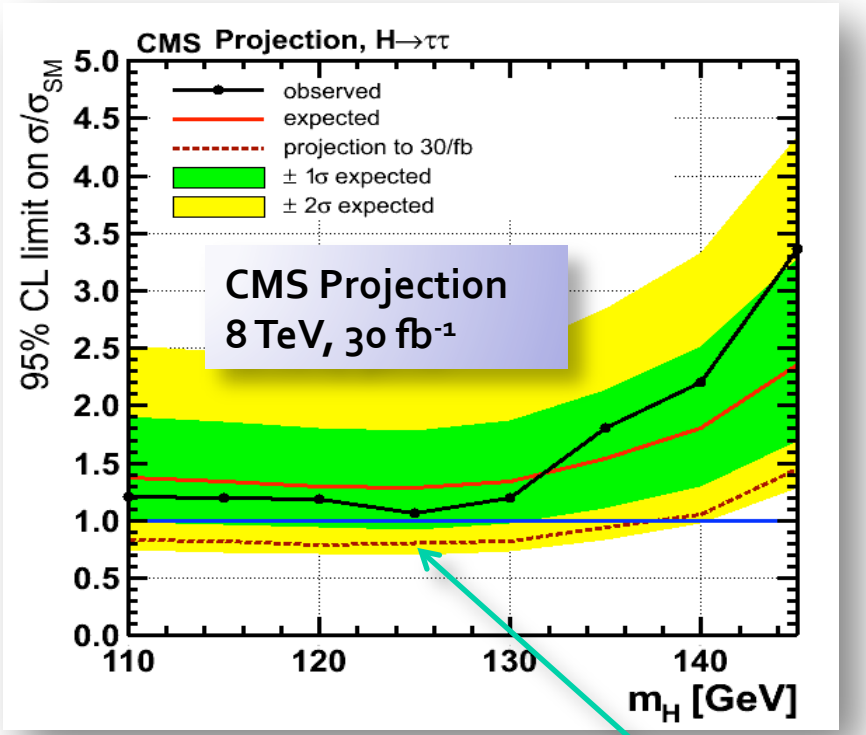
- Major part of the Higgs program with 2012 data is measurement of the couplings
  - 15% measurement of the signal strength is possible, which would allow for a confirmation of SM-like nature of the observed particle or, conversely, that it's not a SM Higgs

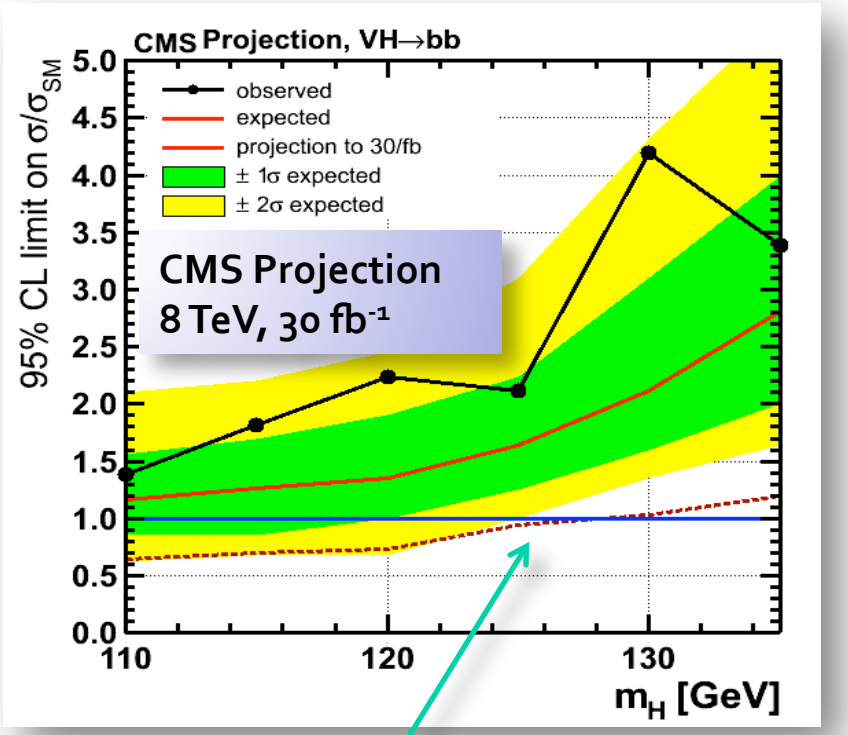




Higgs: Fermionic Channels

- Established only the bosonic channels thus far
  - Major focus now is the study of fermionic decays
    - Do they exist and are they consistent with the SM predictions?





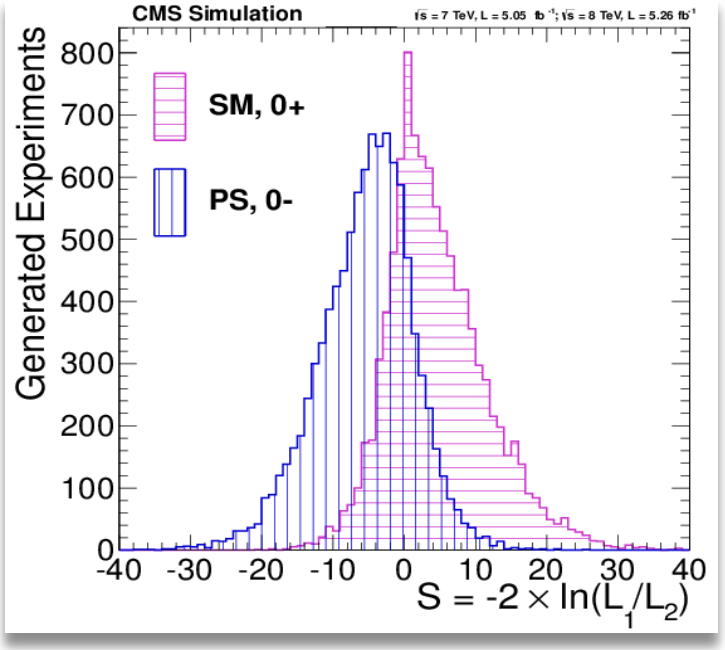
SM sensitivity is reached or exceeded (dashed red lines)

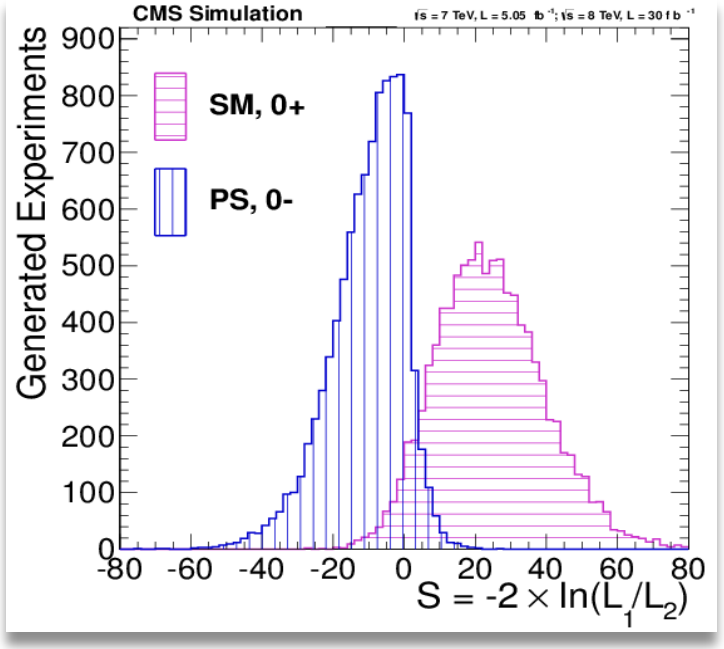
Study of parity in H->ZZ*

- Matrix element (MELA)

$$\text{pseudo MELA} = \left[1 + \frac{\mathcal{P}_{0^-}(m_1, m_2, \theta_1, \theta_2, \Phi, \theta^*, \Phi_1 | m_{4\ell})}{\mathcal{P}_{0^+}(m_1, m_2, \theta_1, \theta_2, \Phi, \theta^*, \Phi_1 | m_{4\ell})}\right]^{-1}$$

  - for hypothesis discrimination
  - 3.1σ by the end of the run (expectation = 1.6σ for July 4th sample)
    - depends on assumed yield, ~4σ with mean SM expectation
      - SM expectation is higher than observed significance in this channel in CMS
  - H->ZZ channel most promising for spin-0 parity determination
    - add H->WW and γγ for spin-2 analysis



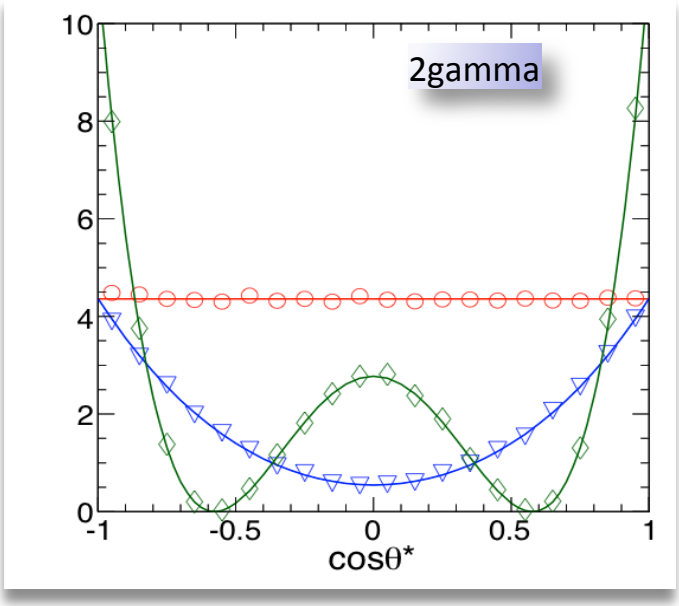


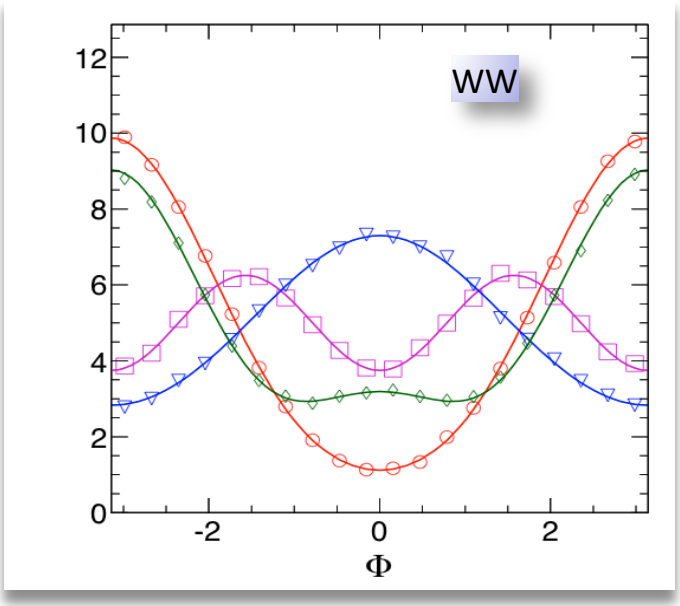
H->ZZ, WW, γγ

- Follow-up simplified generator study
  - S.Bolognesi et al., arXiv:1208.4018
  - WW feature: angle between decay planes
  - γγ: production angle

scenario	$X \to ZZ$	$X \to WW$	$X \to \gamma\gamma$	combined
0^+_m vs bkg	7.1	4.5	5.2	9.9
0^+_m vs 0^-	4.1	1.1	0.0	4.2
0^+_m vs 2^+_m	1.6	2.5	2.5	3.9

spin-2, minimal, 35/fb spin-0, parity-odd, 35/fb



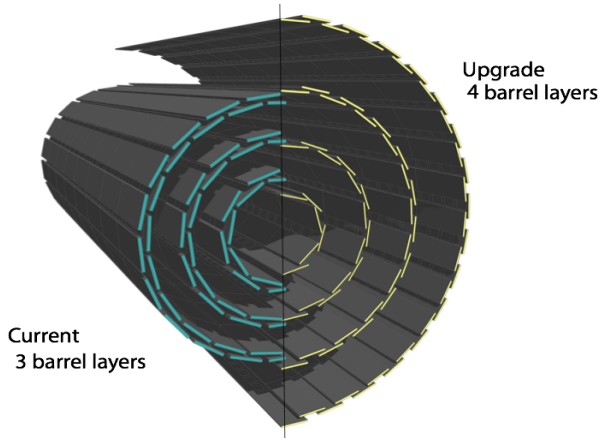


- Close to 4σ separation possible
  - for both odd parity and spin-2
  - more scenarios are open…

Upgrades

Upgrades

- Upgraded Pixel Detector
  - Less material, better radial distribution
  - New ROC & extra layer recovers tracking efficiency (and lowers fake rate)
- Upgraded HCAL
  - Improve background rejection
  - Improve MET resolution
  - Improve Particle Flow via improved S/N from new photodetectors
  - Identify depth of shower max utilizing longitudinal segmentation and timing



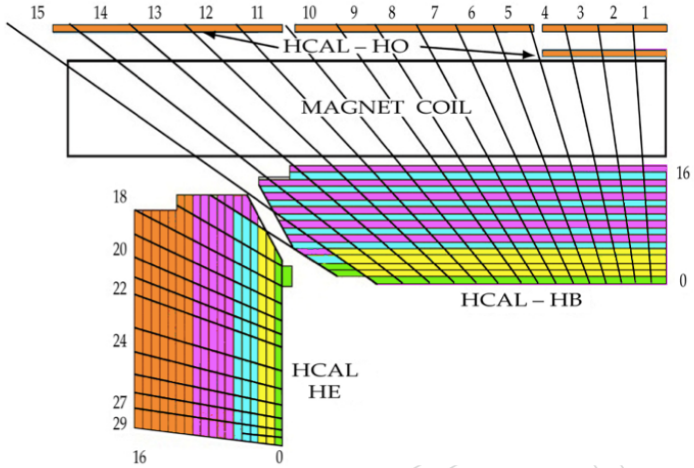
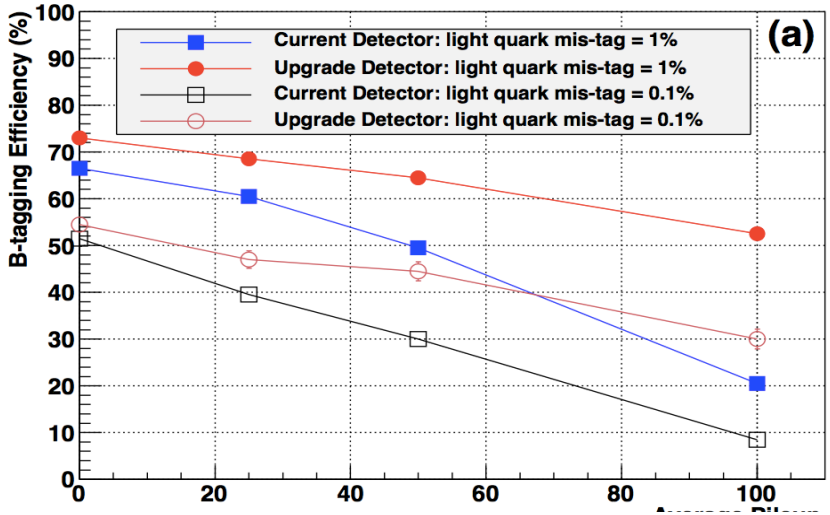
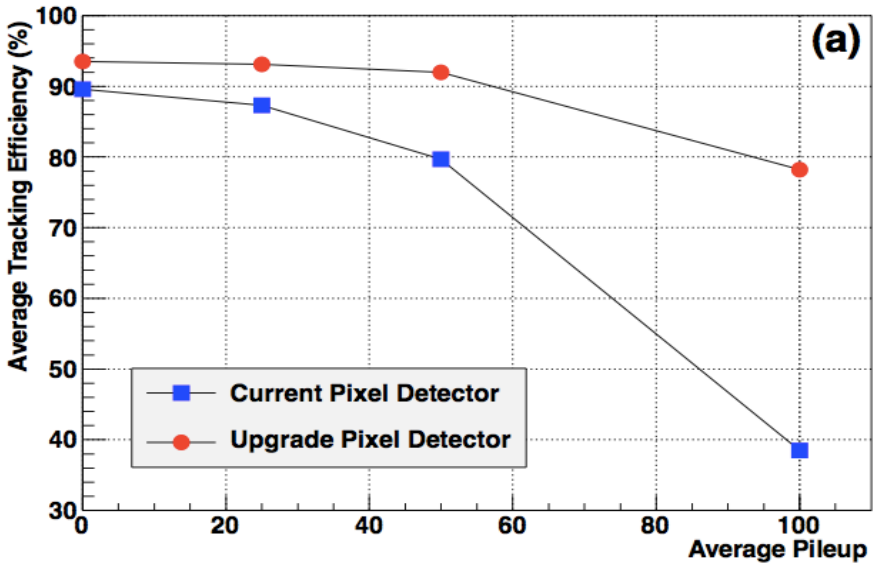


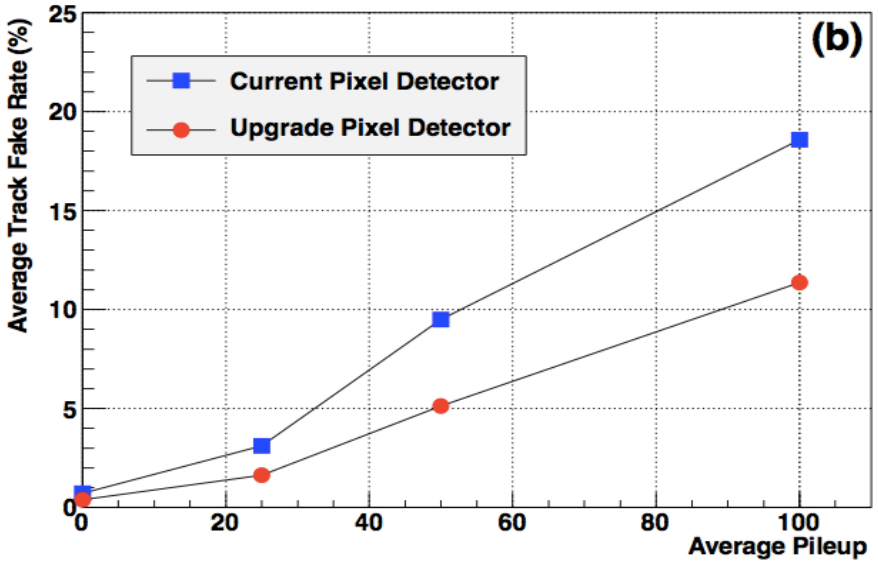
Figure 3.1: Current proposed depth segmentation structure for the HB and HE calorimeters, made possible by the use of SiPM photodetectors.

Improved Tracking & Btagging

- (Right) Improvement in b-tag performance w/ new pixel detector, in ttbar events, as a function of pileup
- (Below) Improvement in tracking efficiency (left) and tracking fake rate (right) w/ new pixel detector, in ttbar events, as a function of pileup



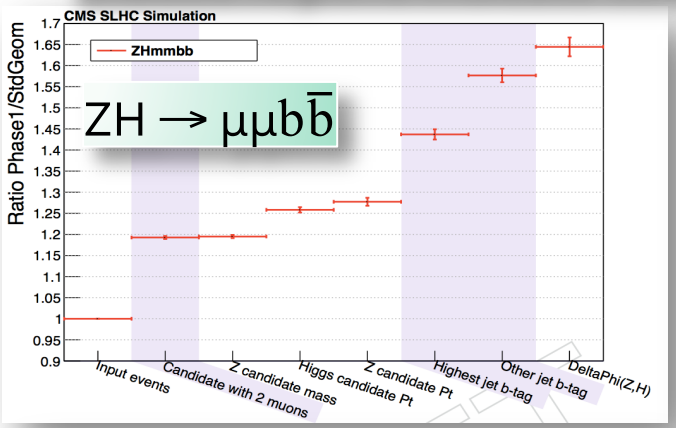


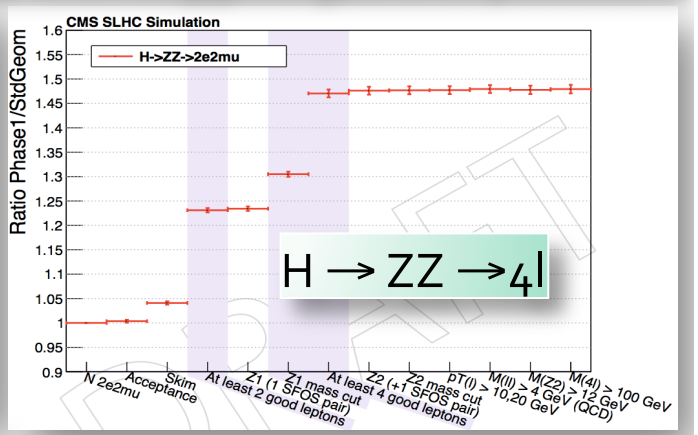


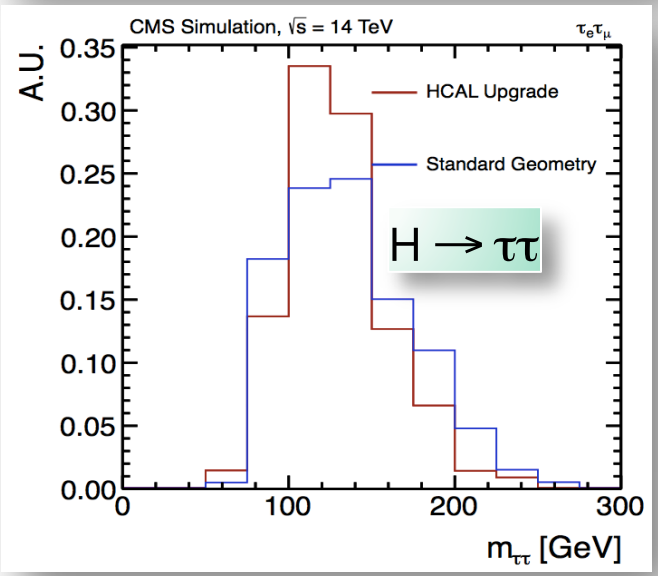
Upgrade's Impact on Higgs Physics

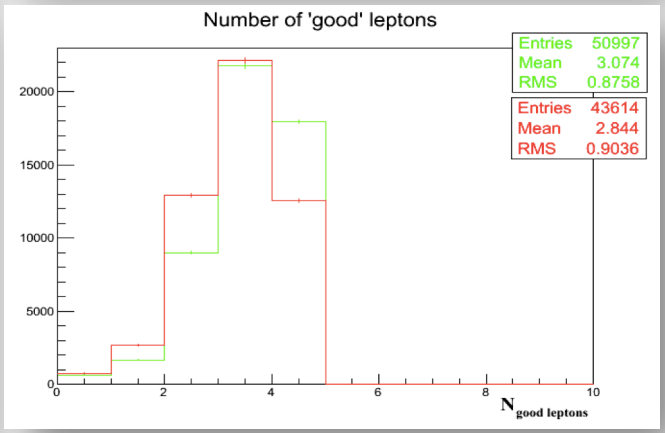
- $H \rightarrow ZZ \rightarrow 4l$
  - Key channel
  - Sensitive to lepton efficiency
- $H \rightarrow b\bar{b}, \tau\tau$
  - Crucial to establishing role in fermion masses
- $ZH \rightarrow \mu\mu b\bar{b}$ requires
  - High muon ID efficiency
  - High b-tagging efficiency
  - Good dijet mass resolution
- $H \rightarrow \tau\tau$ (including VBF)
  - Improved
    - MET resolution
    - Forward jet tagging capability
    - Identification

Improved signal yield (relative to current detector):
shaded regions indicate cuts with biggest gains expected









- Improved $m_{\tau\tau}$ resolution

- More good leptons
  better tracking & isolation

Conclusions

- CMS is running well
- Lot's of physics results and many more to come!
  - Full 2011+2012 data set should be interesting…
- Much more study planned
  - To understand potential for precision measurements of the new boson
- Lot's to do for LS1 and upgrades