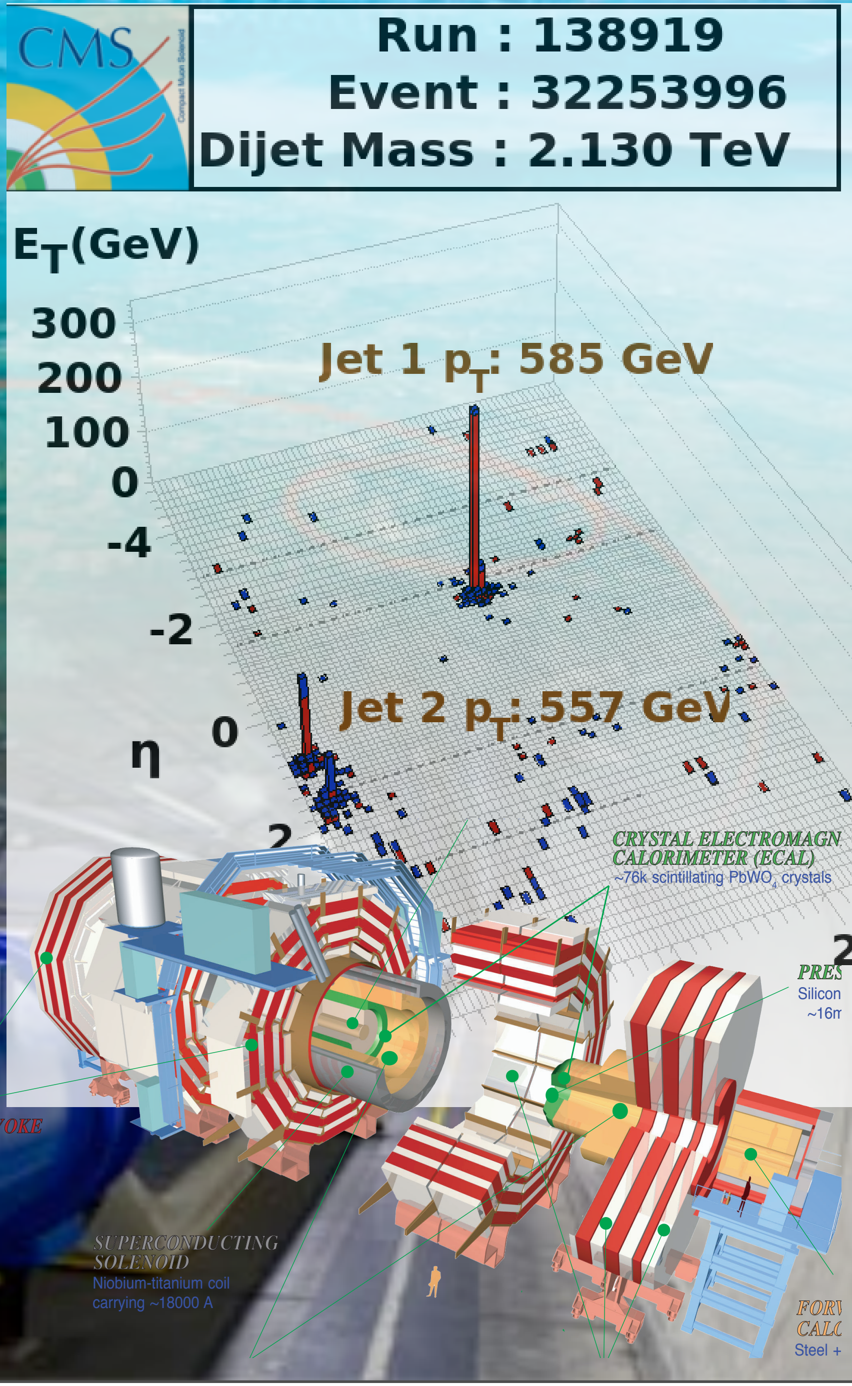
Quest for New Physics with the First LHC data at

Greg Landsberg

BROWN UNIVERSITY

CERN EP/PP/LPCC Seminar

January 24, 2011



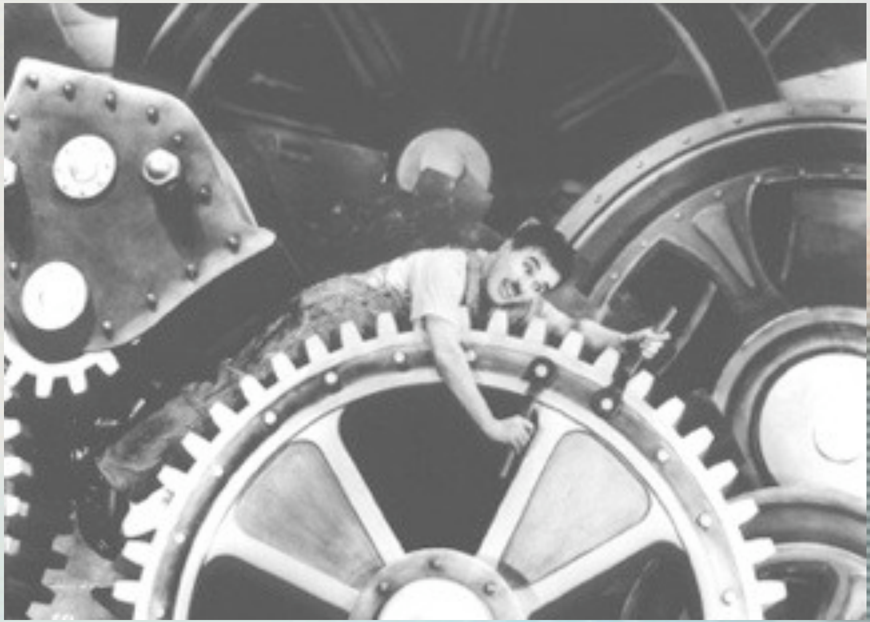
Outline

- CMS Performance
- Bird's Eye View of the SM Physics at CMS
- First Searches
  - Dijets
  - Additional Gauge Bosons
  - Long-Lived Particles
  - Fourth Generation
  - Large Extra Dimensions
- Toward SUSY and Higgs
- Conclusions

- Please refer to: https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults for more details

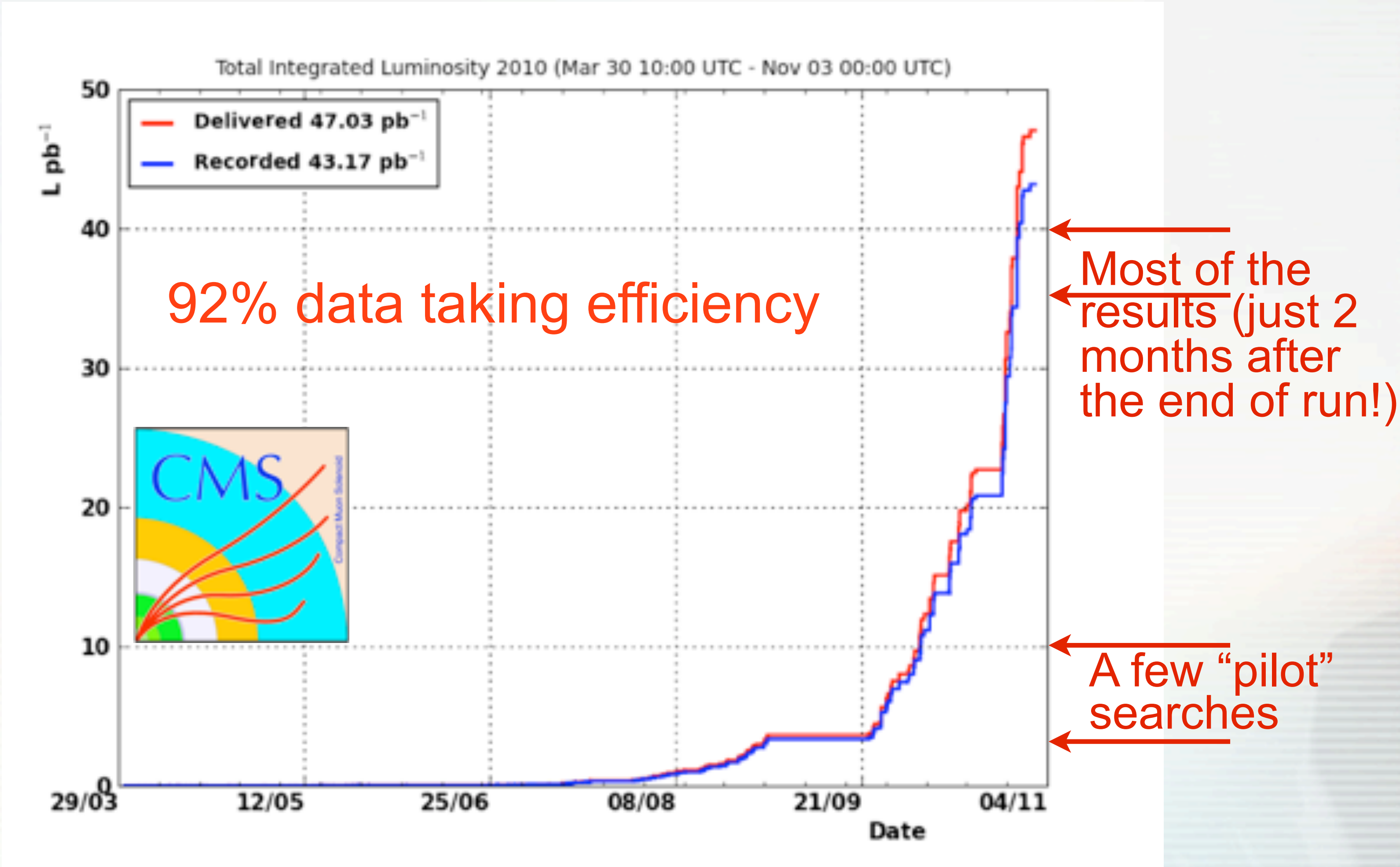
The Machine

The LHC

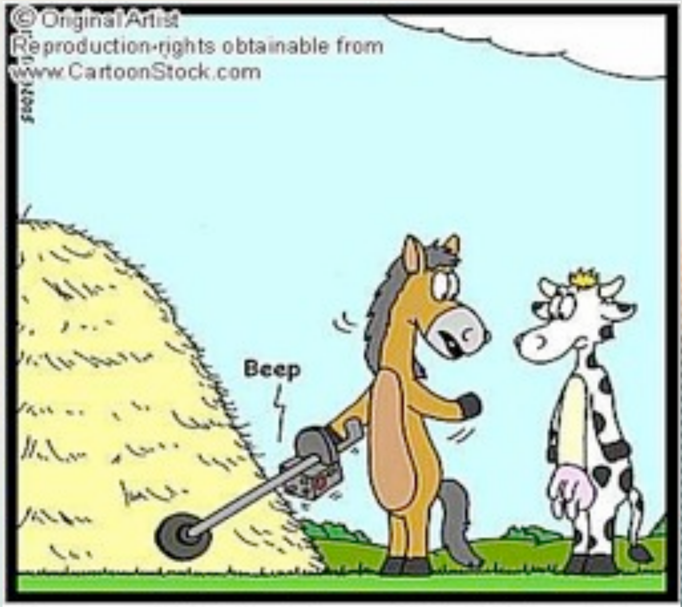


Thank You, the LHC!

- Spectacular machine performance since late August
- Thank you for delivering the first 50 inverse picobarns!
- Eagerly awaiting for a few fb^{-1} at 8 TeV in the next two years



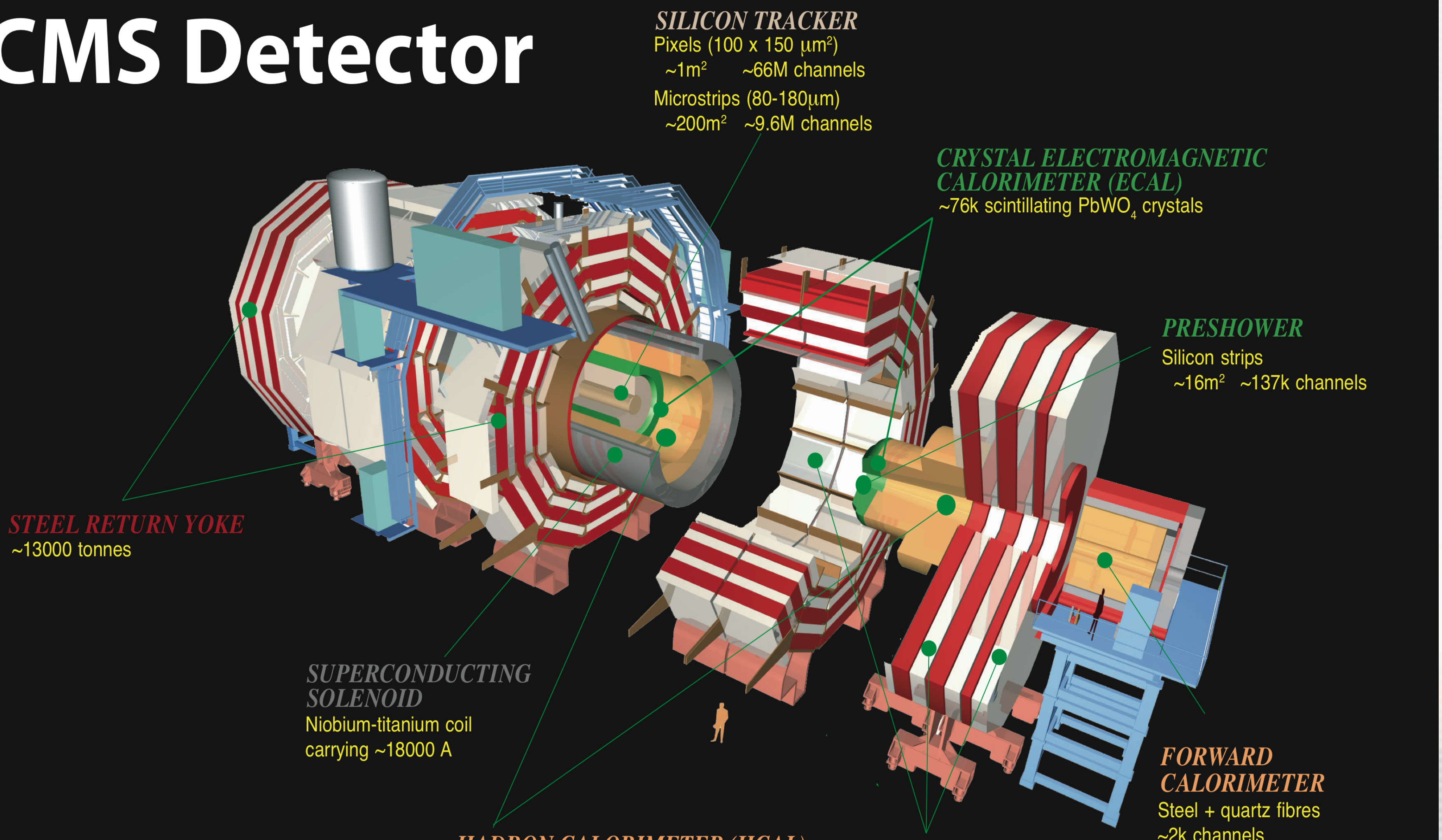
The Detector



You were right: There's a needle in this haystack...

Compact Muon Solenoid

CMS Detector



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

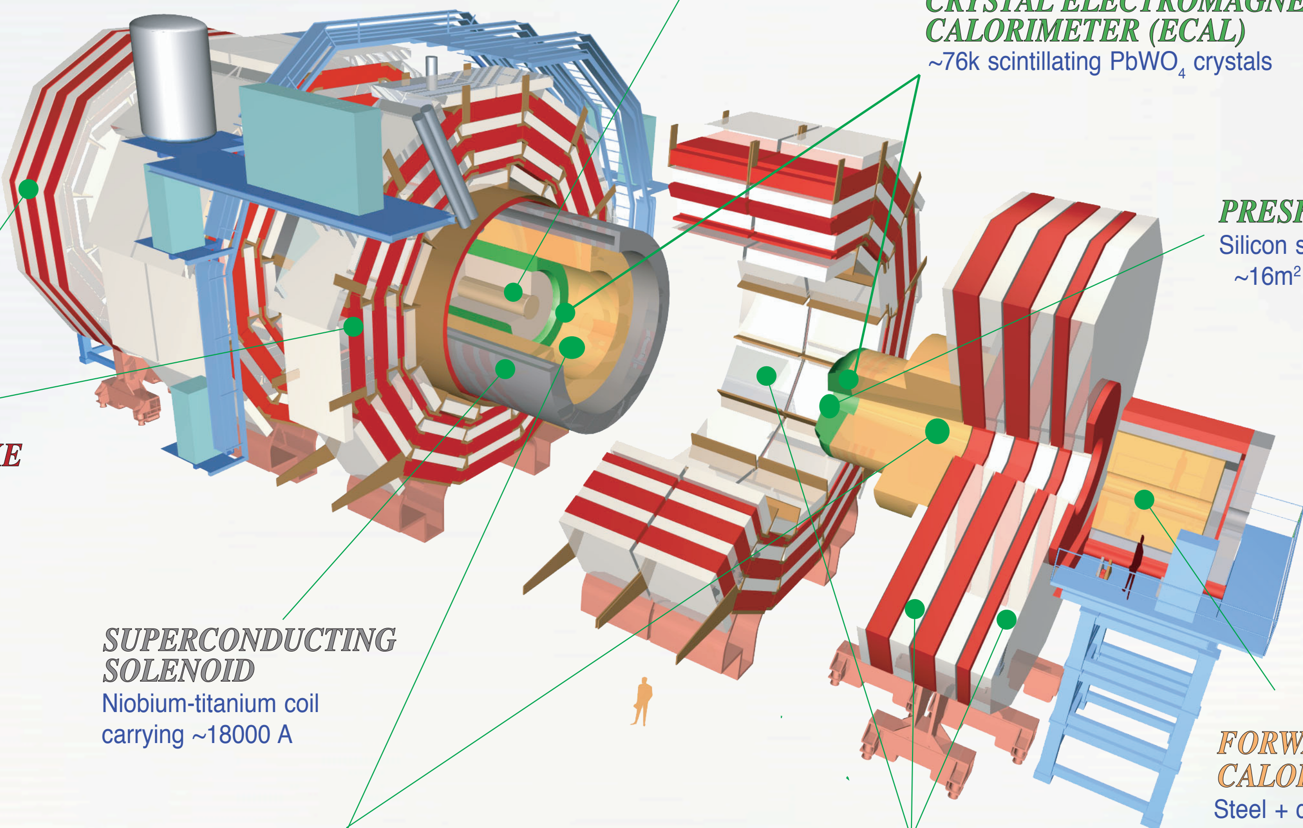
Compact Muon Solenoid

CMS Detector

(Some of the) 3170 Scientists and Engineers (800 Graduate Students) from 182 Institutions in 39 countries

Understanding CMS: Tracker

CMS Detector



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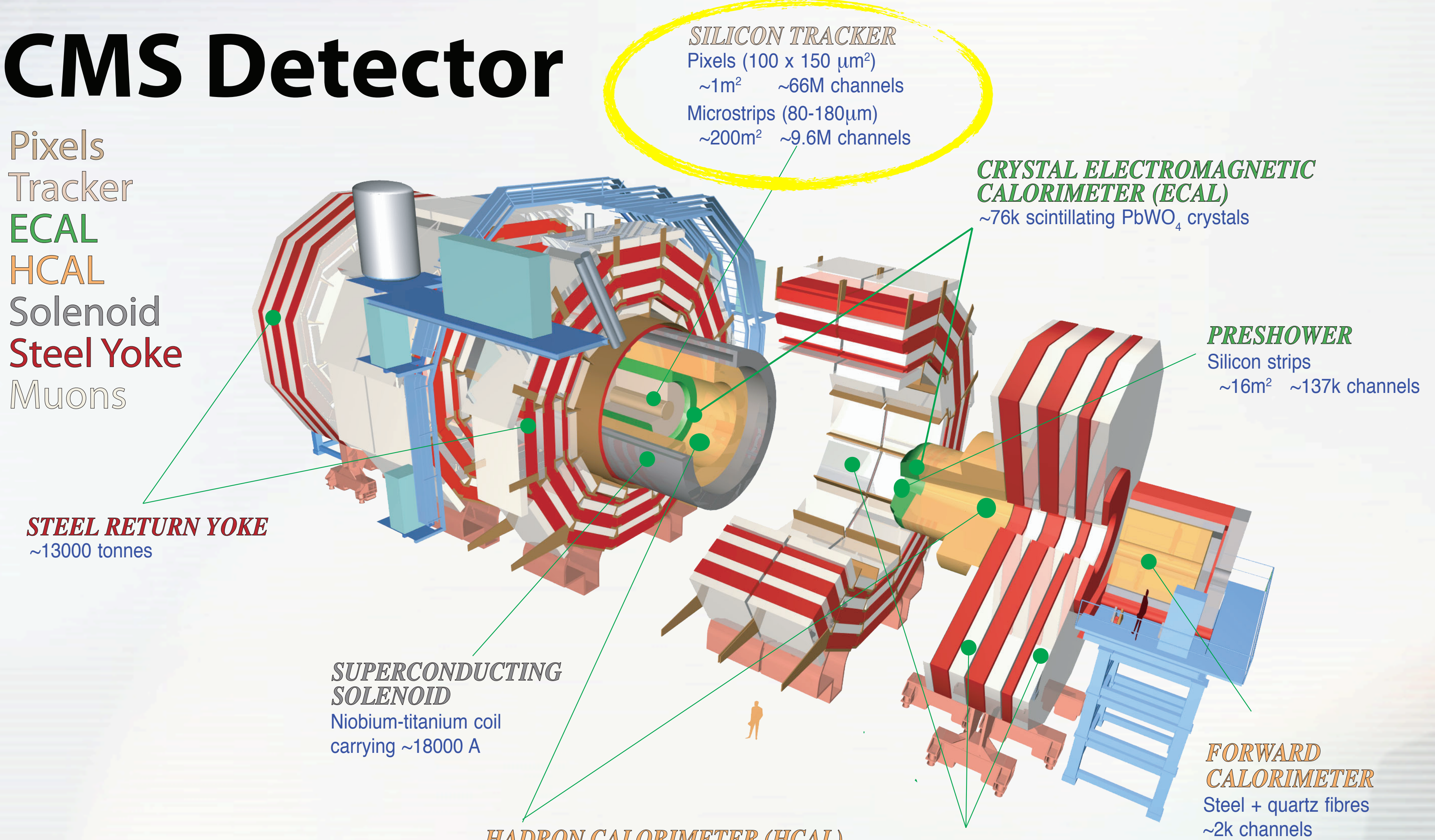
CMS Detector



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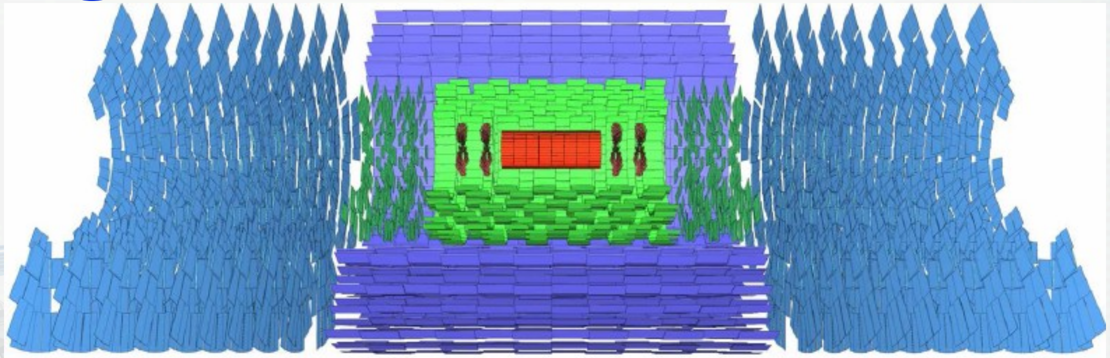
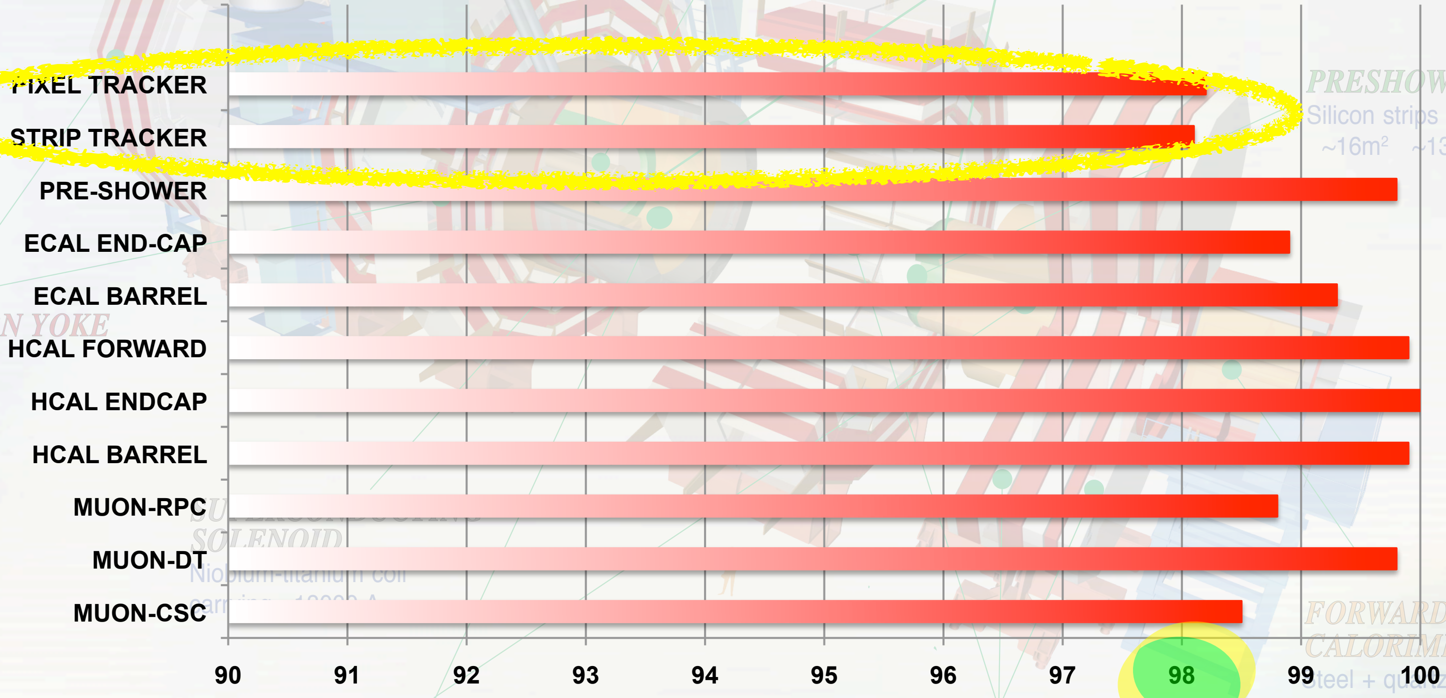
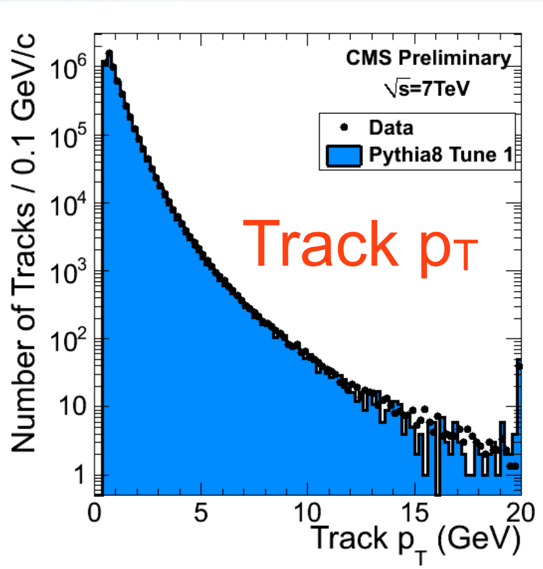


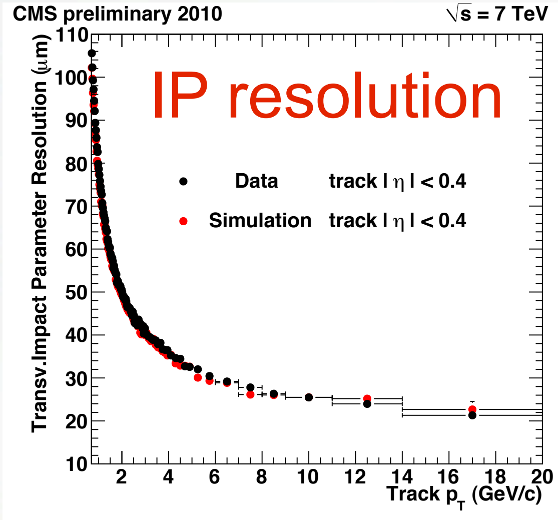


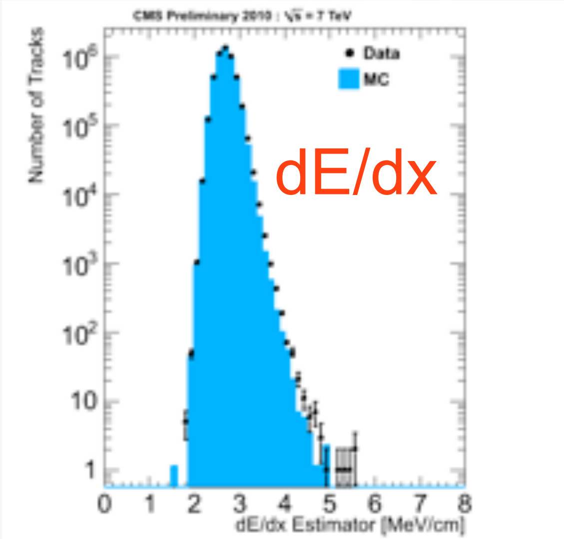
	MUON-CSC	MUON-DT	MUON-RPC	HCAL BARREL	HCAL ENDCAP	HCAL FORWARD	ECAL BARREL	ECAL END-CAP	PRE-SHOWER	STRIP TRACKER	PIXEL TRACKER
Series1	98.5	99.8	98.8	99.9	100	99.9	99.3	98.9	99.8	98.1	98.2

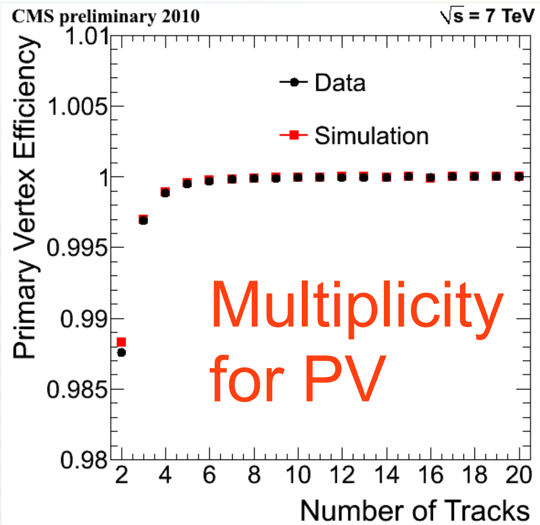
Tracker Performance

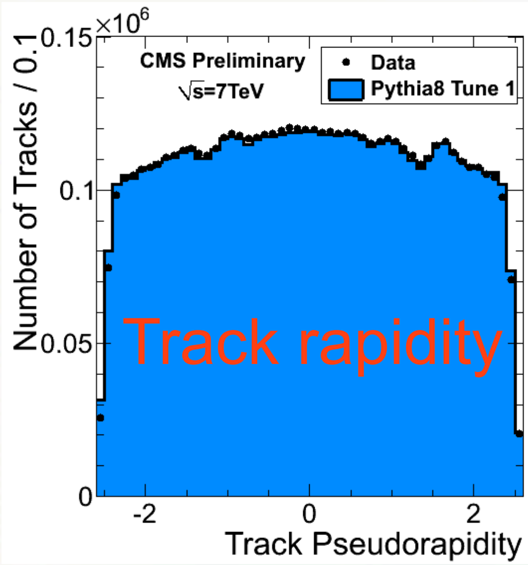
- 75 Million Channels, 200 m^2 of Silicon; >98% operational
- Remarkable agreement between the data and the simulations

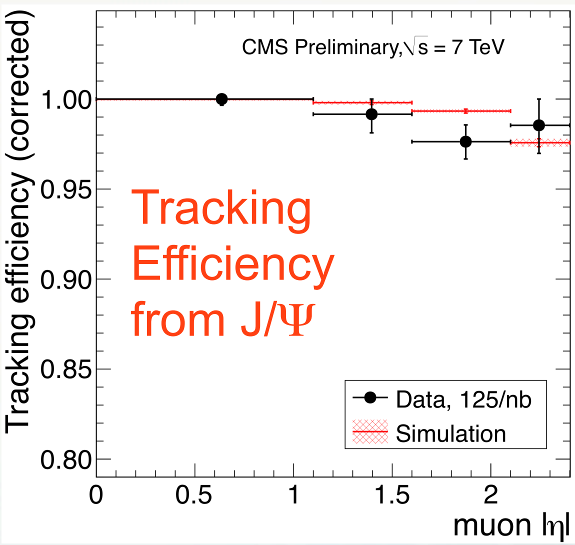












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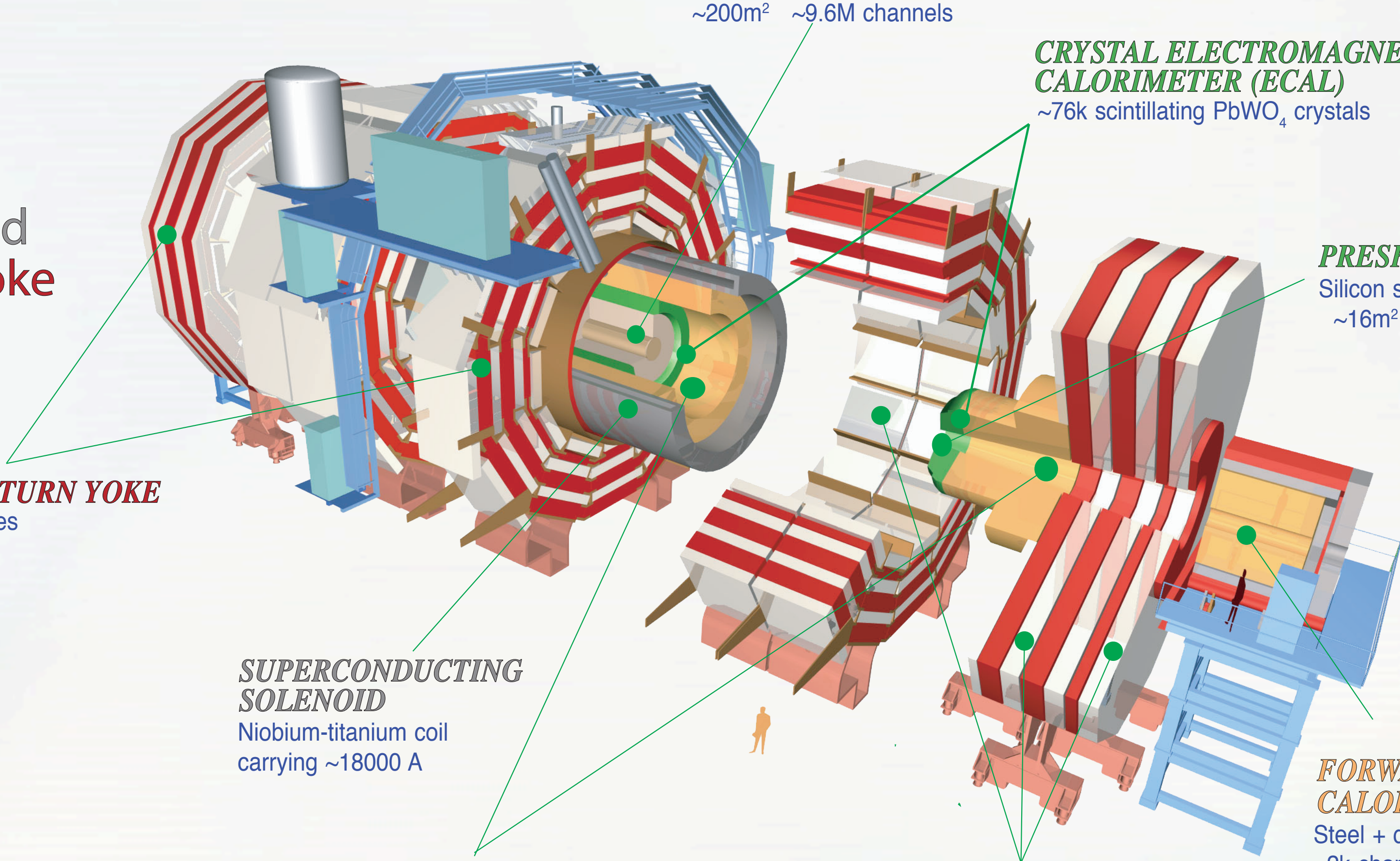
Understanding CMS: ECAL

CMS Detector

Pixels
Tracker
ECAL
HCAL
Solenoid
Steel Yoke
Muons



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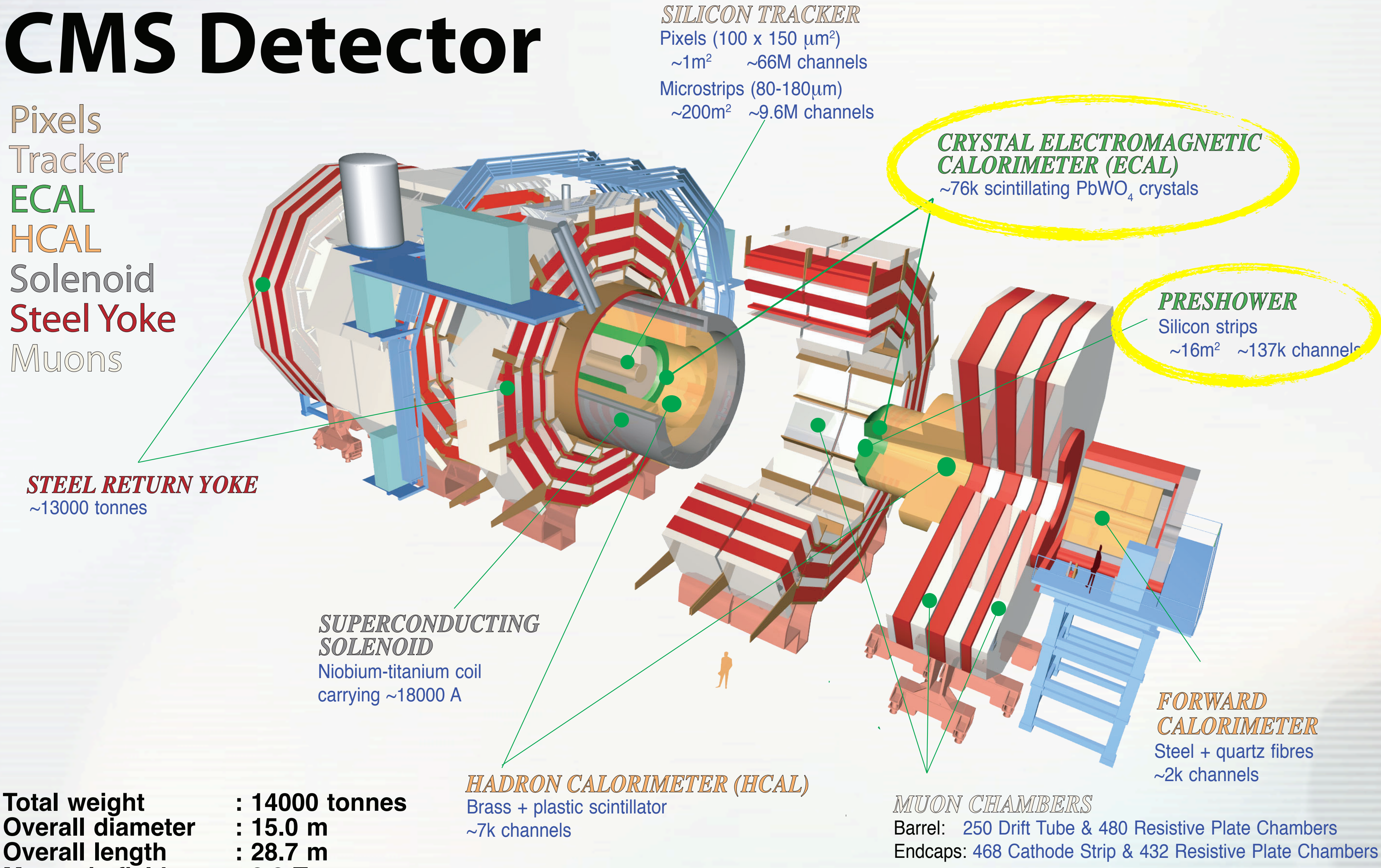

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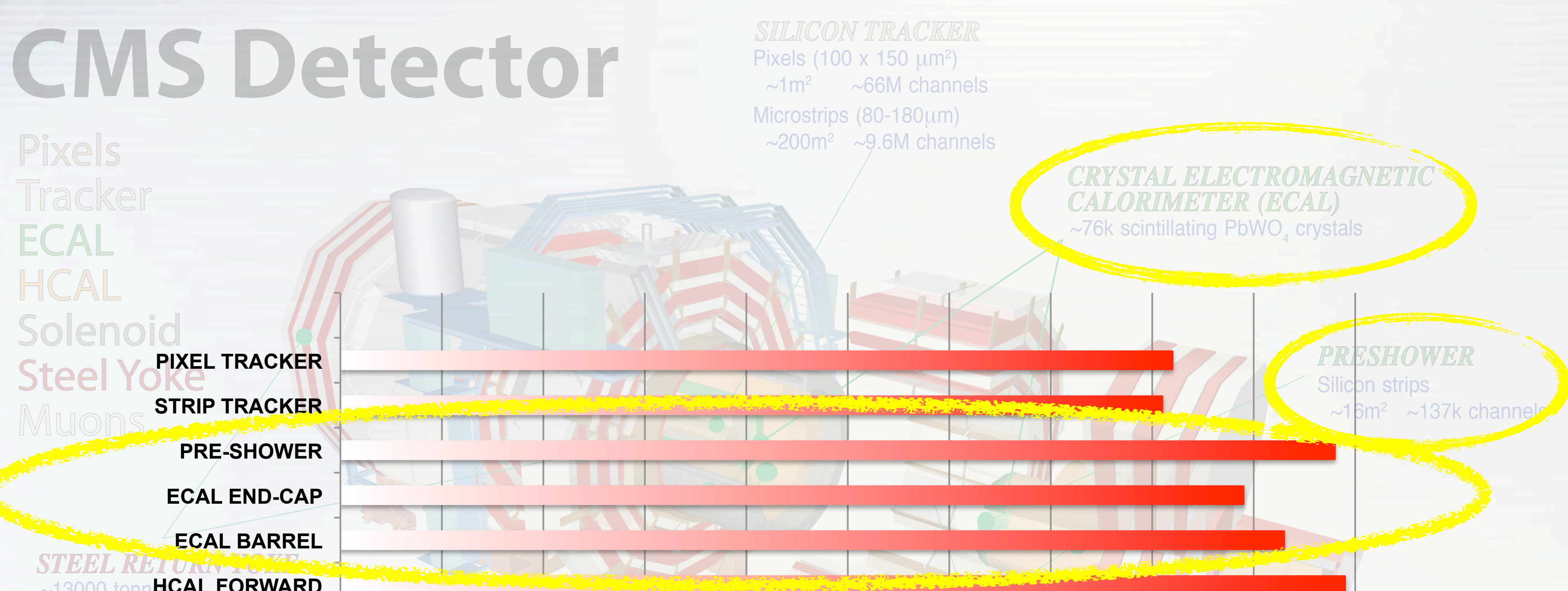
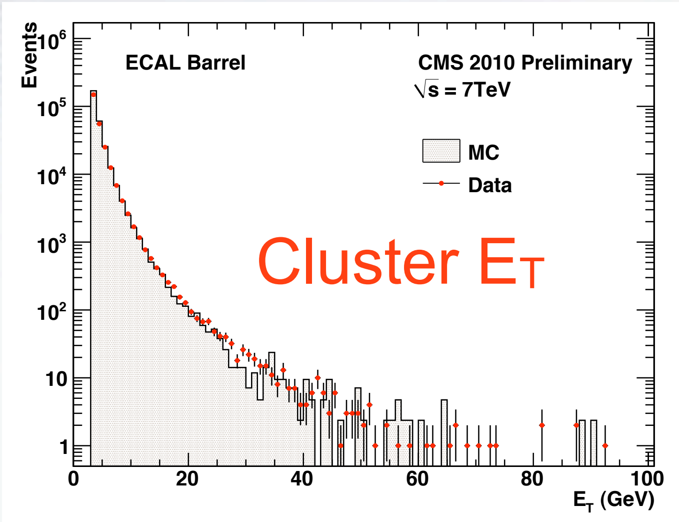
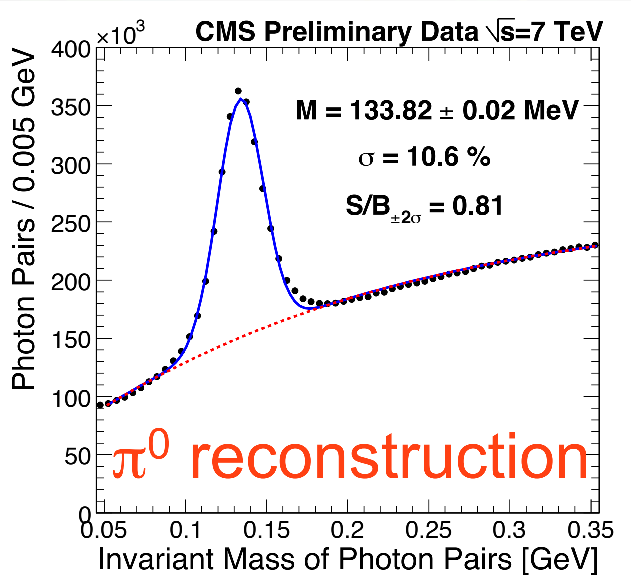
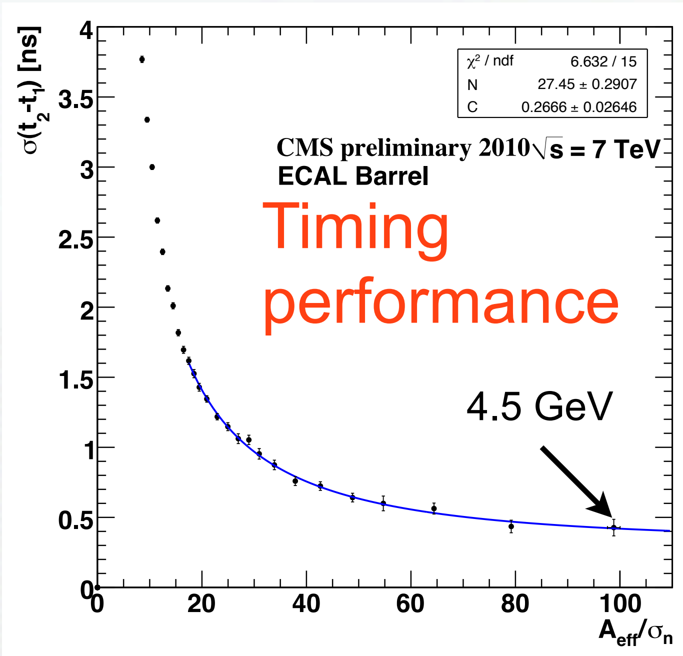


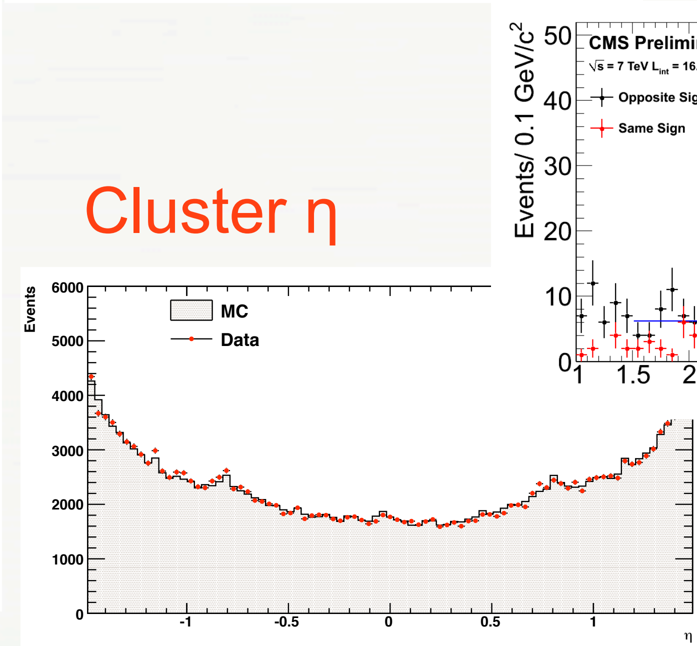
HCAL ENDCAP	HCAL FORWARD	ECAL BARREL	ECAL END-CAP	PRE-SHOWER	STRIP TRACKER	PIXEL TRACKER
100	99.9	99.3	98.9	99.8	98.1	98.2

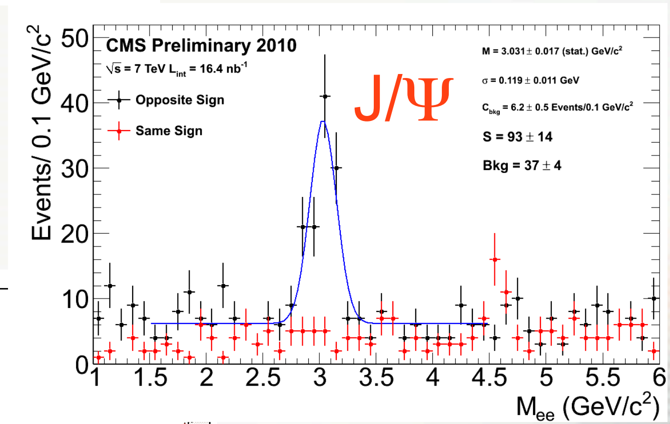
ECAL Performance











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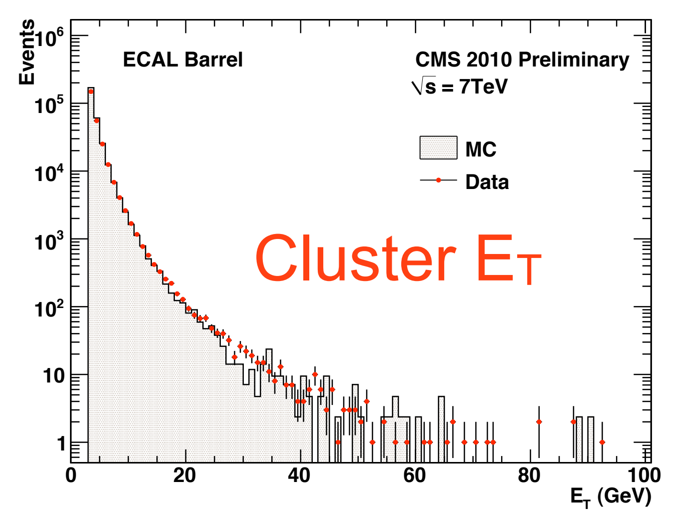
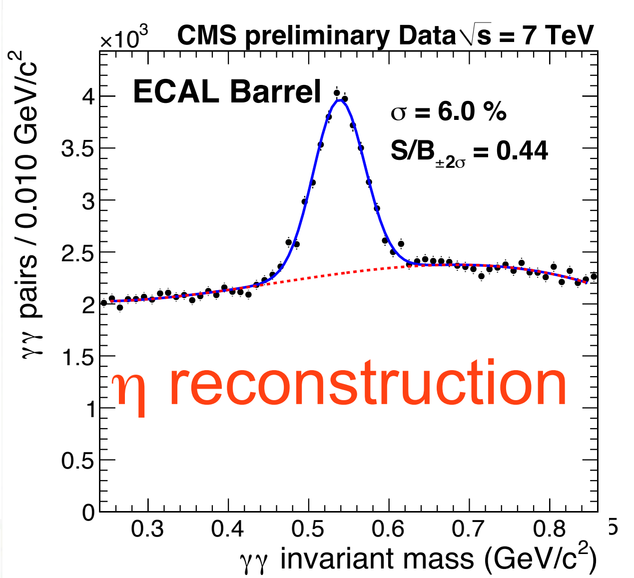
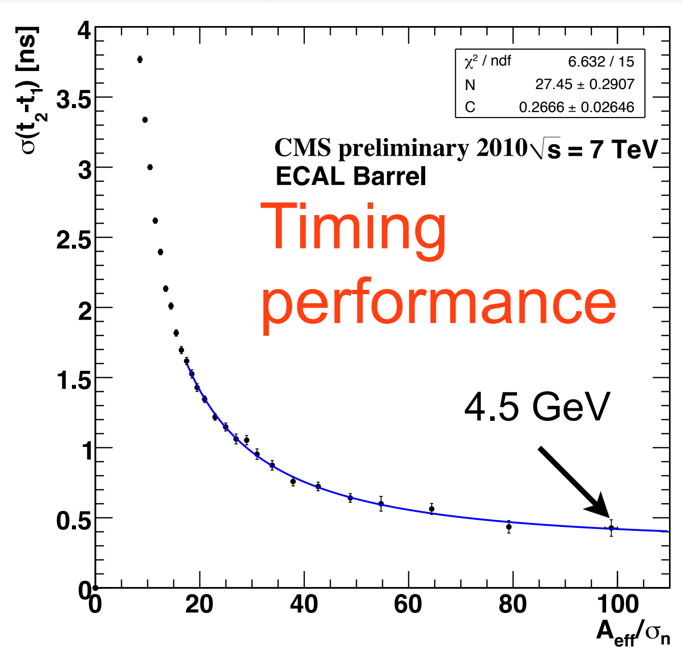
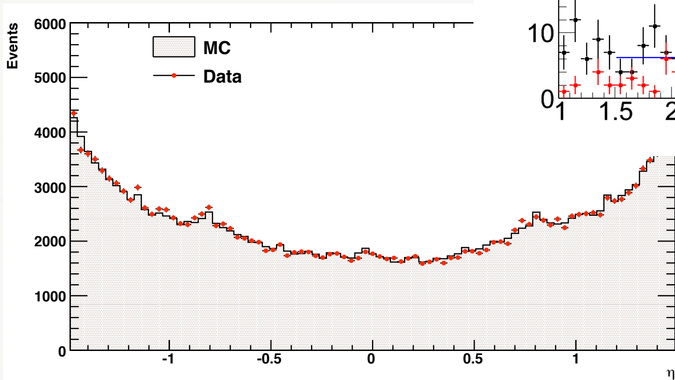
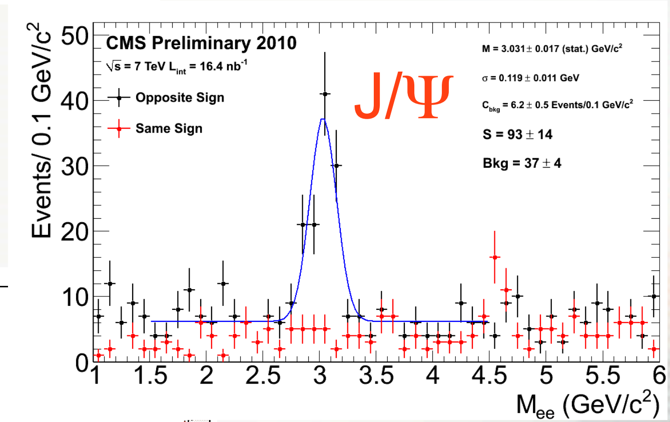






Cluster η





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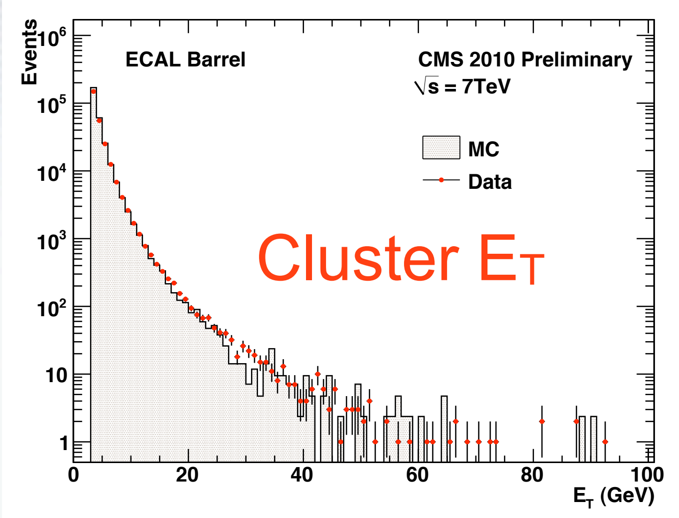

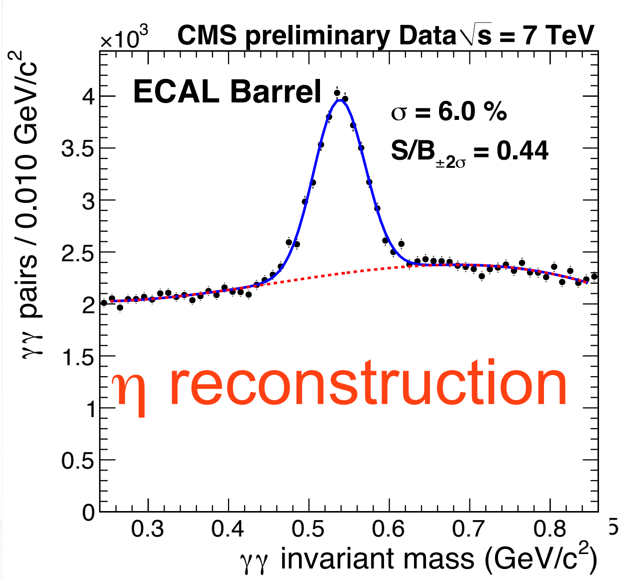

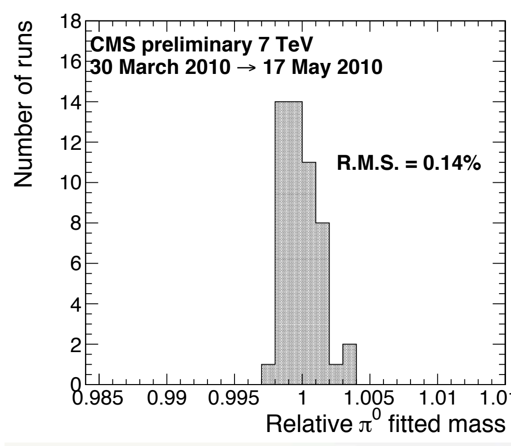

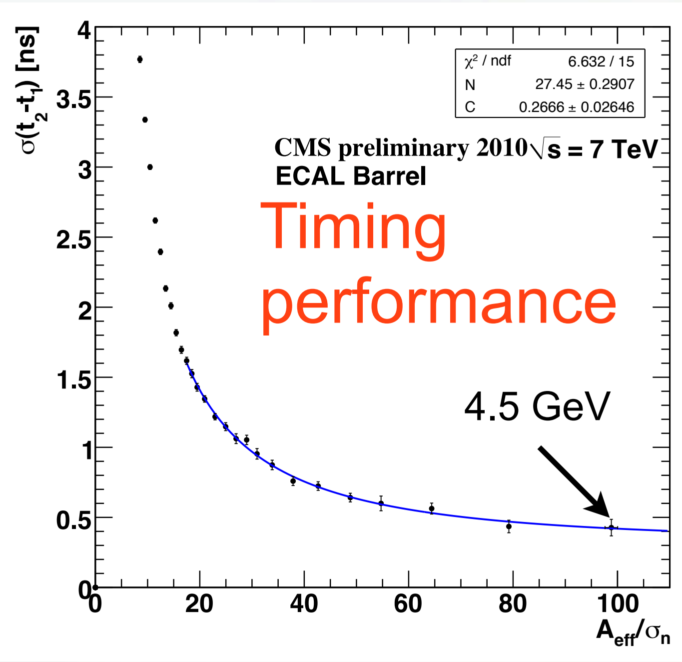

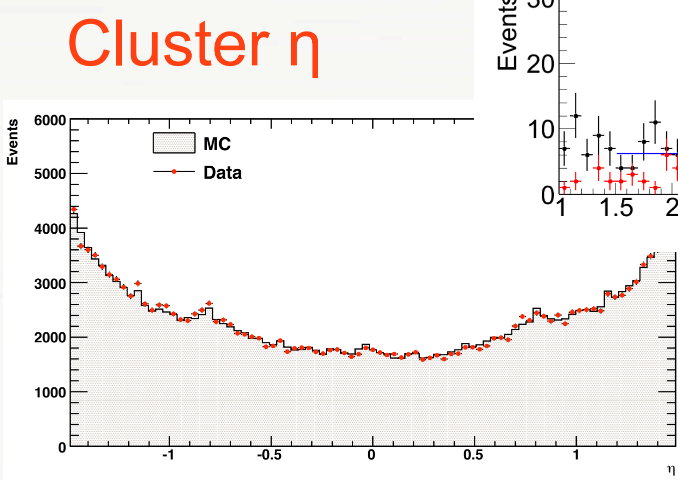

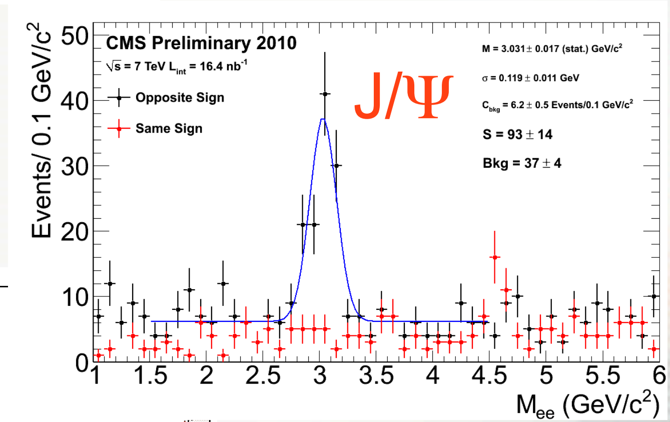

Understanding CMS: HCAL

CMS Detector

Pixels
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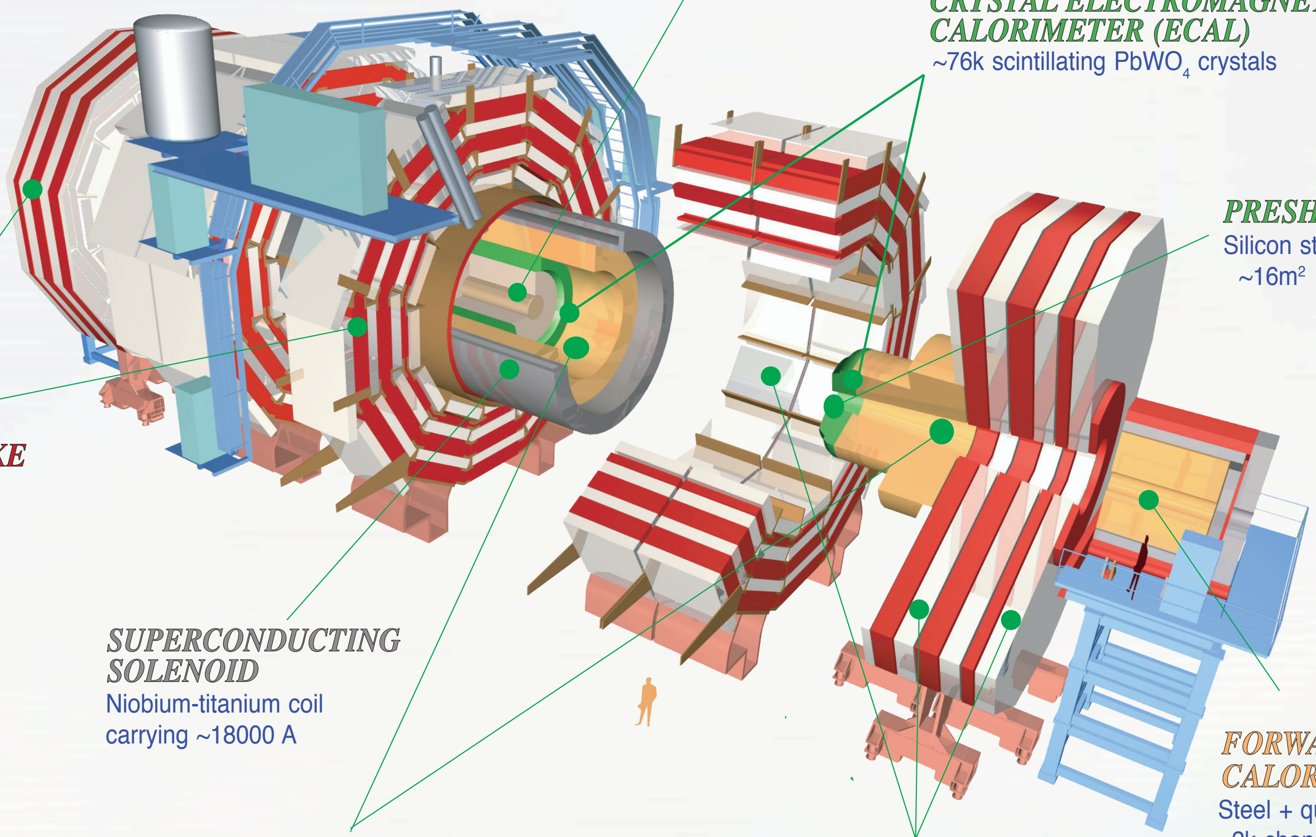
Muons



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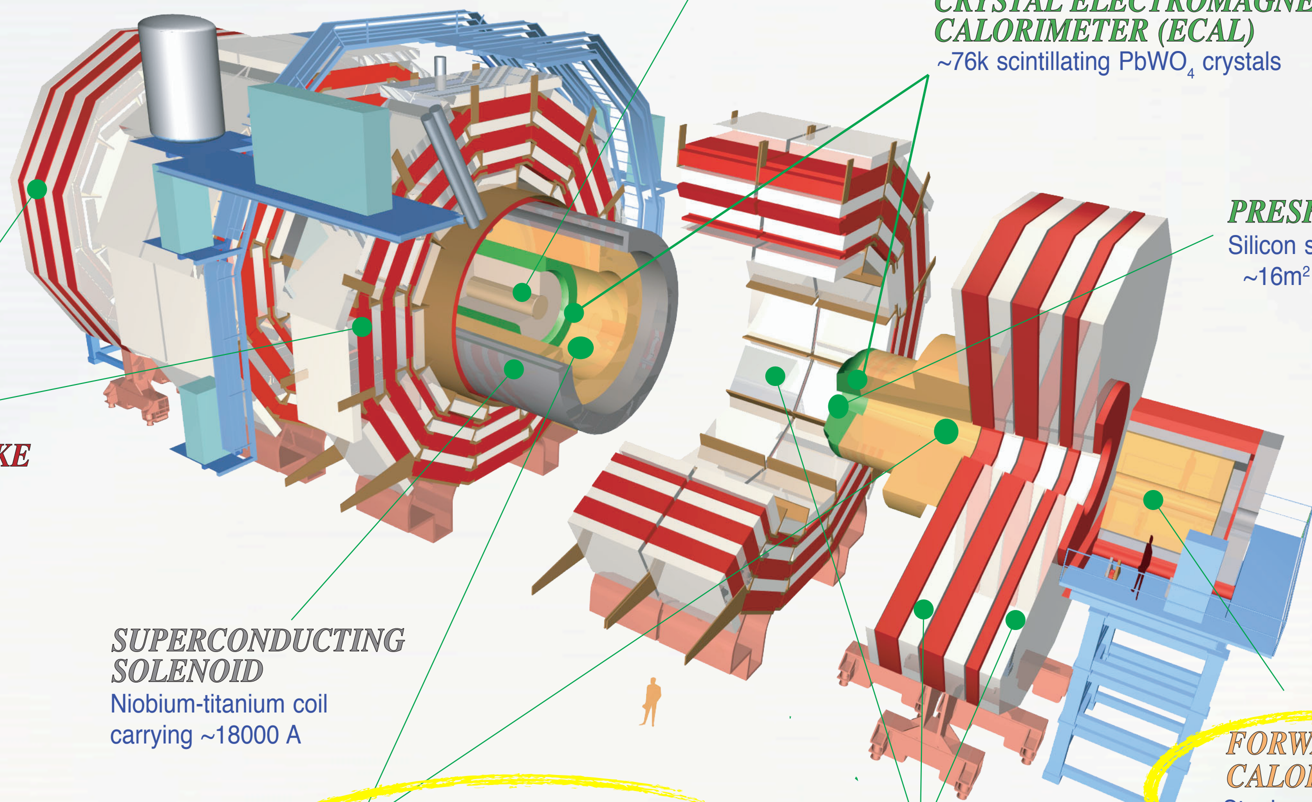

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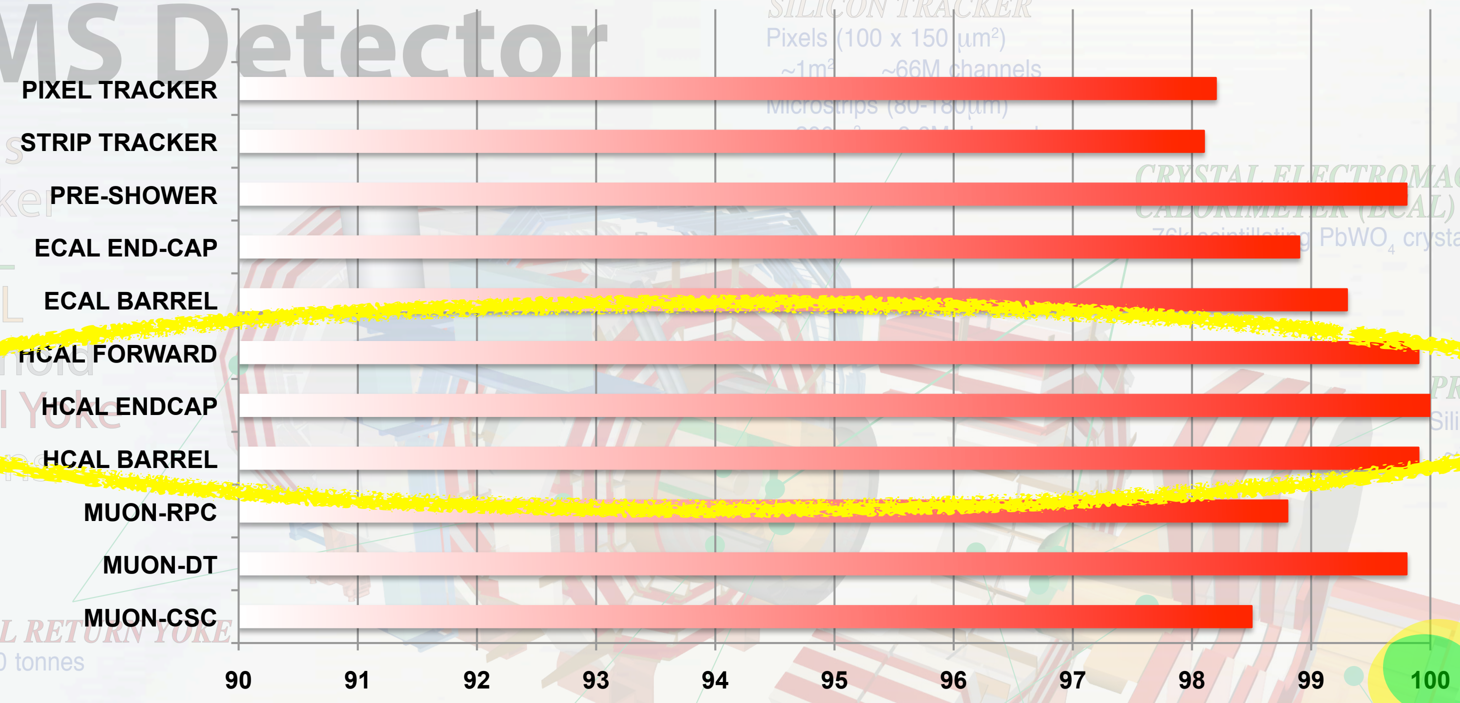

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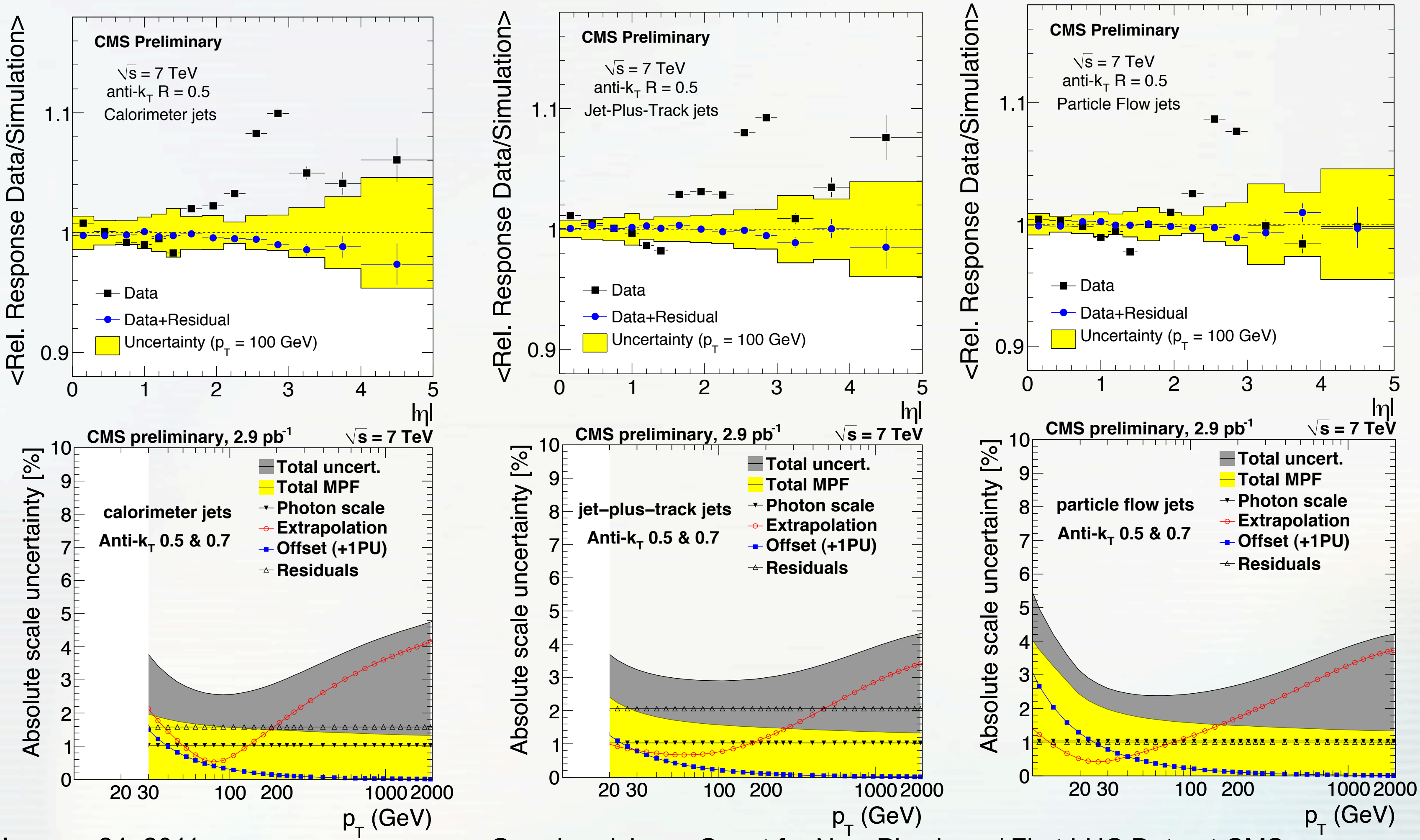
[illegible]	[illegible]	[illegible]	99.9	100	99.9	99.3	98.9	99.8	98.1	98.2	

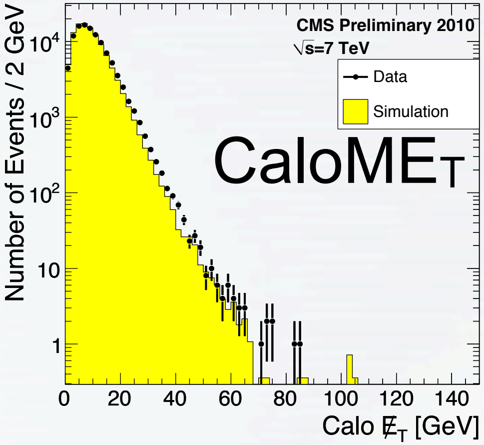
Jets at CMS

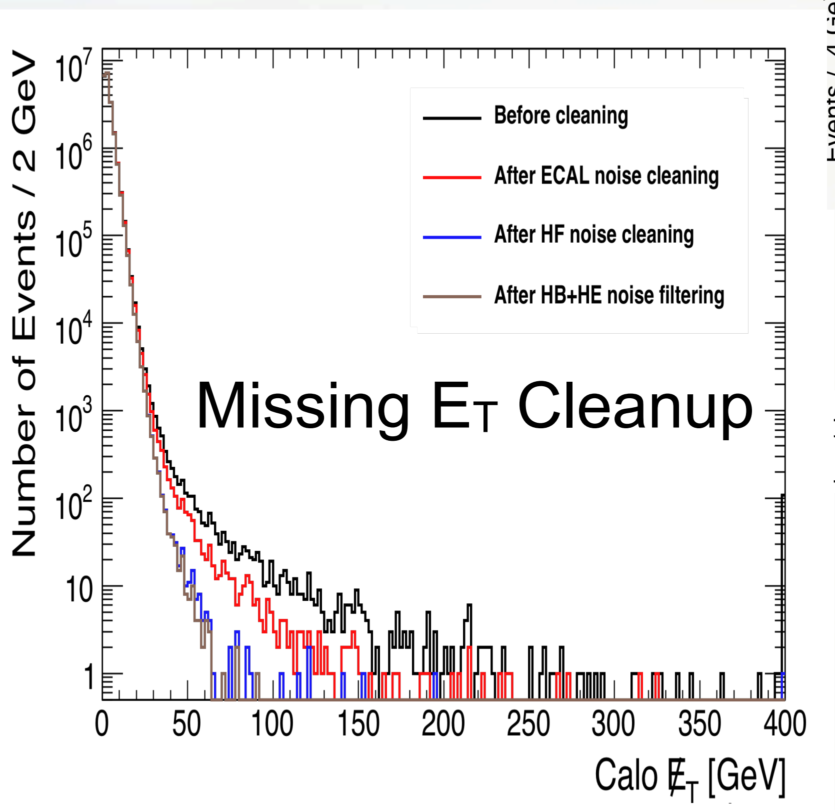
- Three types of algorithms have been commissioned: CaloJets, Jets-Plus-Tracks, Particle Flow Jets
- Good description of basic jet properties with the MC
- JES from MC has been shown to agree with data to 3-4%

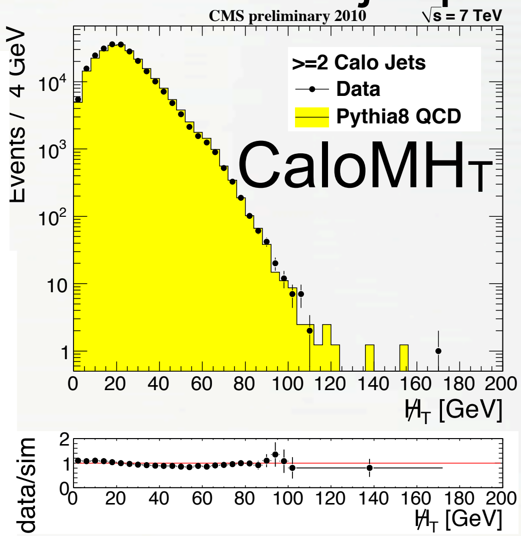


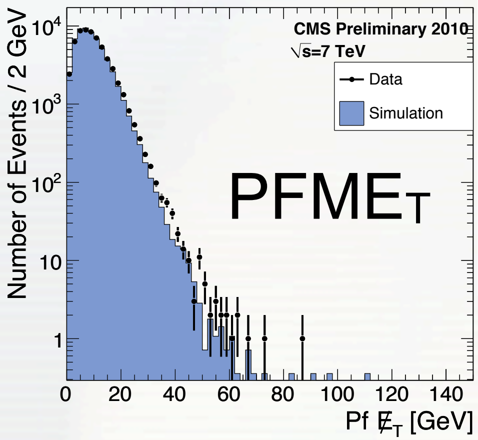
Missing E_T Commissioning

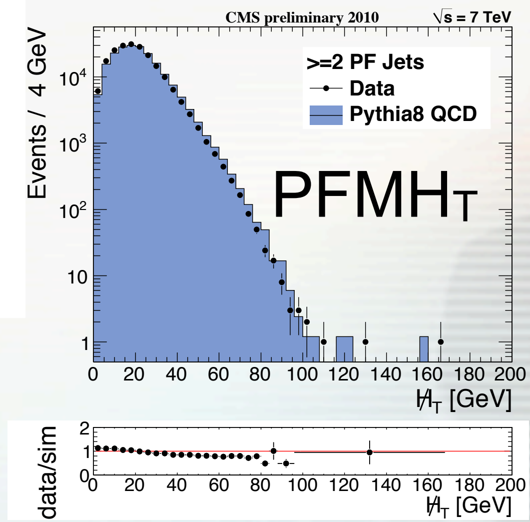
- Three types of ME_T, depending on jet algorithm and corresponding JES corrections (and additional unclustered energy corrections)
- Also three types of MH_T, defined as a negative vector sum of jet p_T











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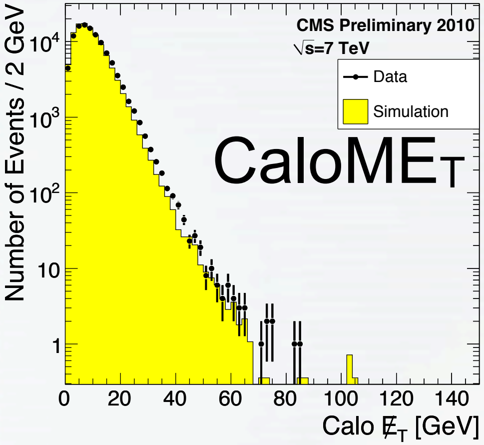
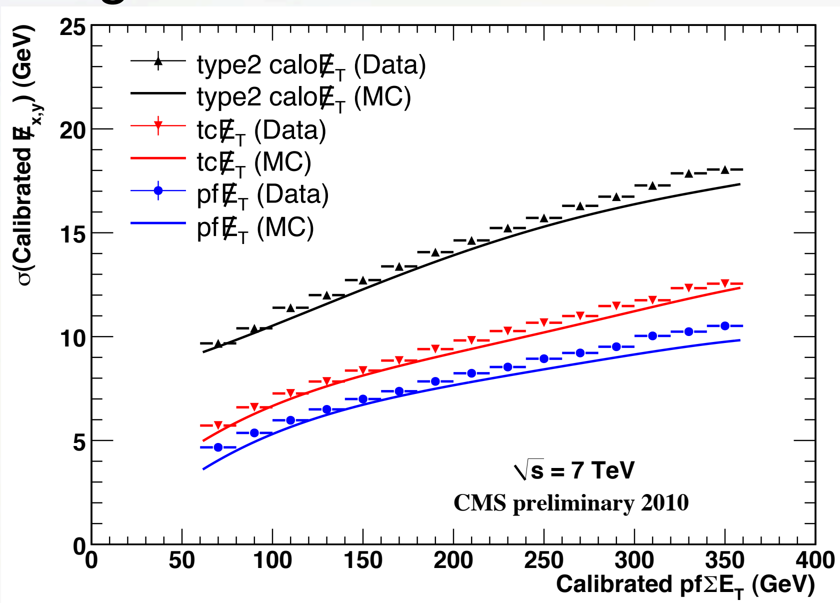
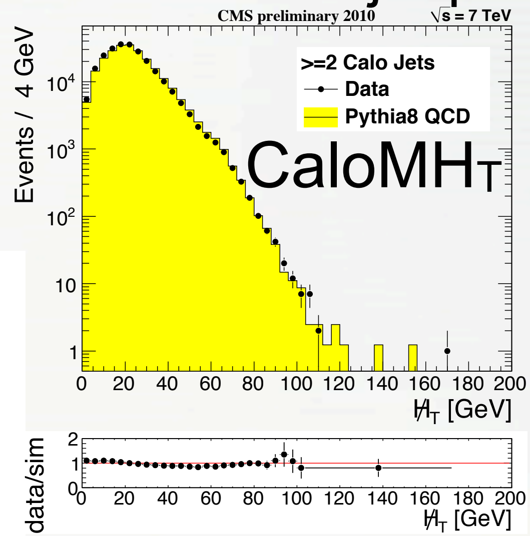
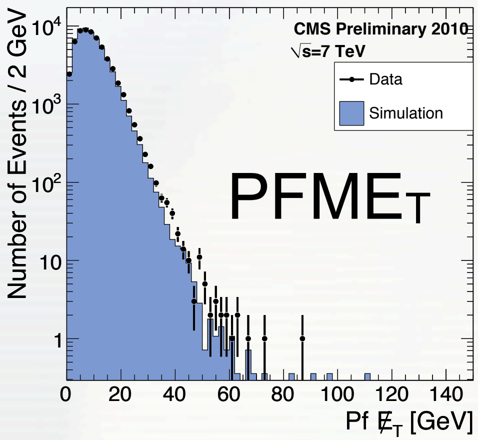
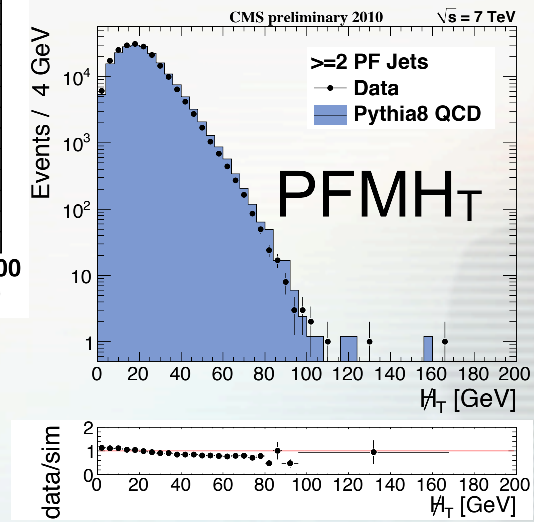


MET resolution as a function of scalar sum E_T for the three algorithms



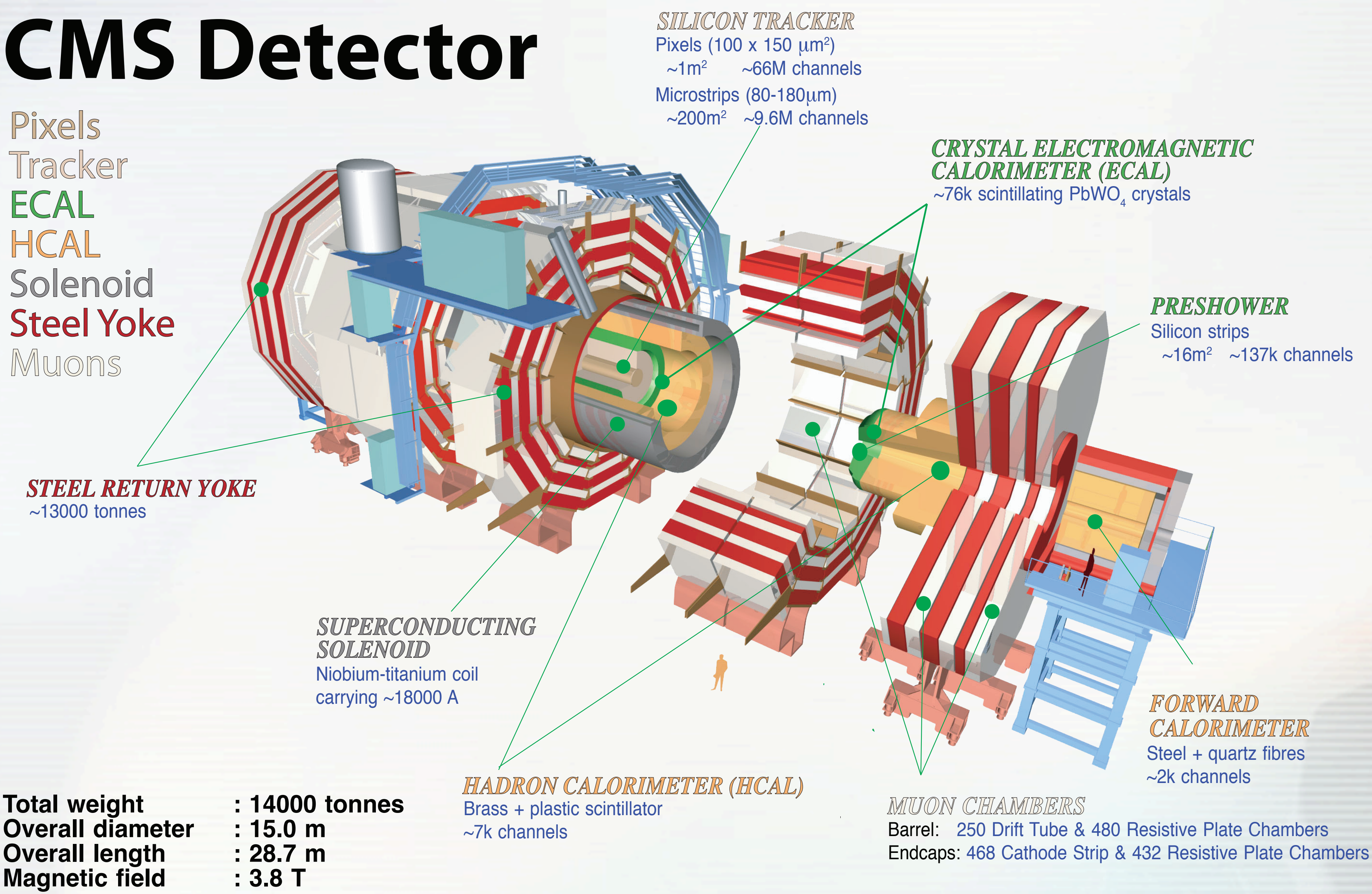






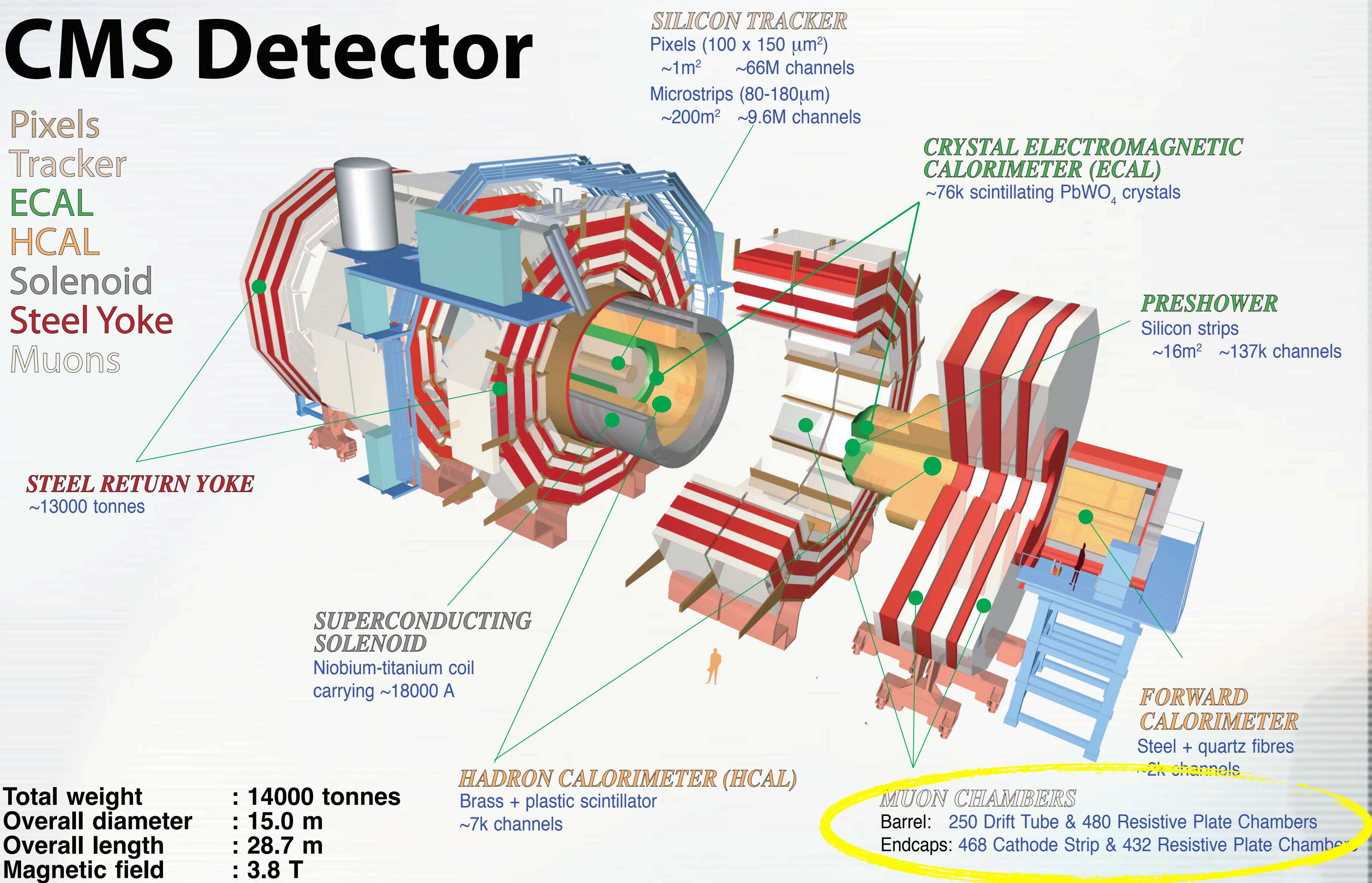
Good overall agreement with the MC (amazing as it is!)

Understanding CMS: Muons



Understanding CMS: Muons

CMS Detector



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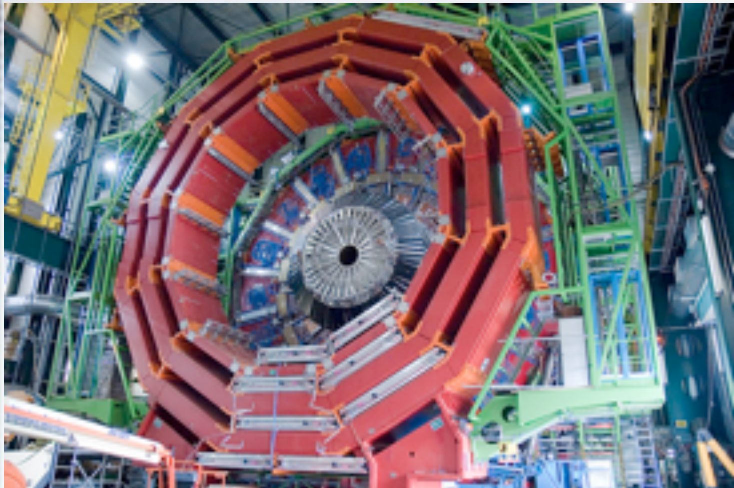

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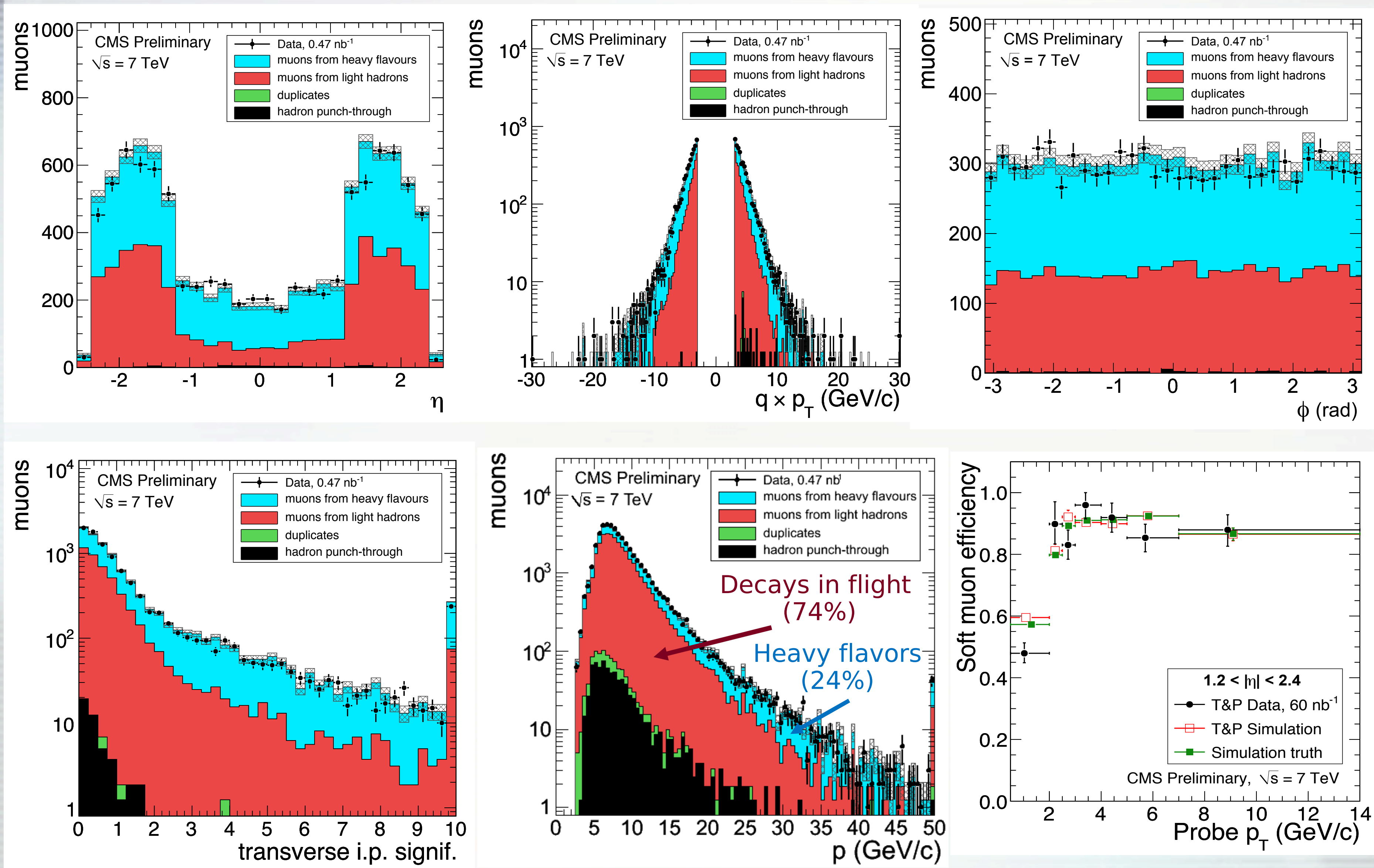
Muon is Our Second Name!



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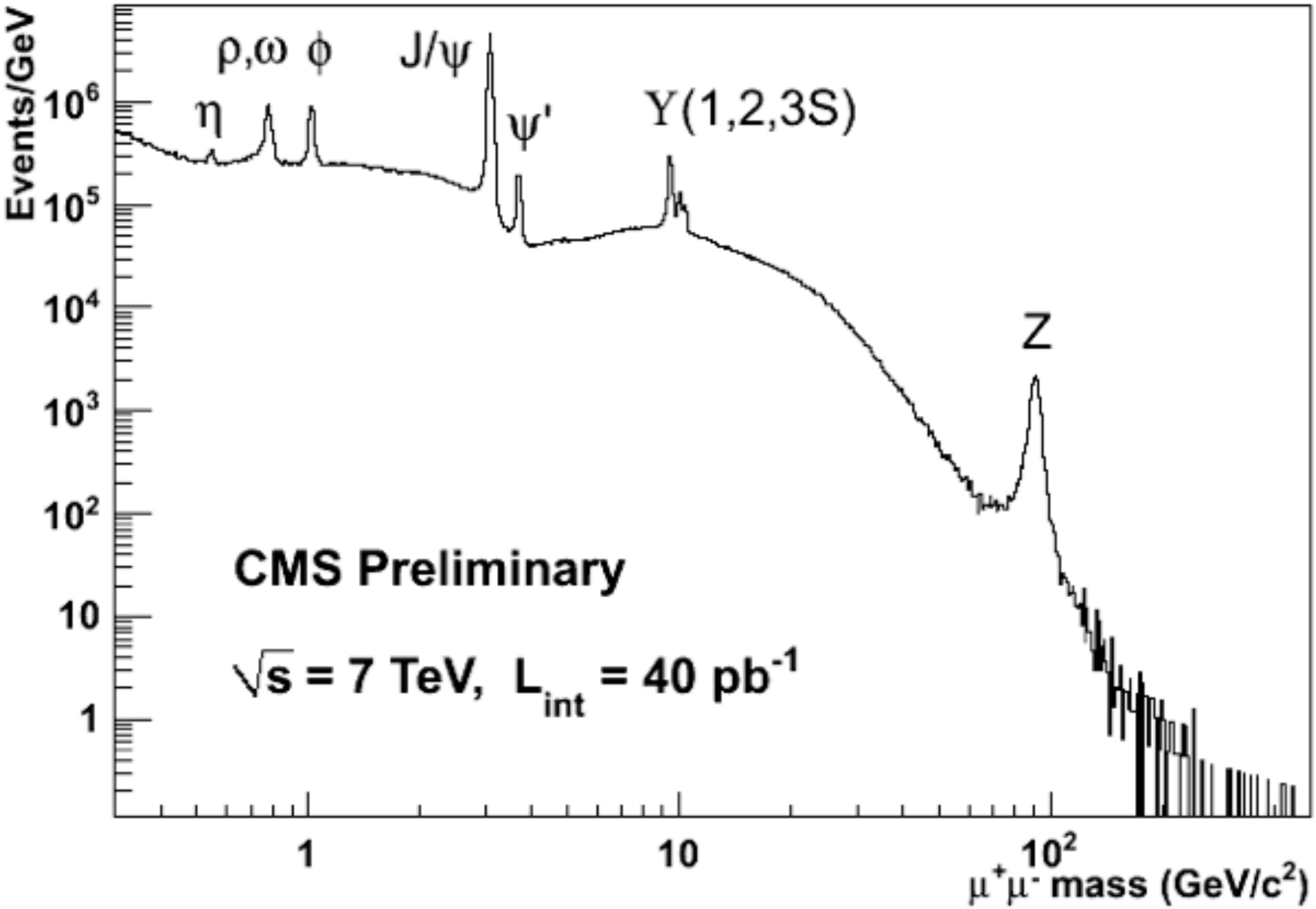
muons

muons



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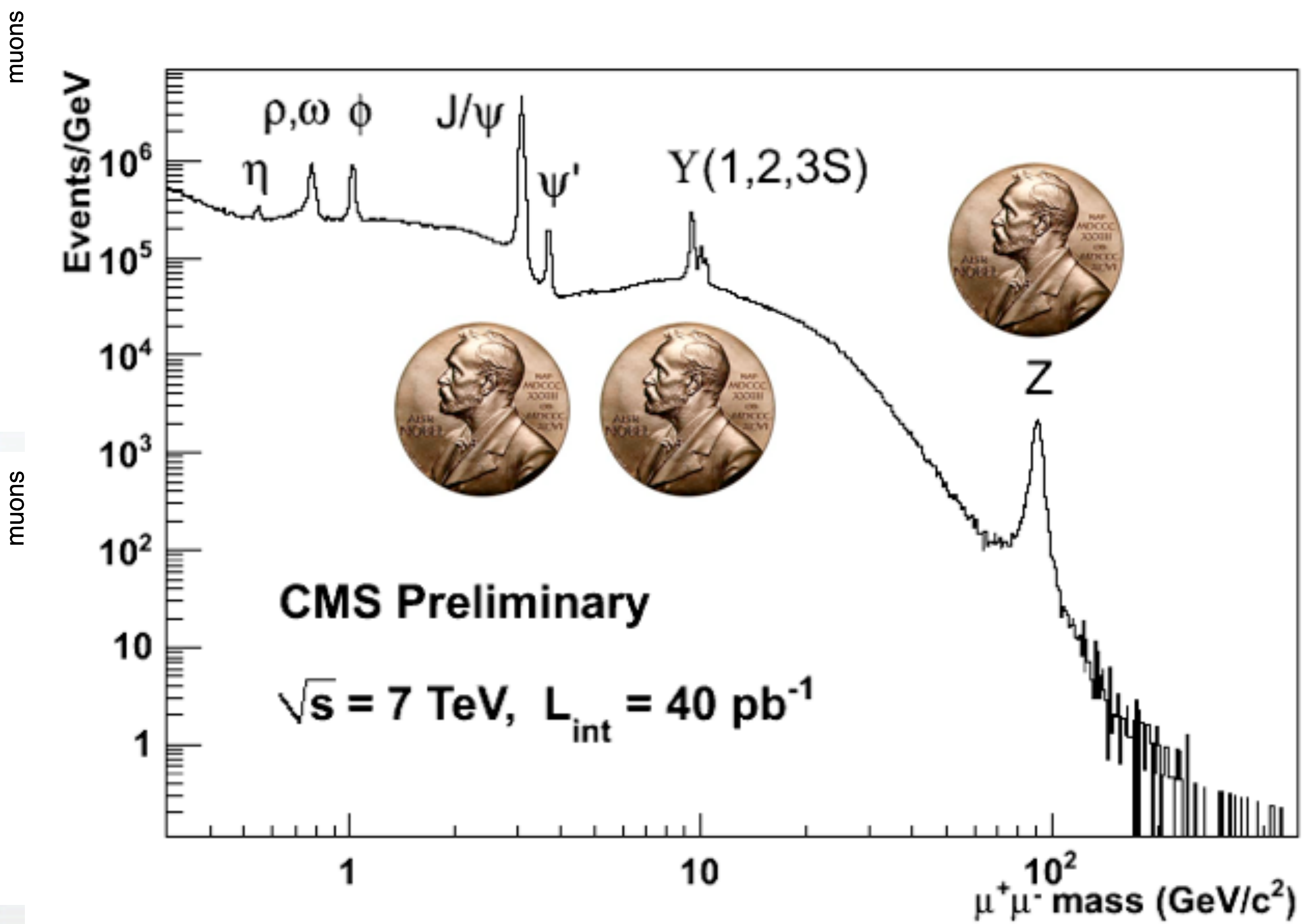

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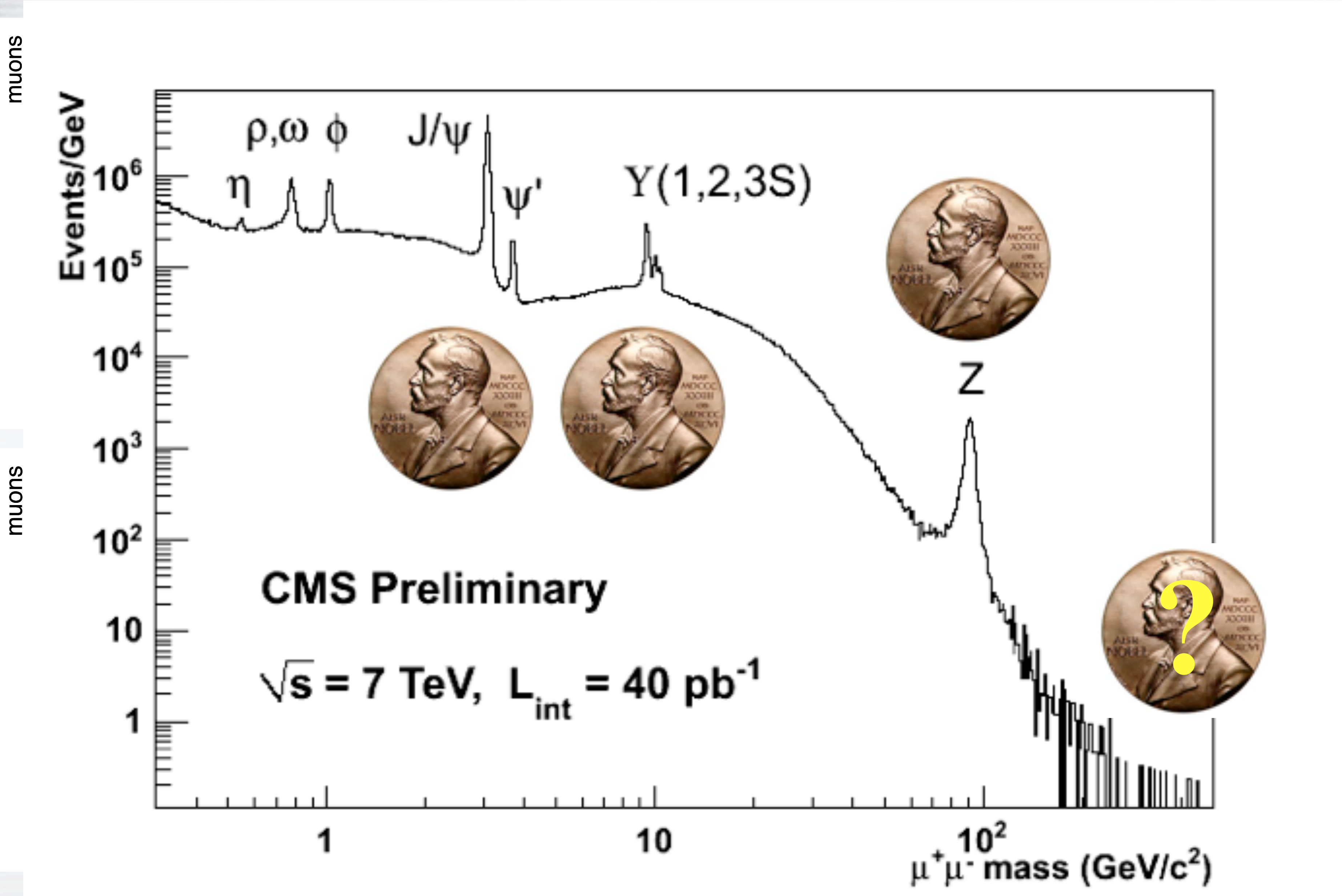

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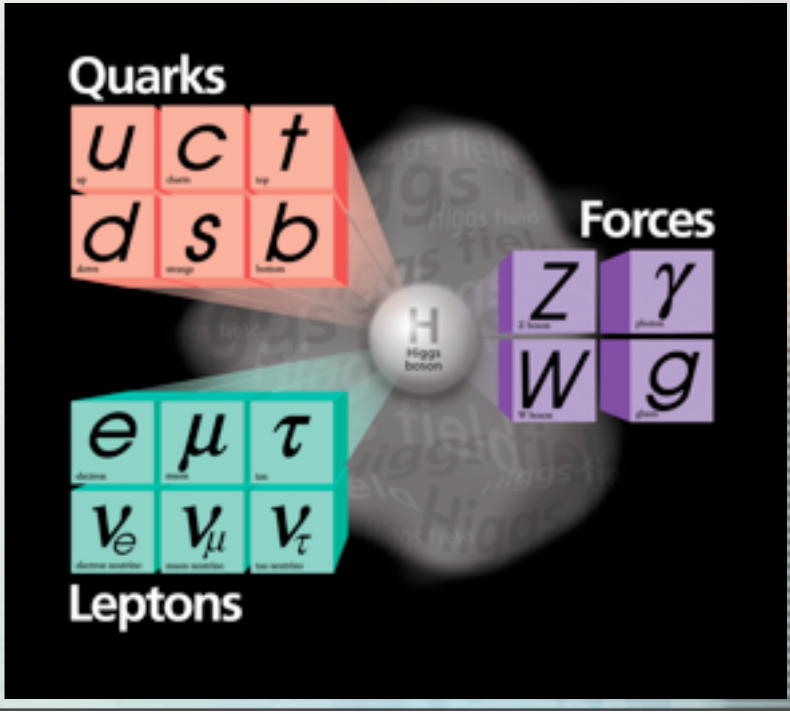
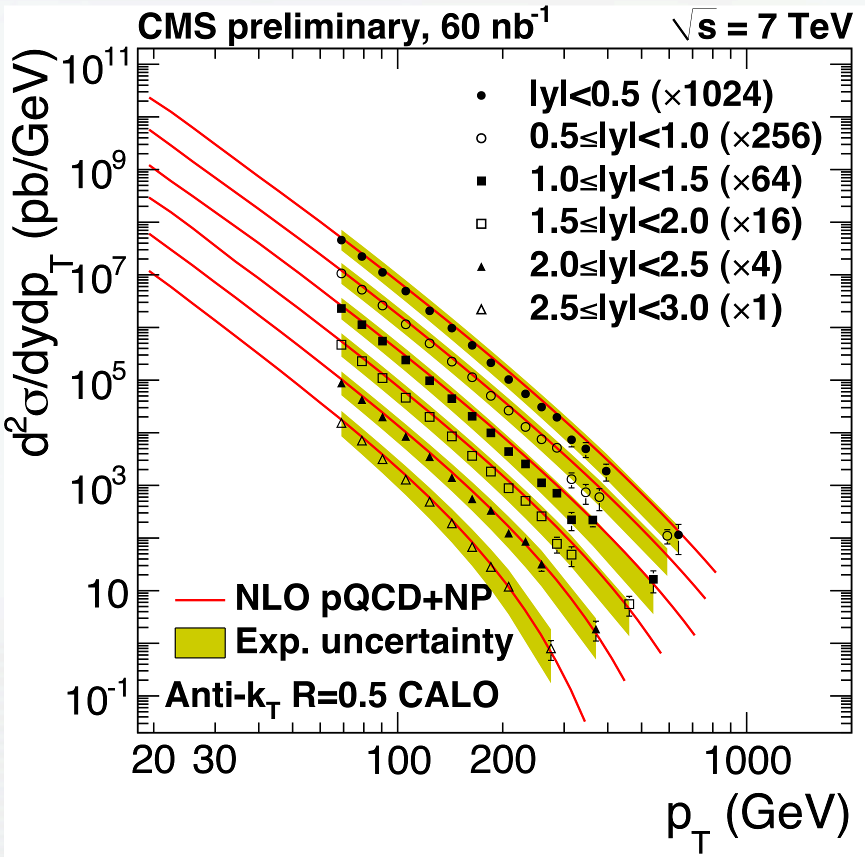
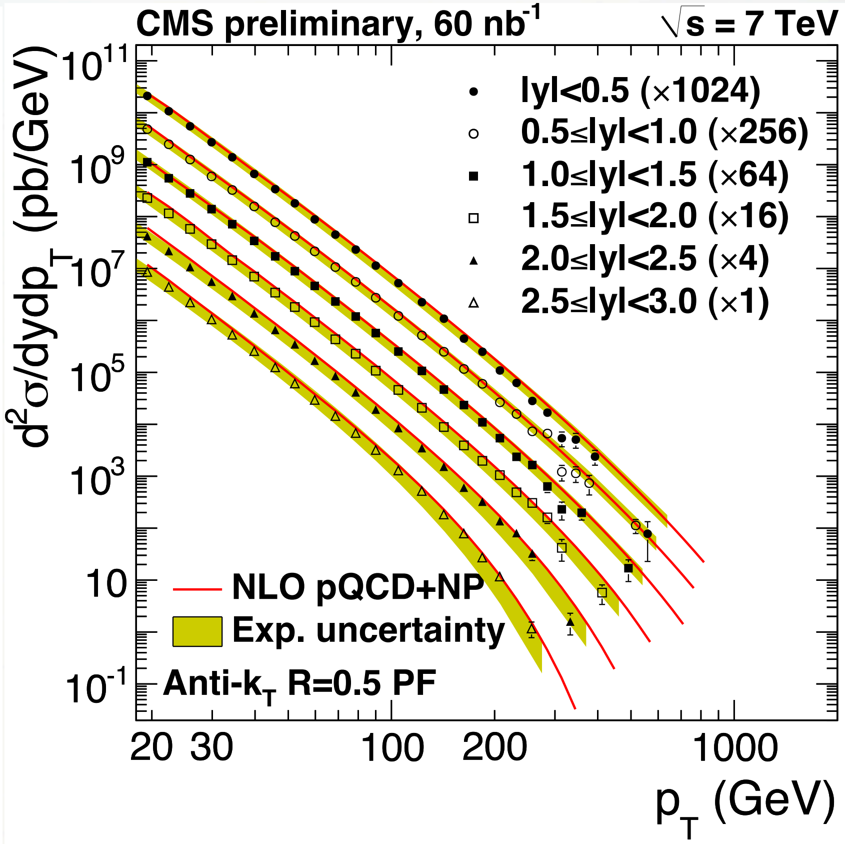
The Standard Model



Hard QCD

- Inclusive jet cross sections agree well with the NLO pQCD predictions over 9 decades in range





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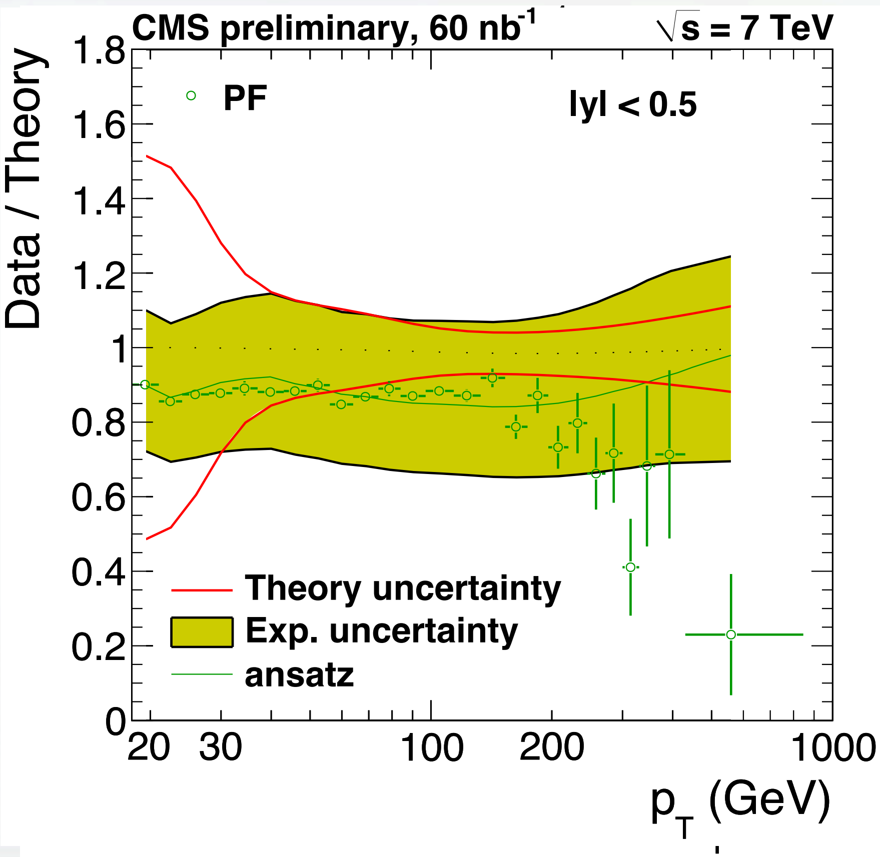
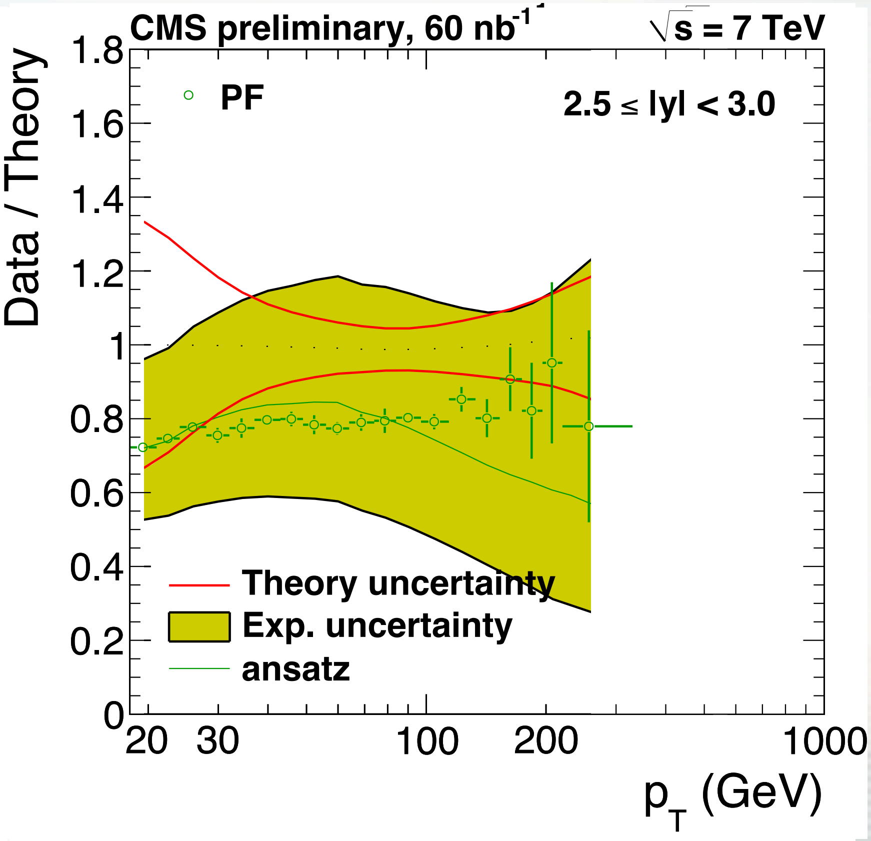
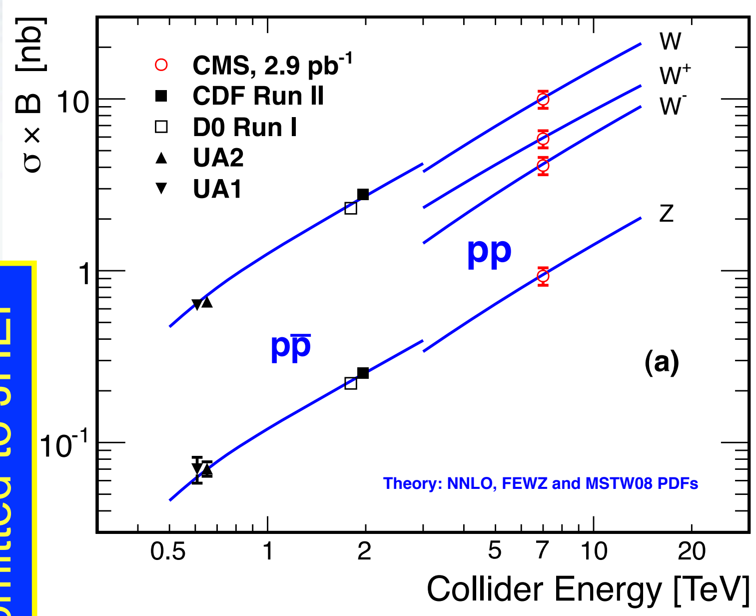


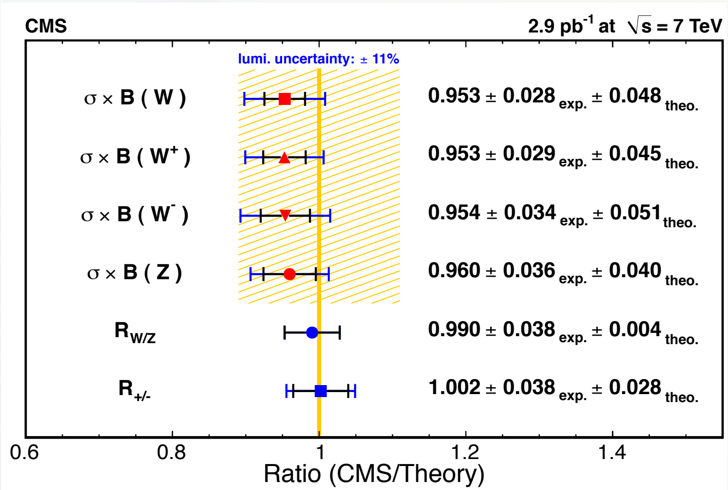


Electroweak Physics

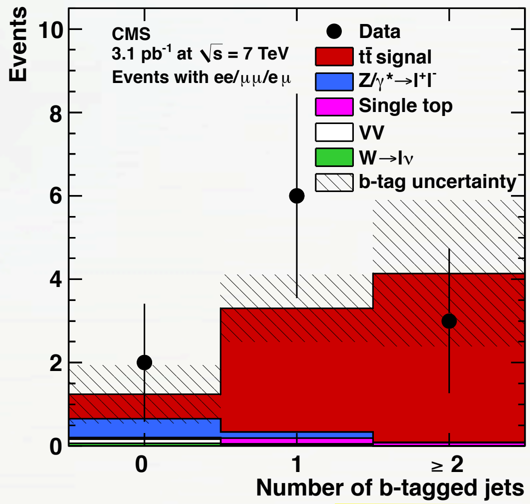
- Measurement of the W/Z and top cross section

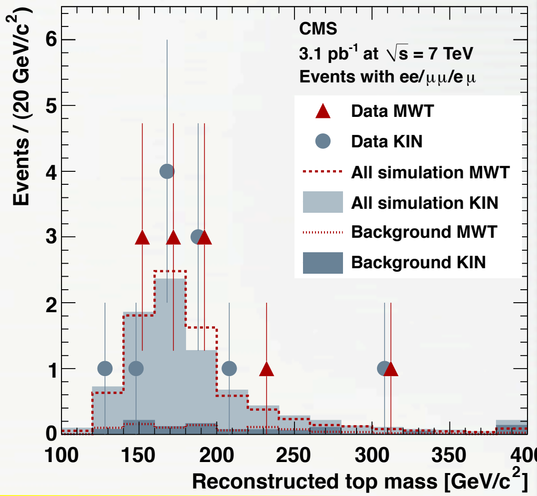
arXiv:1012.2456, submitted to JHEP



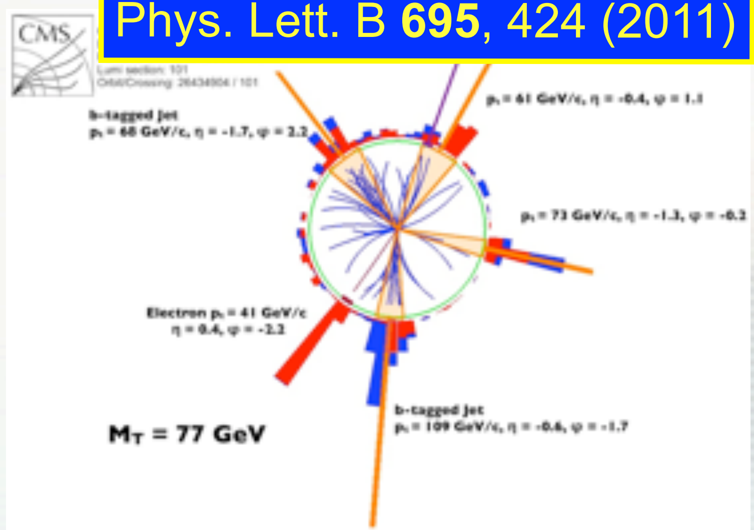


$$\sigma(\mathrm{pp} \to \mathrm{t\bar{t}}) = 194 \pm 72(\mathrm{stat.}) \pm 24(\mathrm{syst.}) \pm 21(\mathrm{lumi.})\ \mathrm{pb}$$

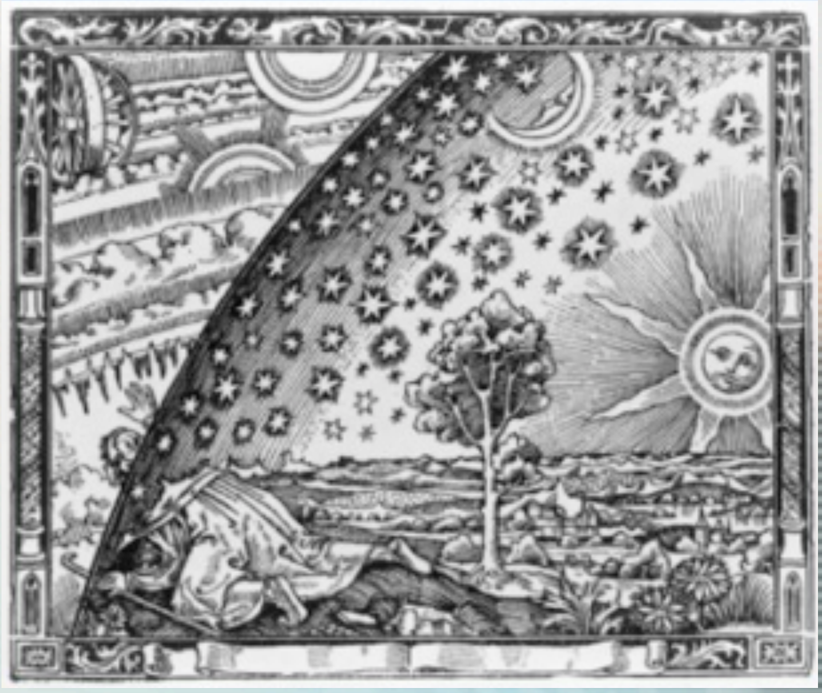




Phys. Lett. B **695**, 424 (2011)

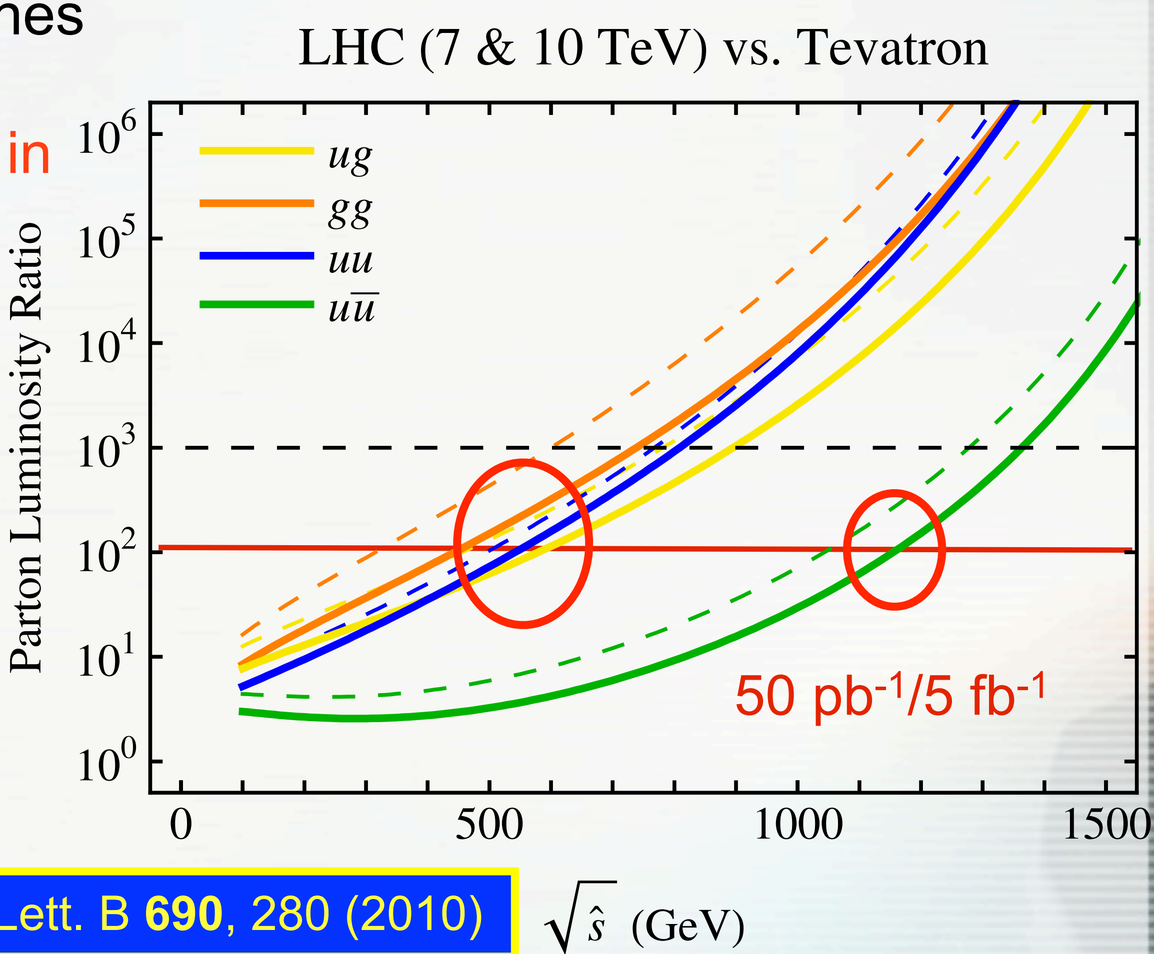


Beyond the Standard Model



How to Win Over the Tevatron?

- Ratio of parton luminosities at the LHC and the Tevatron exceeds the inverse ratio of integrated luminosities (~100 = 5 fb^{-1} /50 pb^{-1}) for mass scale >500-600 GeV (gg, qg, qq) and 1150 GeV (qq)
- Hence, focus the searches on intermediate-mass objects (pair) produced in gluon fusion, qg, or diquark interactions, and massive (>1 TeV) objects produced in quark-antiquark annihilation
- This defined the CMS search strategy in 2010



Bauer et al., Phys. Lett. B **690**, 280 (2010)

Searches for New Physics with Dijets

Searches in Dijets

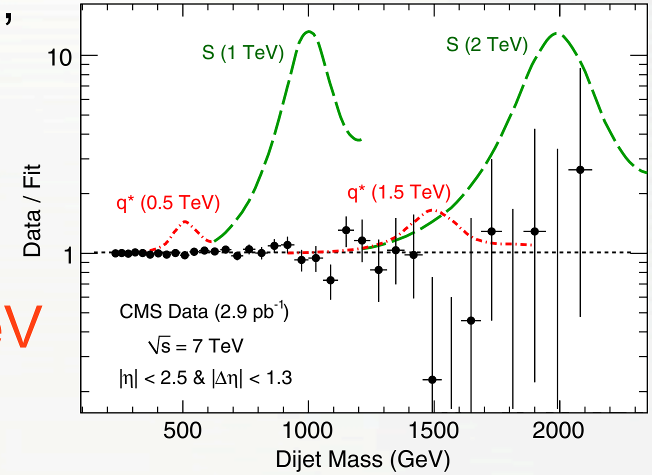
- Strong s-channel production of colored objects at high mass has huge advantage at the LHC w.r.t. the Tevatron, particularly in the gg-fusion channel
- Main background are steeply falling, t-channel dominated QCD processes
  - Look for an excess in the central region and/or high mass
- Can exceed the Tevatron reach even with < 1 pb^{-1} at 7 TeV
- Examples: generic compositeness, excited quarks, diquarks, colorons, axigluons, string resonances, etc.
  - String resonances: degenerate Regge-like excitations of $q\overset{(-)}{q}$, $\overset{(-)}{q}g$, and gg produced with high cross-section due to strong coupling and decaying back into pairs of partons
- Weakly produced s-channel objects can also be probed, but at higher luminosity (W′/Z′, G_{KK}, etc.)
- Three ways of looking for these objects:
  - “Bump search” in the dijet spectrum (resonances);
  - Dijet centrality ratio, with fine mass binning (compositeness, resonances);
  - Dijet angular distribution, with coarse mass binning (compositeness)
- At CMS we pursue all three type of searches

Dijet Bump Hunt

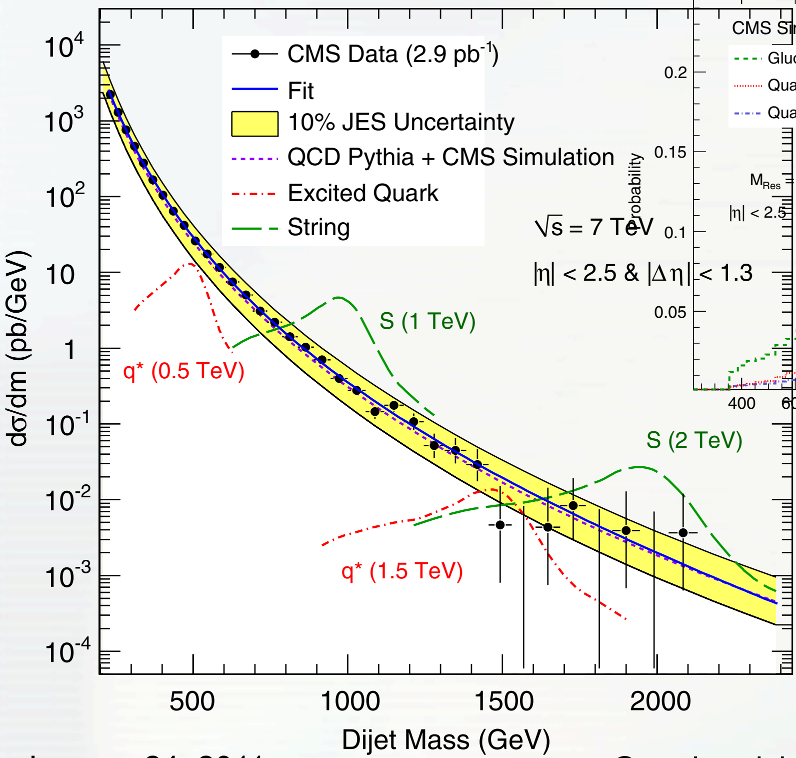
- Parameterize dijet mass spectrum with a smooth, 4-parameter fit function: $$\frac{d\sigma}{dm} = \frac{P_0(1 - m/\sqrt{s})^{P_1}}{(m/\sqrt{s})^{P_2+P_3\ln(m/\sqrt{s})}},$$ and look for bumps
- In their absence, set limits

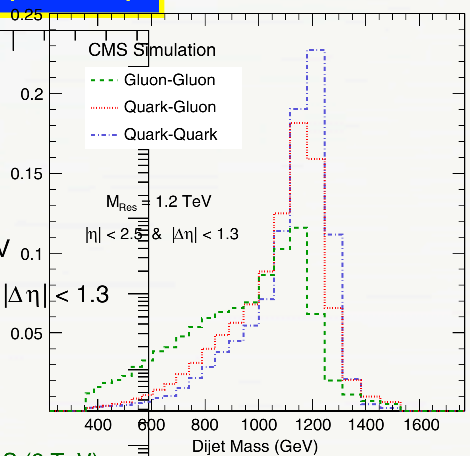
$M_{q^*} > 1.58$ TeV

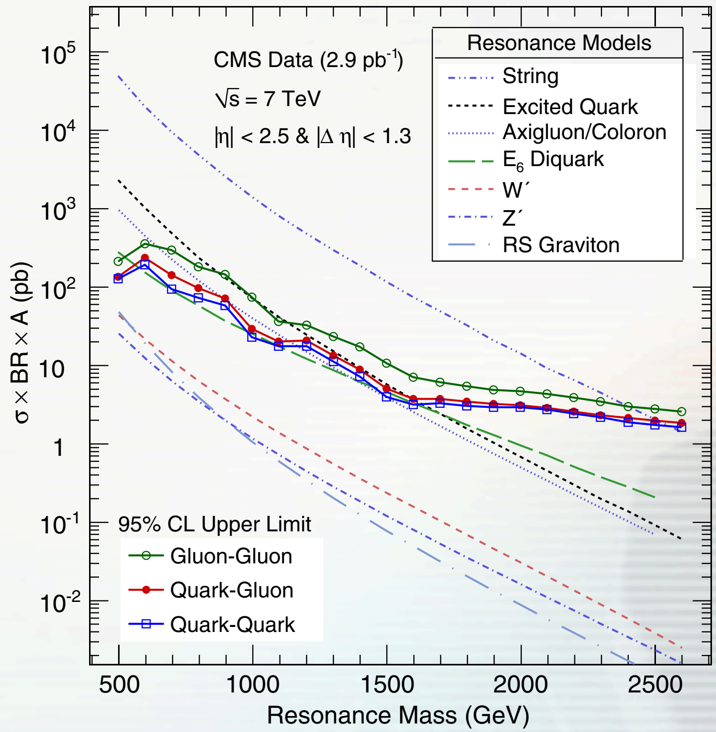
$M_S > 2.5$ TeV



Phys. Rev. Lett. **105**, 211801 (2010)







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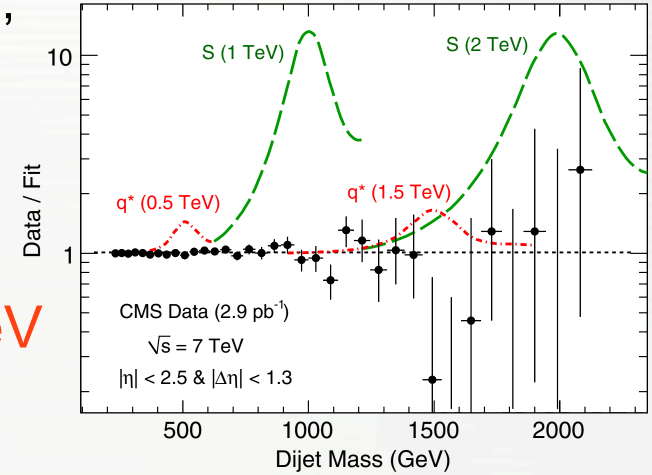

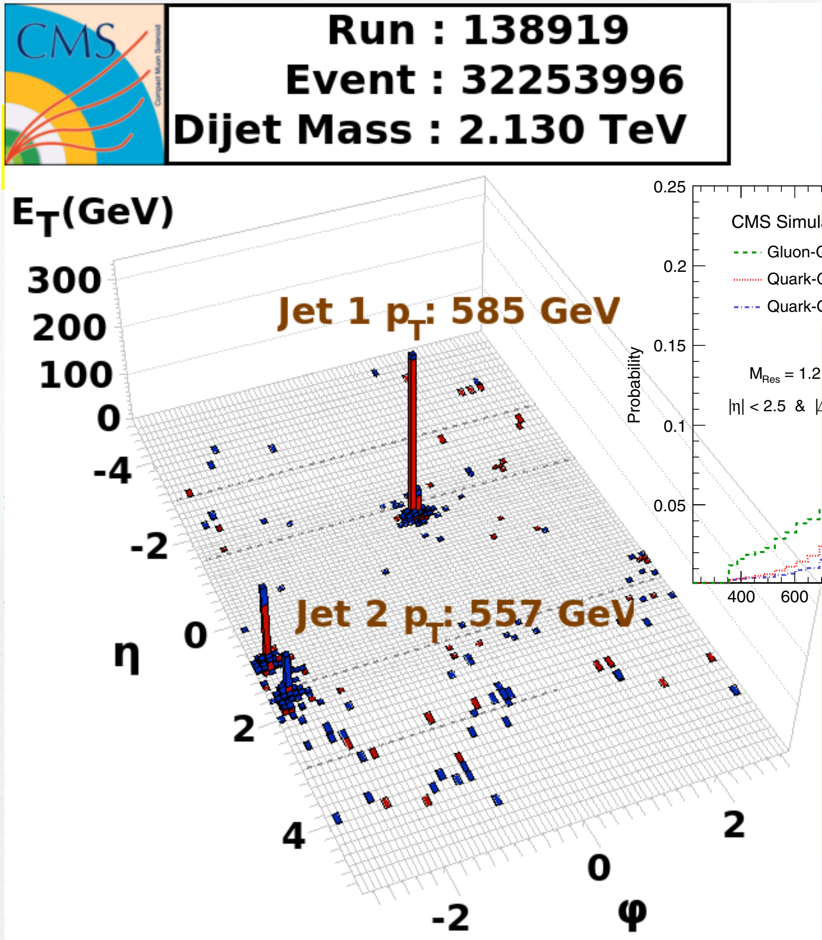

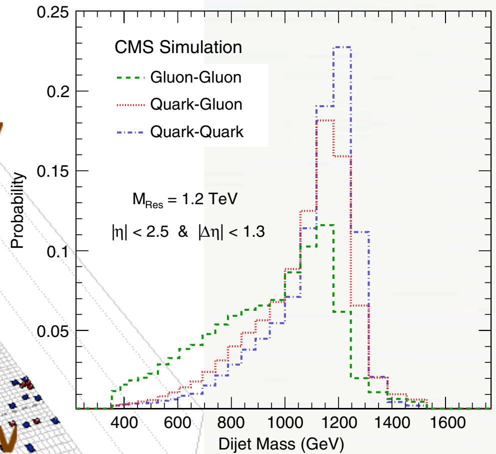

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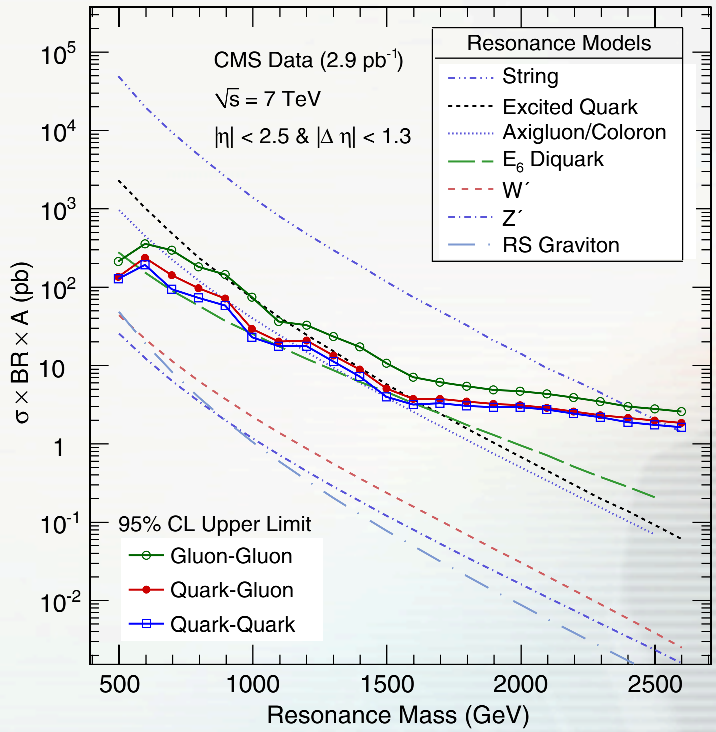
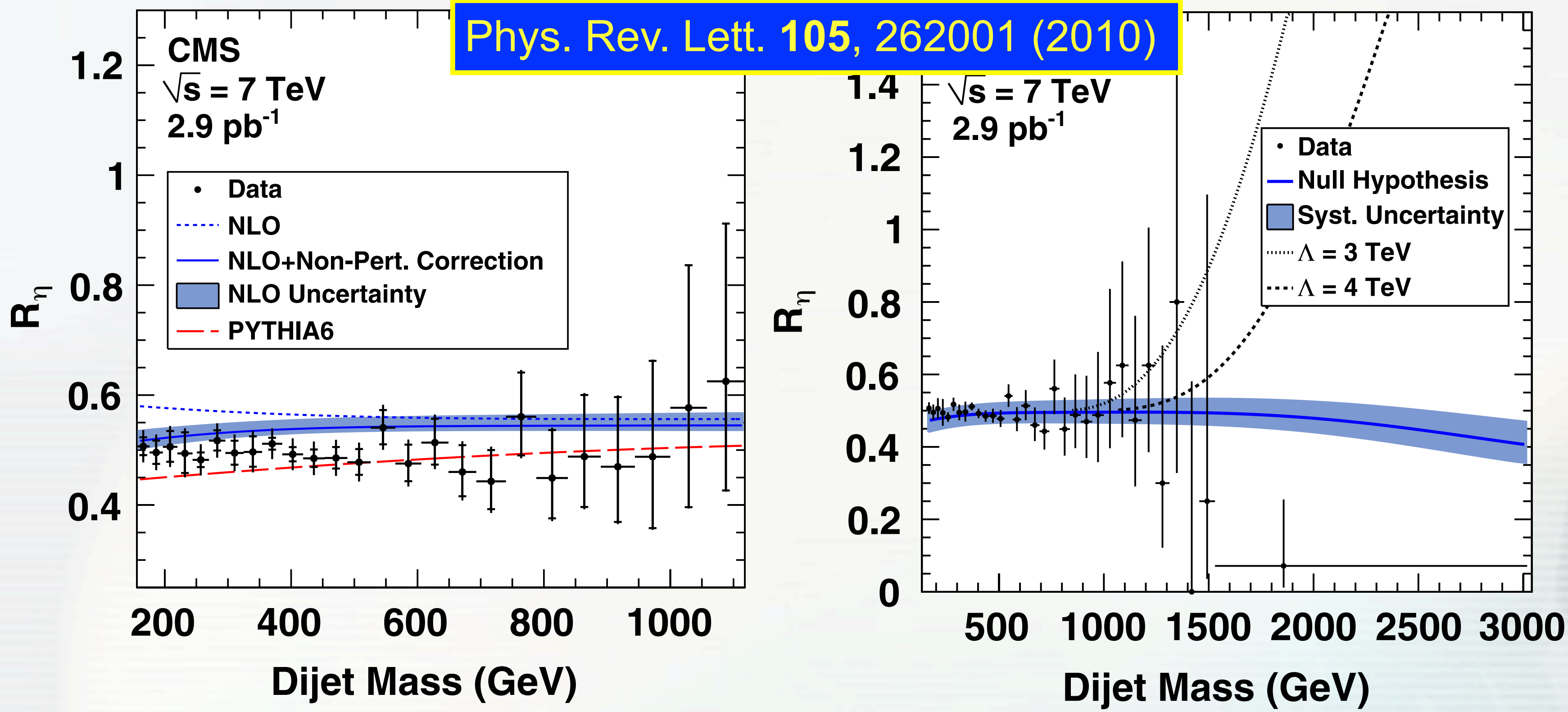


Dijet Centrality Ratio

- Use centrality C, i.e. the ratio of the number of events with both jets within $|\eta| < 0.7$ to that with both jets within $0.7 < |\eta| < 1.3$
- Advantage: SM (LO/NLO) is very flat; sensitive to compositeness, which can be "fitted away" in the bump-hunt analysis
- C is poor's man angular distribution based on just two bins, but it allows for fine mass binning and hence resonance searches too!

Phys. Rev. Lett. **105**, 262001 (2010)



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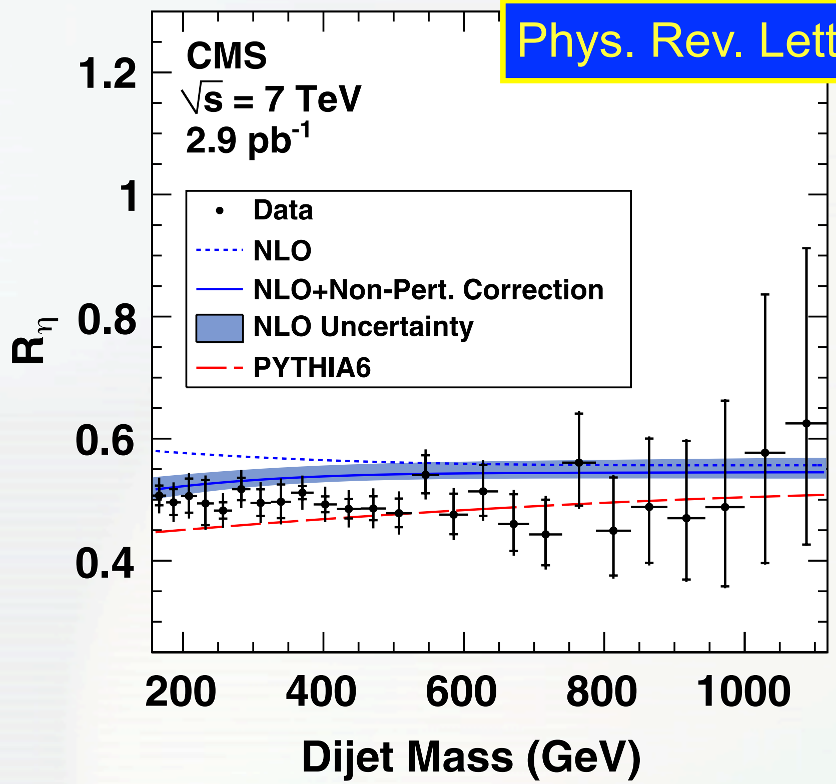
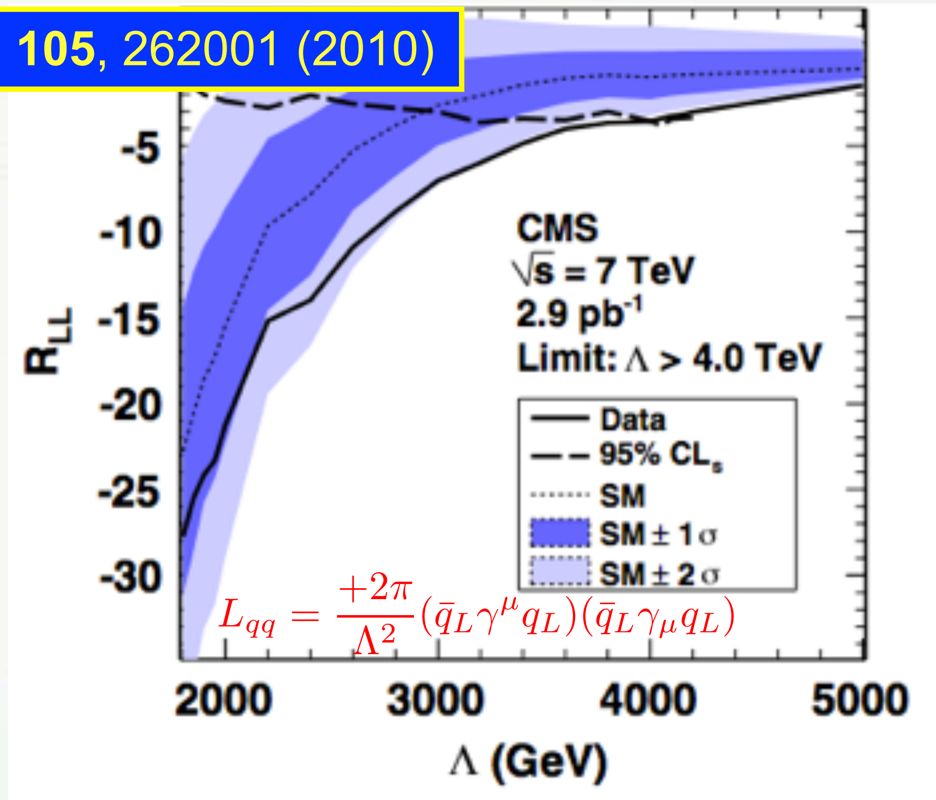
Phys. Rev. Lett. **105**, 262001 (2010)





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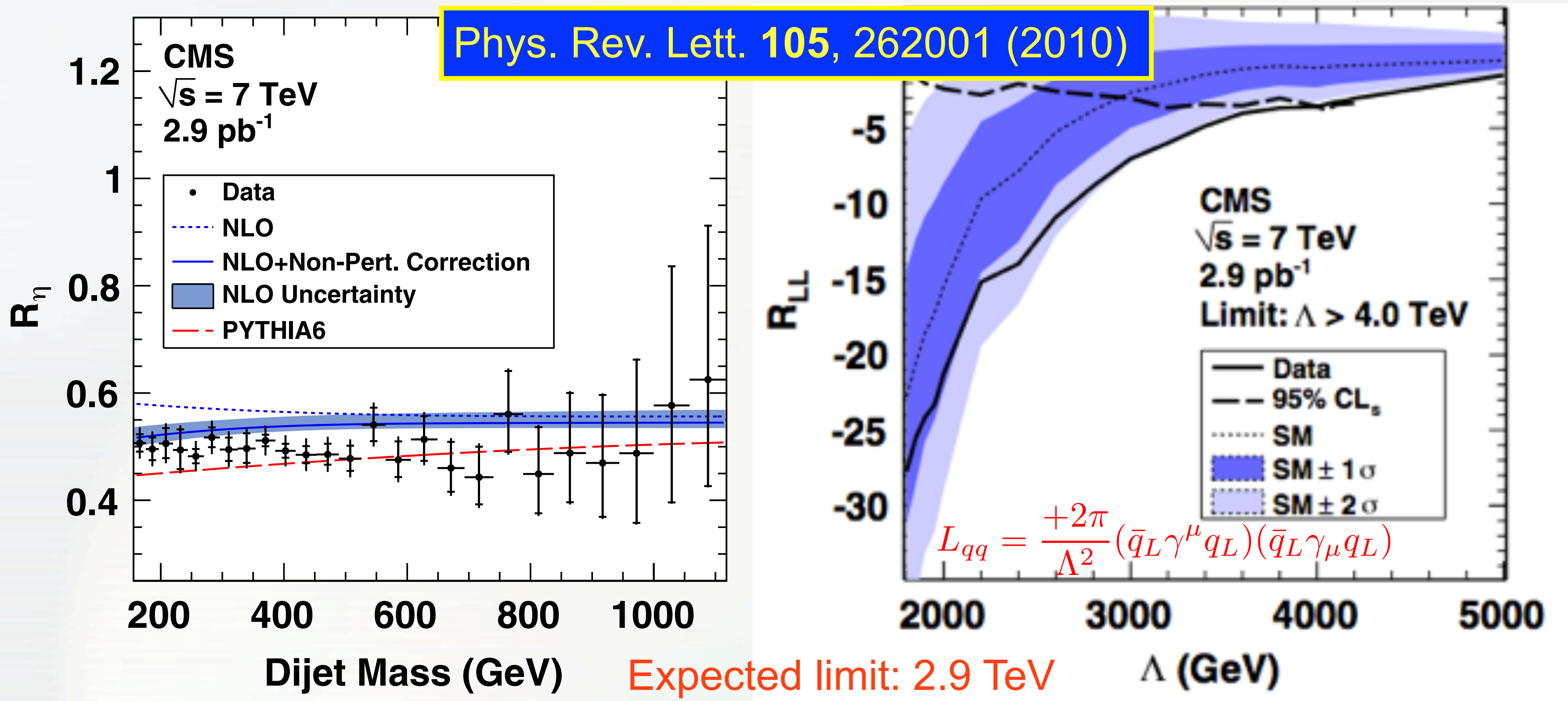
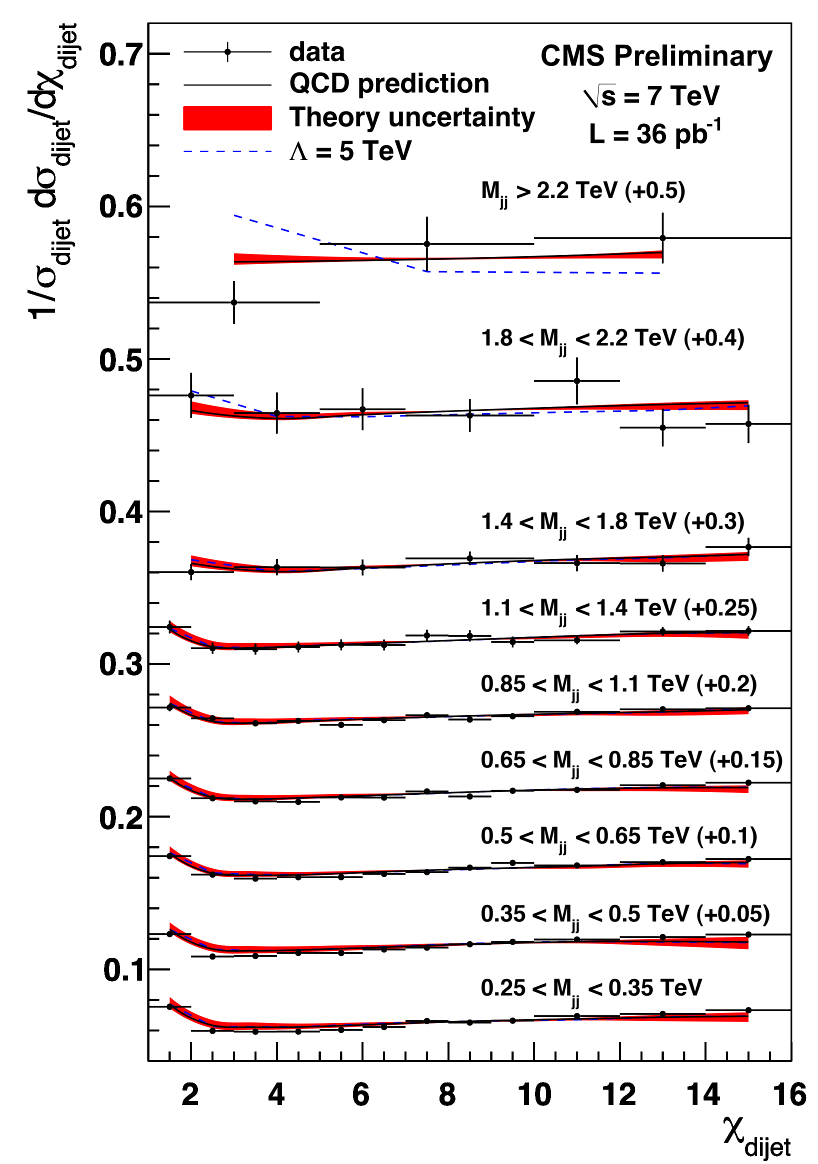
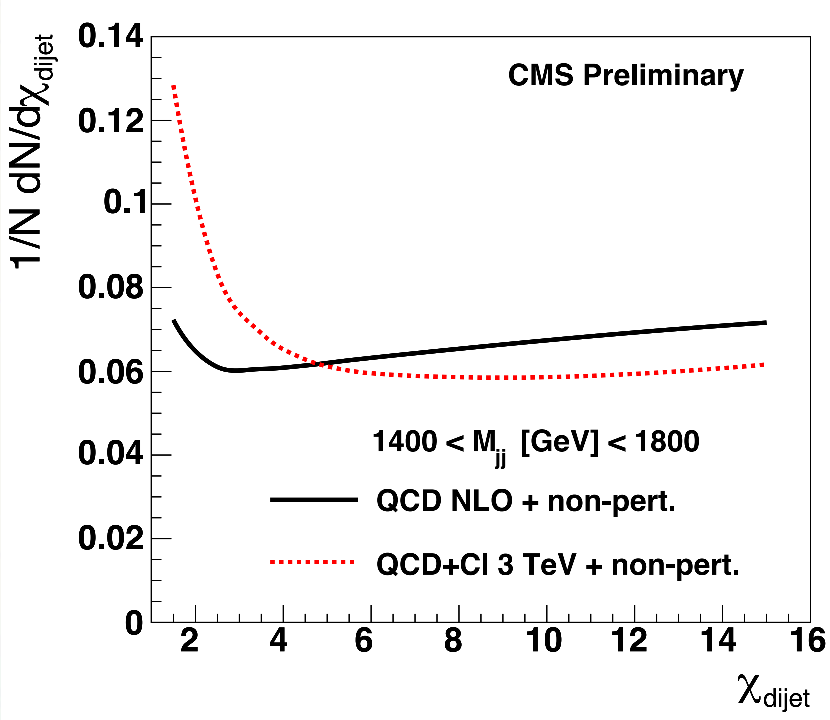


Dijet Angular Distribution

- Use dijet c.o.m. scattering angle, via $\chi = e^{2y^*} = \frac{1+\cos\theta^*}{1-\cos\theta^*}$



- Complementarity of the two approaches: ratio uses coarse angular bins but fine mass bins; χ uses much finer angular info, but coarse mass bins



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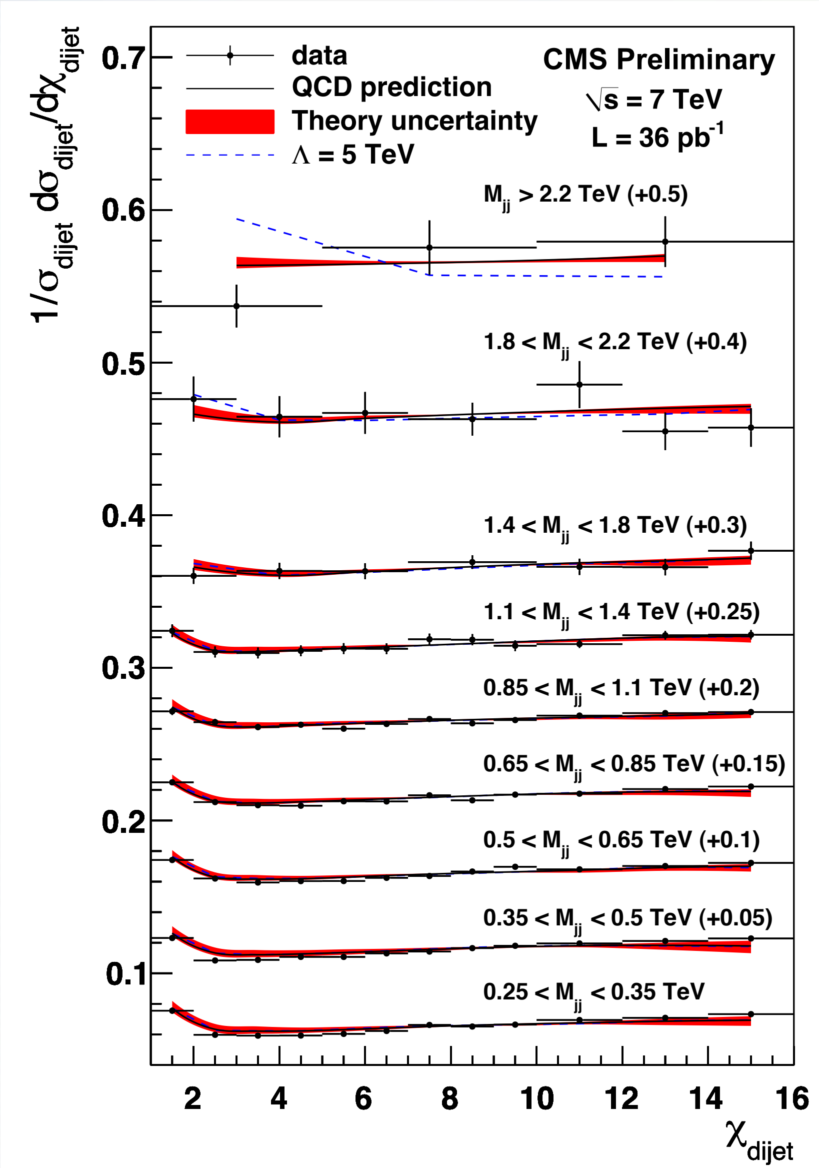

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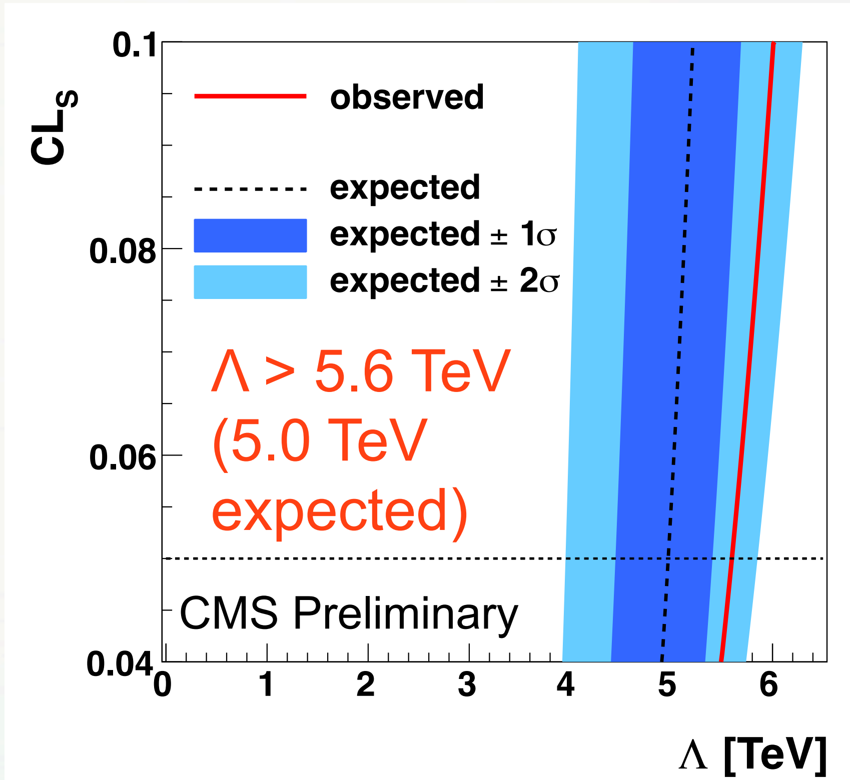

Summary of the Dijet Searches

Particle	CMS, 2.9 pb^{-1} PRL **105**, 211801 (2010)	ATLAS, 0.32 pb^{-1} PRL **105**, 161801 (2010)	CDF, 1130 pb^{-1} PRD **79**, 112002 (2009)
q*	M > 1.58 (1.32) TeV	M > 1.26 (1.06) TeV	M > 0.87 TeV
S	M > 2.50 (2.40) TeV		M > 1.4 TeV (our estimate)
Axigluon/ Coloron	M > 1.17 TeV (M > 1.23 TeV) and not (1.42 < M < 1.53)		M > 1.25 TeV
E6 diquark	Exclude 0.50-0.58 & 0.97-1.08 & 1.45-1.60 TeV (M > 1.05 TeV)		M > 0.63 TeV

Quark Compositeness (left-handed quarks)		
CMS Centrality PRL **105**, 262001 (2010)	2.9 pb^{-1}	Λ > 4.0 (2.9) TeV actual (observed)
CMS Angular Distributions (to be submitted soon)	36 pb^{-1}	Λ > 5.6 (5.0) TeV
ATLAS (Angular Distributions) (Centrality) PLB **694**, 327 (2011)	3.1 pb^{-1}	Λ > 3.4 (3.5) TeV Λ > 2.0 (2.6) TeV
D0 (Angular Distriburions) PRL **103**, 191803 (2009)	700 pb^{-1}	Λ > 2.84-3.06 (2.76-2.91) TeV

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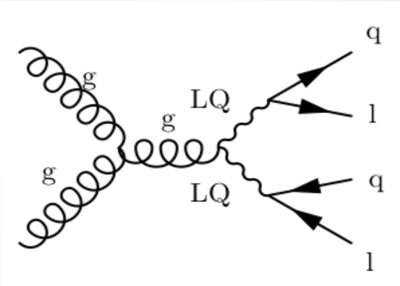
CMS has set the most stringent limits to date on ALL the listed new phenomena

Search for Additional Gauge Bosons

Dance of the Gauge Bosons in Vacuum, 2010

Leptoquarks

- Hypothetical bosons that carry properties of both leptons and quarks (color, baryon and lepton number)
  - Can be either scalar or vector particles (focus on scalars)
  - Often appear in GUT-inspired models to provide connection between three lepton and quark generations
- Decay into ℓq (νq) with the branching fraction β (1-β)
  - Cross-generational couplings are restricted by the FCNC constraints; assume decay into one generation only
  - In the simplest model, β is fixed to 1, 1/2, or 0; here we consider it a free parameter $0 < \beta < 1$
- Consider leptoquarks of three generations independently
  - Focus on the first two generations, LQ1 and LQ2 in this search
- Explore pair-production via gluon fusion, with subsequent decays into dileptons and jets



Monday, January 24, 2011

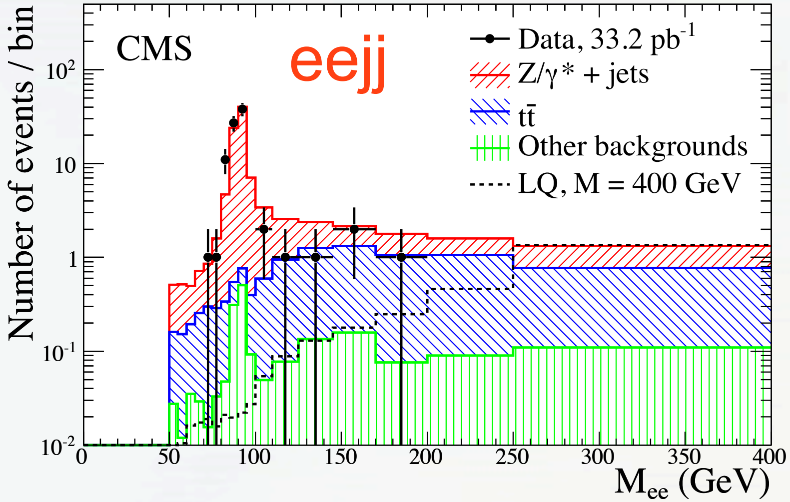
Search Strategy

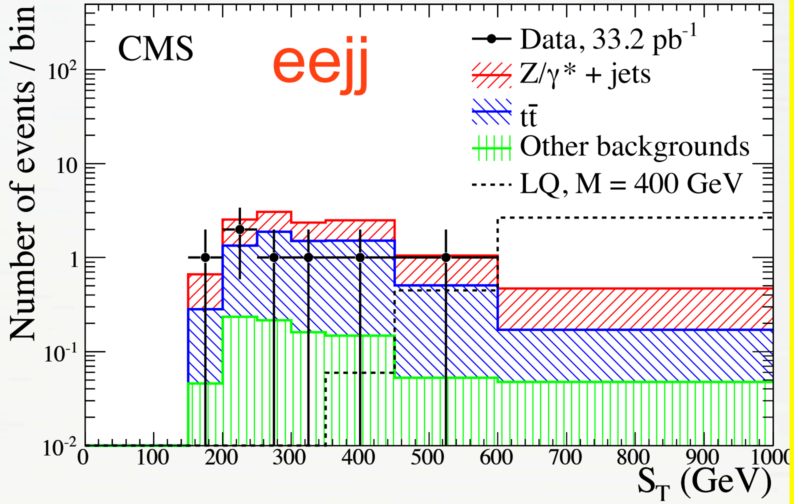
- A single, most powerful variable to discriminate between the signal and backgrounds is scalar sum of leading and sub-leading object transverse energies:
  - $S_T = E_T(\ell_1) + E_T(\ell_2) + E_T(j_1) + E_T(j_2)$
- Another obvious variable, $M(\ell j)$ is not as powerful due to combinatorics and ISR/FSR - it is nevertheless crucial to establish the signal, if an excess in S_T is observed
- Two analyses (LQ1 and LQ2 searches) employ very similar strategies and are closely connected
- The main irreducible background is from DY+jets; top-pair production is the second most important one
- Use in situ Z+jets measurement and our own top cross section measurement (PLB **695**, 424 (2011)) in the dilepton channel to estimate both of them

LQ1 and LQ2 Search

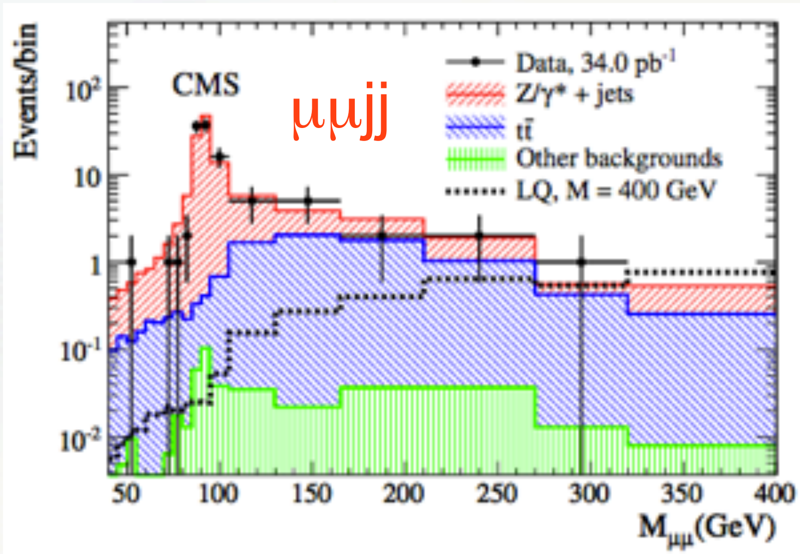
- Normalize DY+jets to the control Z+jets region
- An anti-Z cut and mass-dependent S_T cut optimization

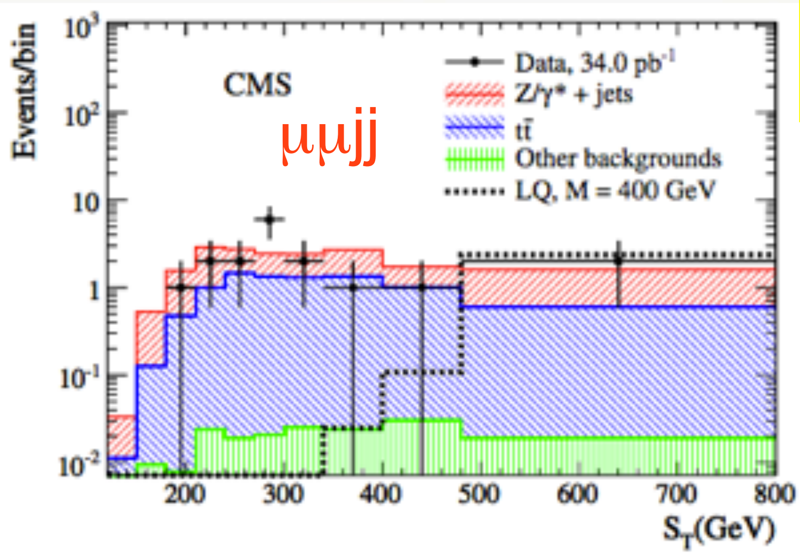
arXiv:1012.4031, submitted to PRL





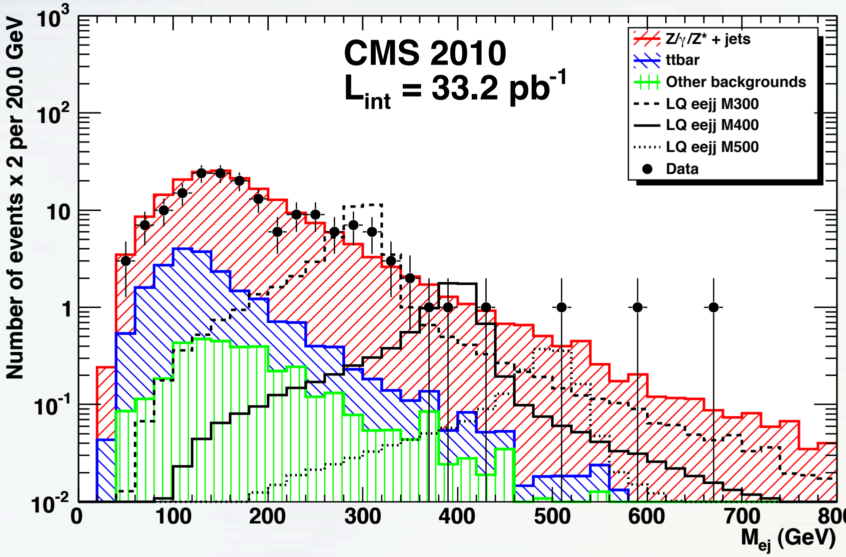
arXiv:1012.4033, submitted to PRL

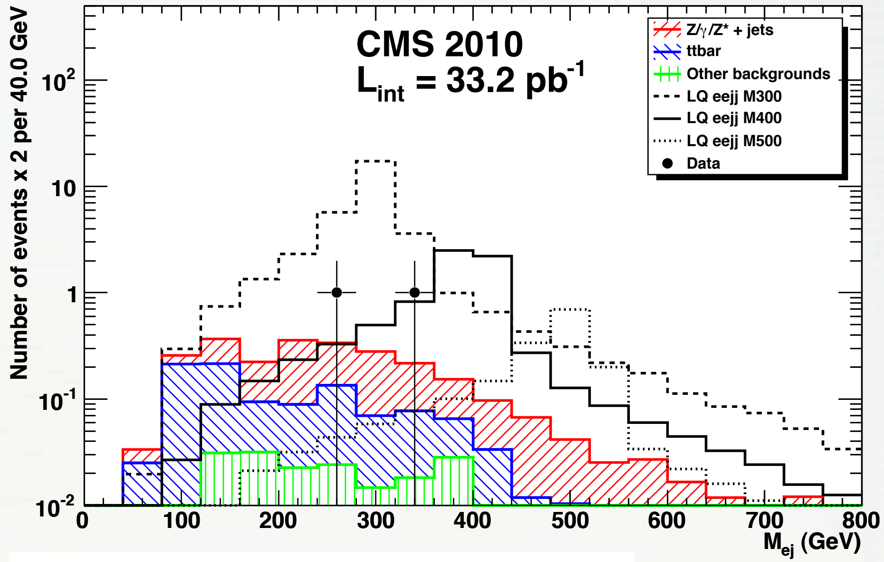


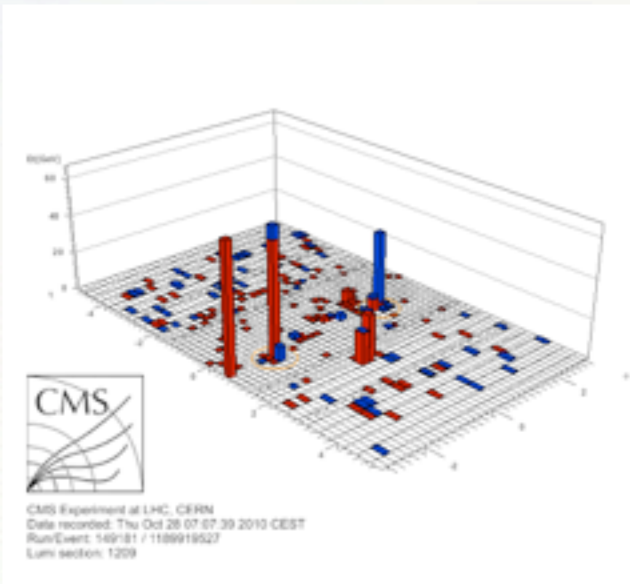


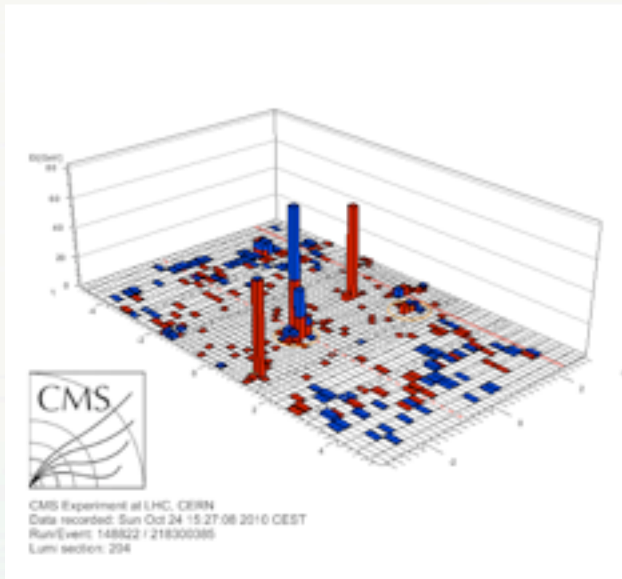
LQ1 Analysis: Some Details

- M_{ej} plots after pre-selection and full selection



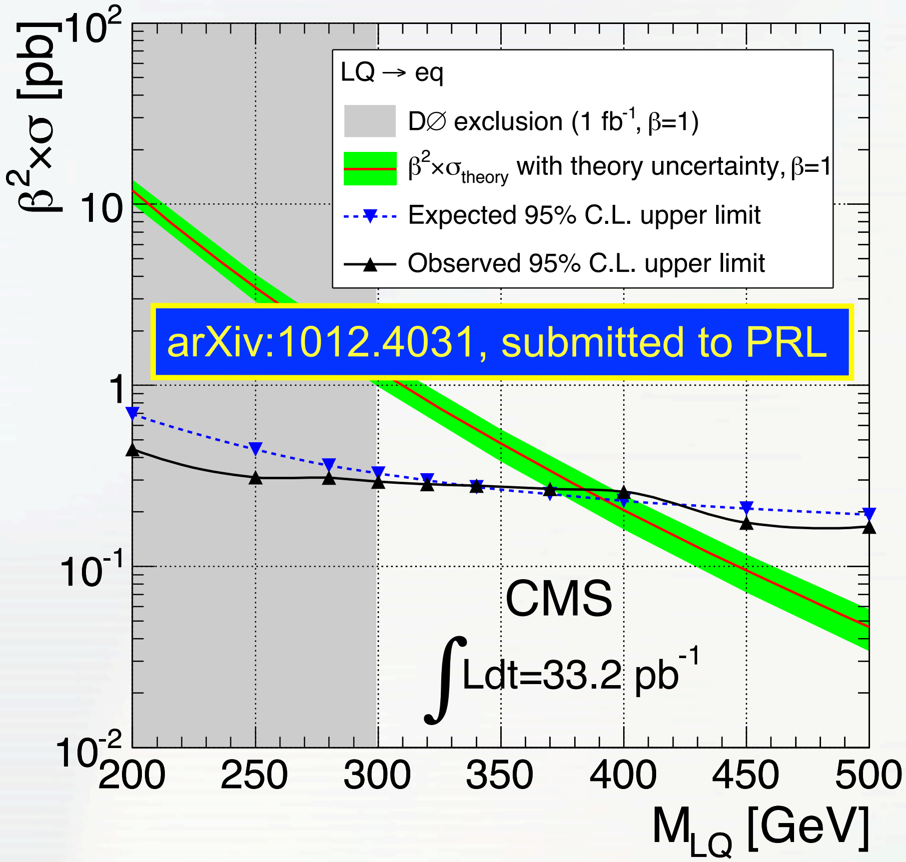


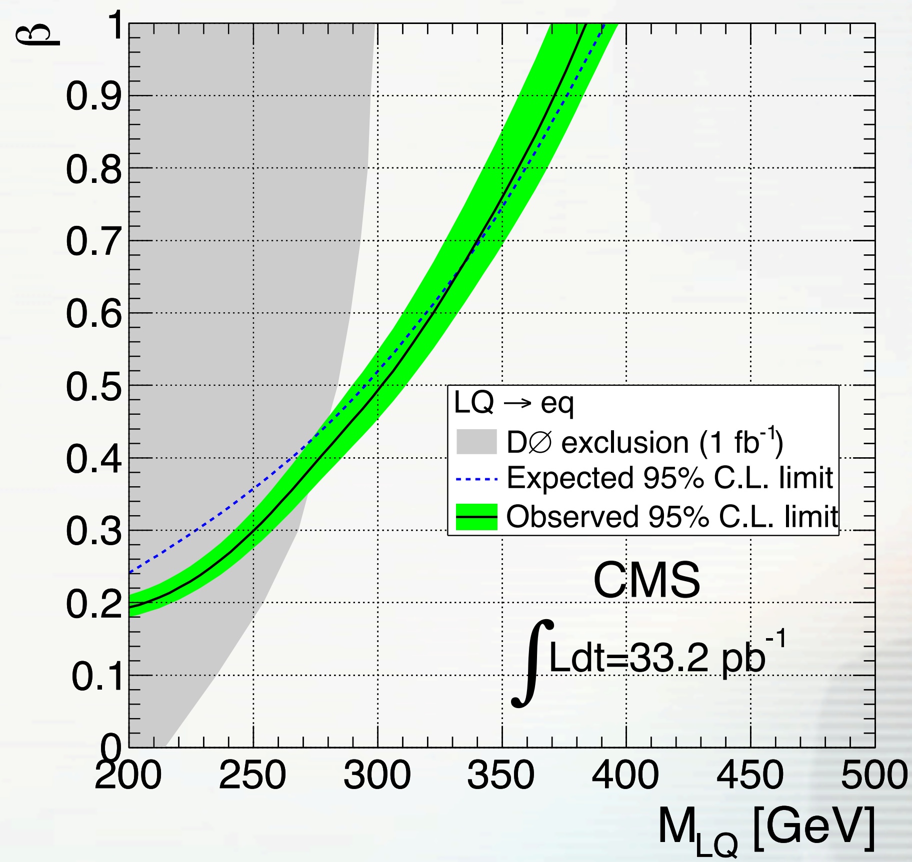




LQ1 Limits

- S_T > 340-660 GeV for M_{LQ1} = 200-500 GeV, 2-0 events observed, consistent with the expected background
- Significant extension of the Tevatron limits (M_{LQ1} > 299 GeV)
- Complementary eνjj analysis ongoing (improved β < 1 sensitivity)

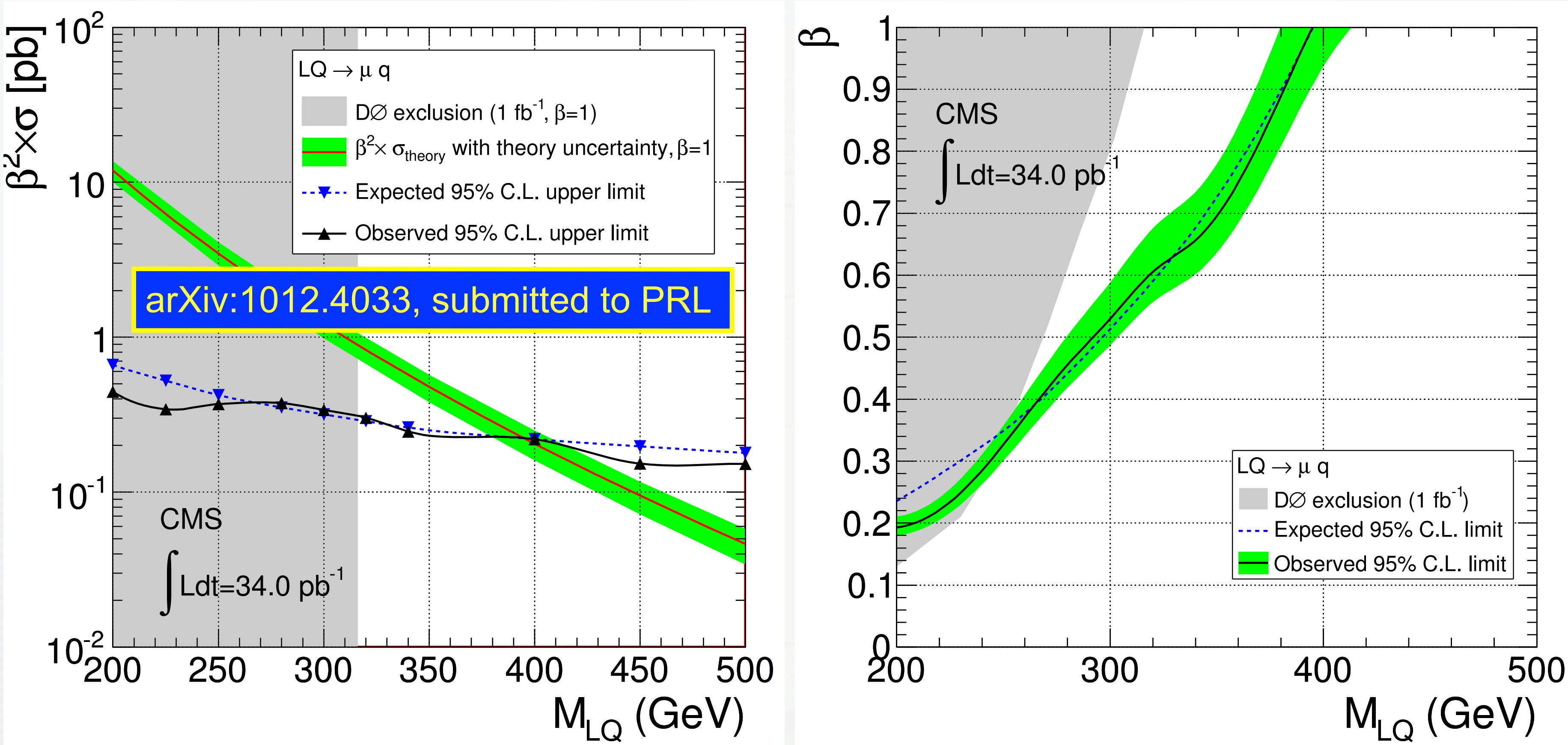




M_{LQ1} > 384 (391 expected) GeV, β = 1

LQ2 Limits

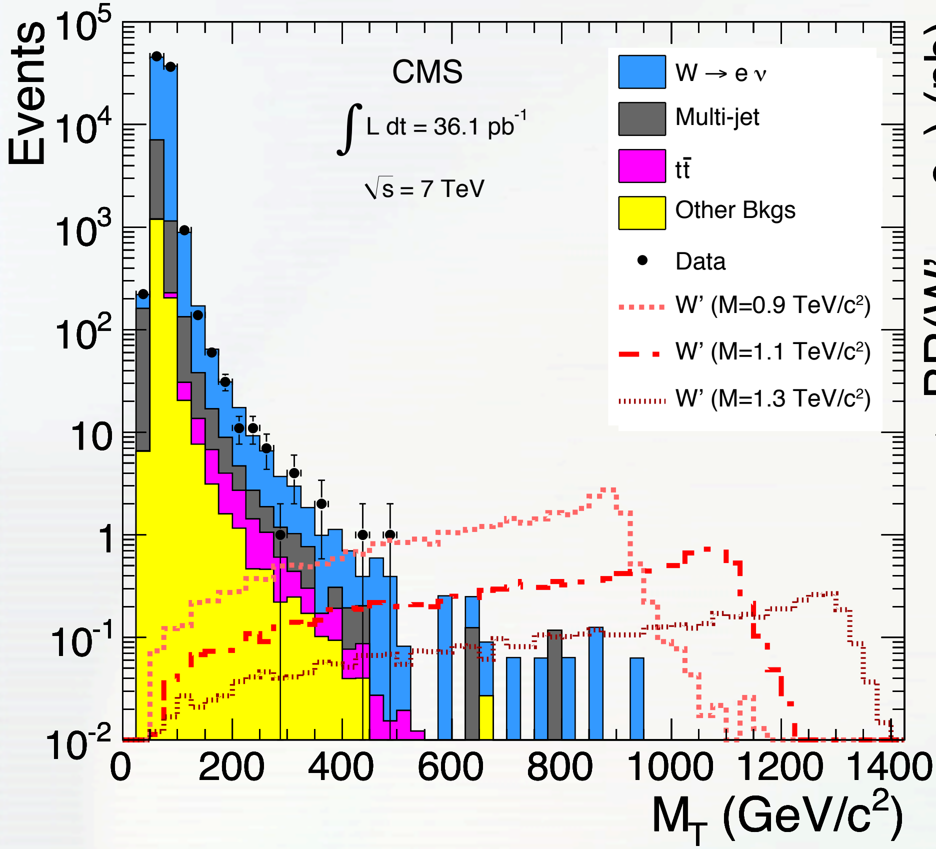
- S_T > 310-700 GeV for M_{LQ2} = 200-500 GeV, 5-0 events observed, consistent with the expected background
- Significant extension of the Tevatron limits (M_{LQ2} > 316 GeV)
- Complementary μνjj analysis ongoing (improved β < 1 sensitivity)

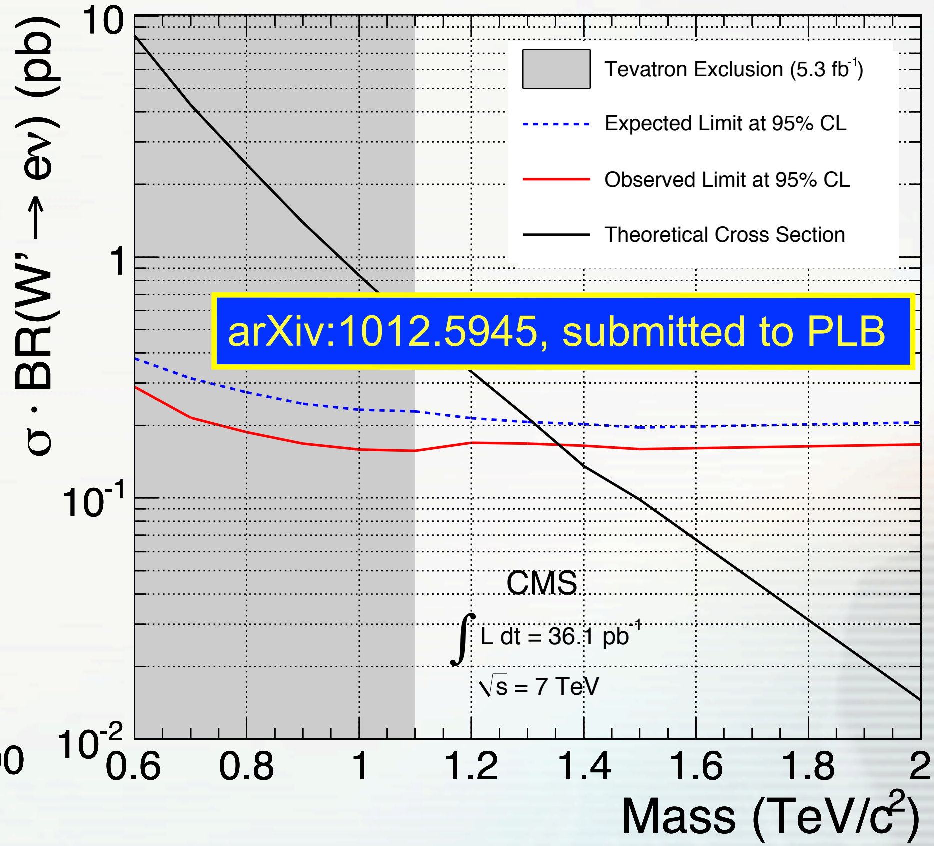


M_{LQ1} > 394 (394 expected) GeV, β = 1

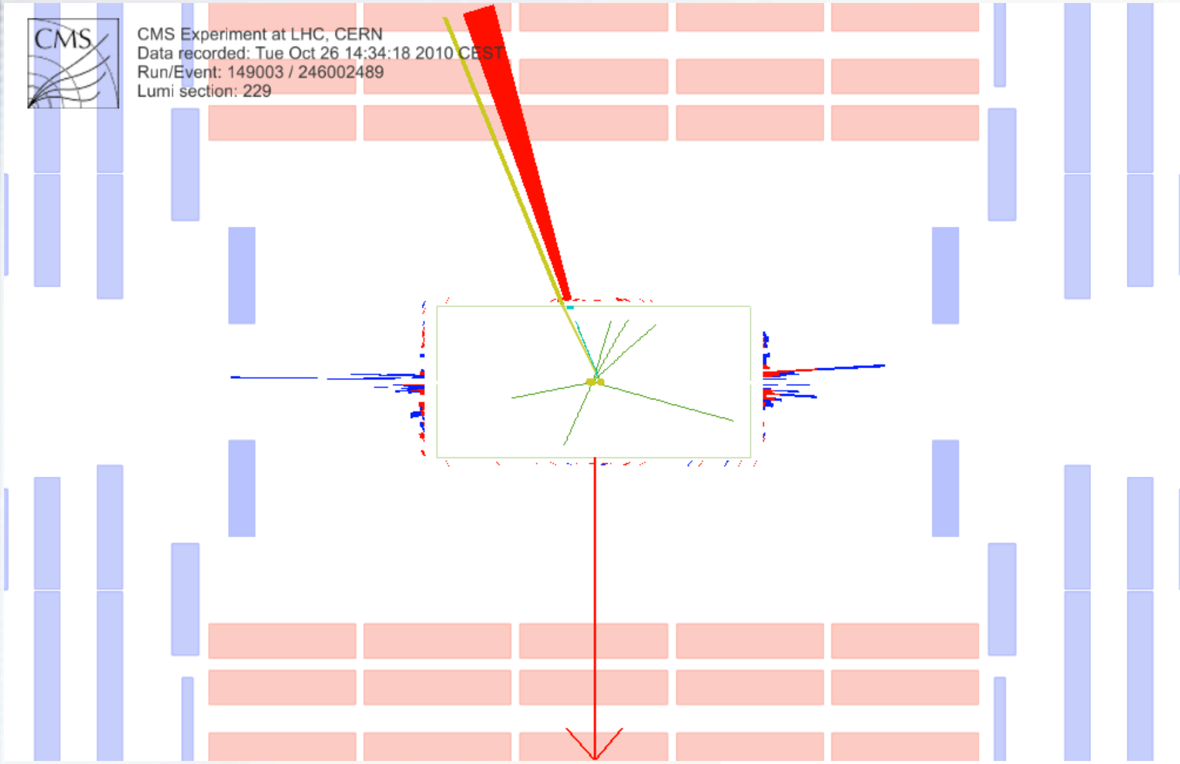
W'(eν) Search

- W* and QCD backgrounds estimated via template method
- M_T > 400-675 GeV for M(W′) = 0.6-2.0 TeV; 2-0 events observed
- M(W′) > 1.36 TeV (eν) - significant extension of the Tevatron limit of 1.12 TeV [CDF, arXiv:1012.5145, 5.3 fb^{-1}]

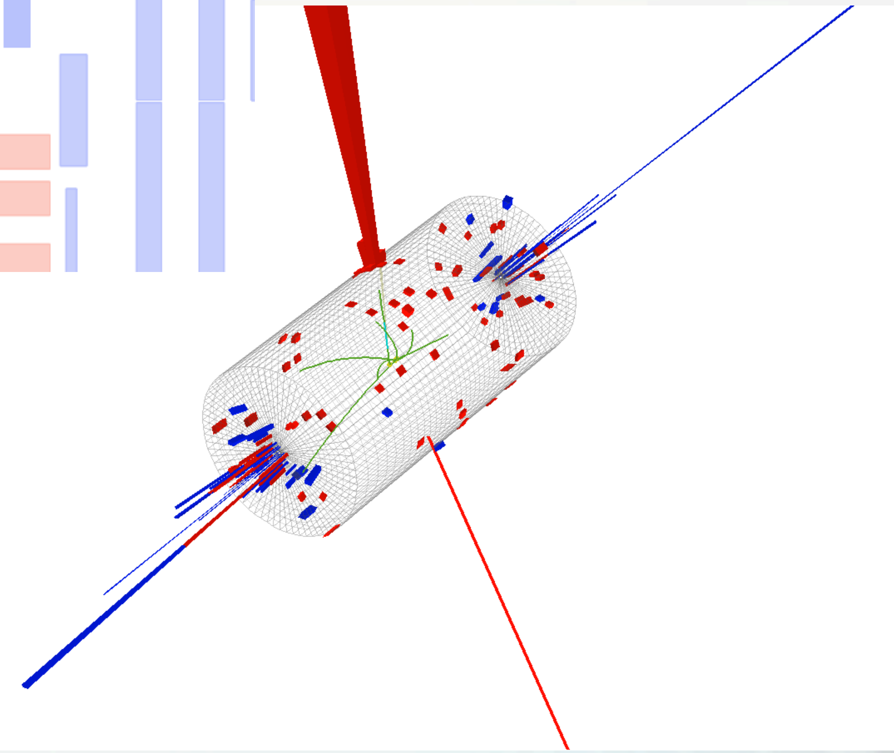




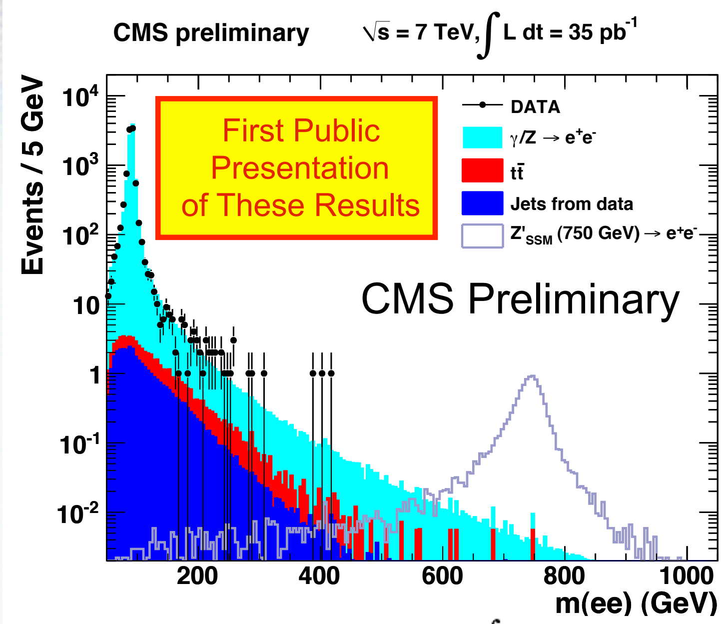
Highest M_T Candidate Event

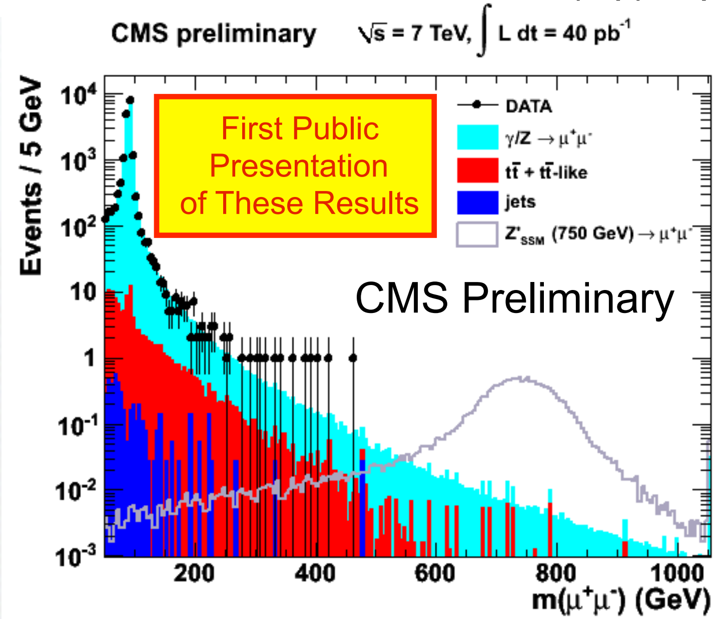


- M_T = 493 GeV candidate event

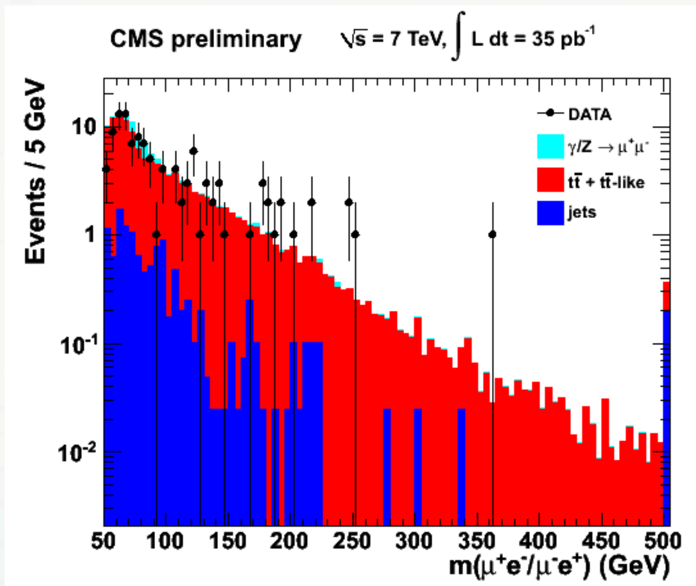


Search for Dilepton Resonances

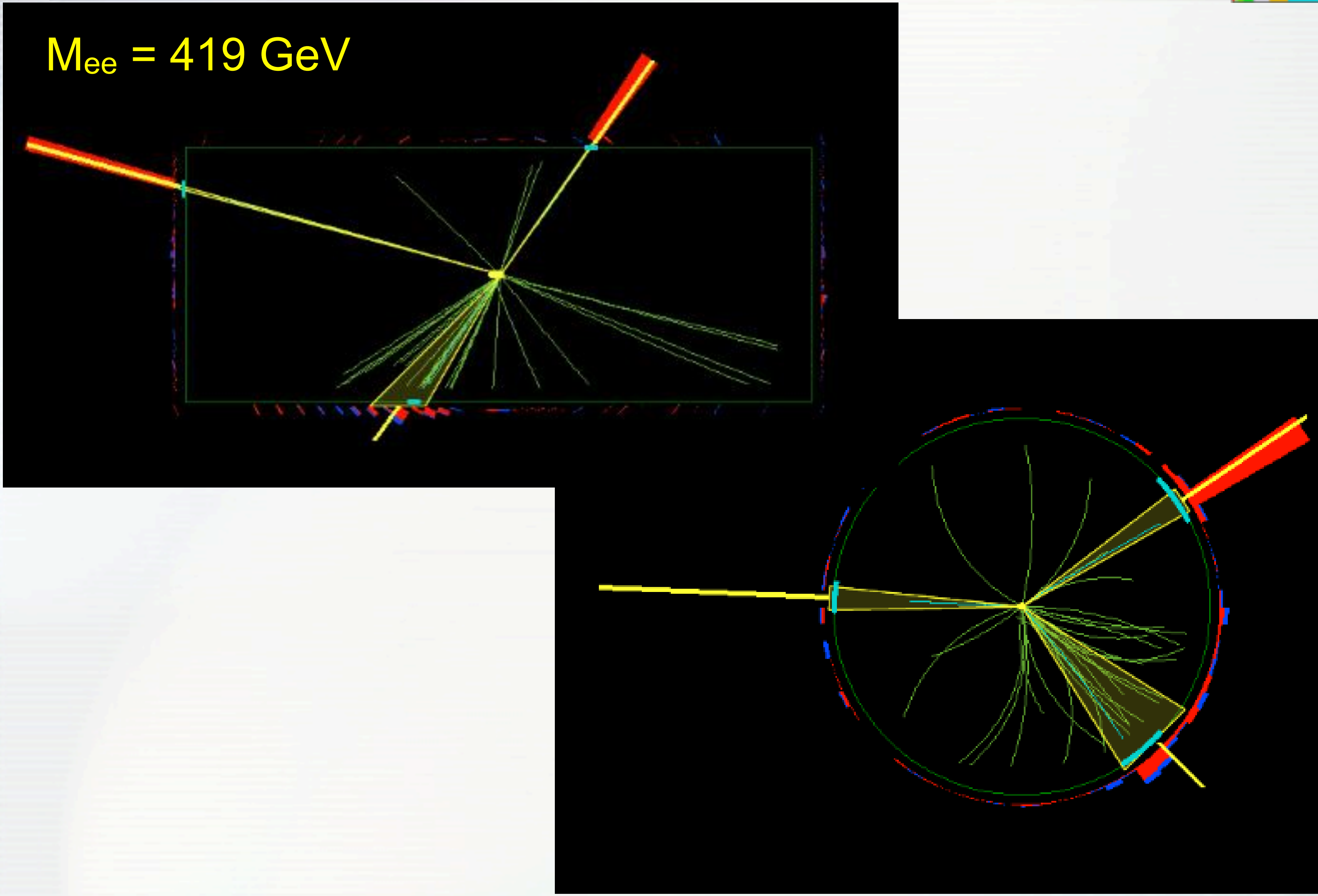




- Coherent ee and $\mu^+\mu^-$ analyses
  - Opposite-sign requirement ensures good momentum determination for dimuons; not needed for ee
- Muon momentum scale checked with cosmics
- DY is the dominant irreducible background
  - Top background from eμ data

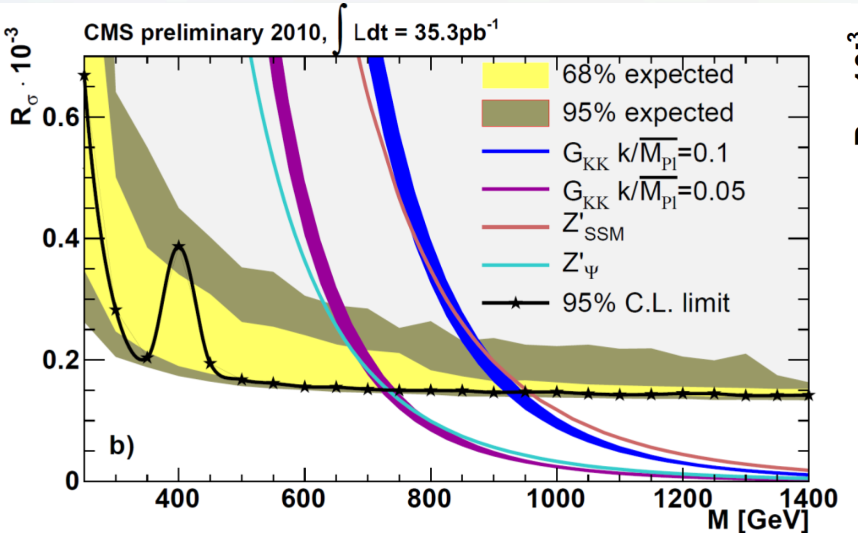


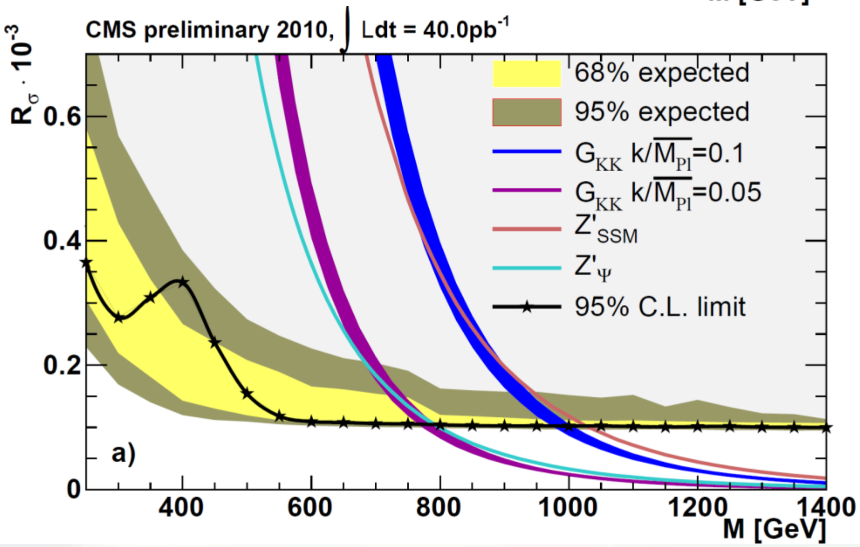
Dielectron Candidate Event

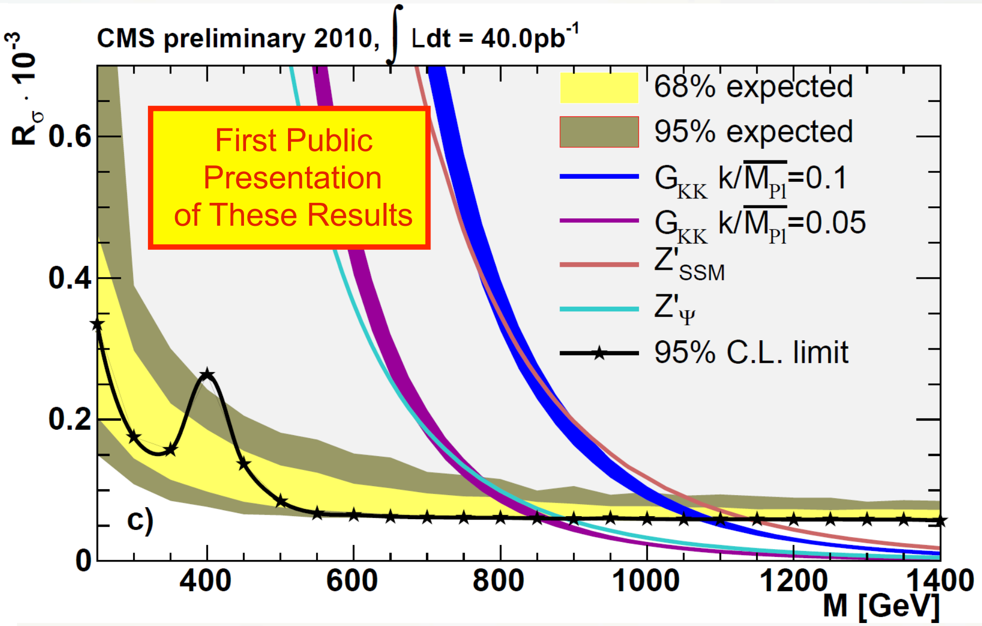


Limits on the Z' and G_{KK}

- Combined limits exceed the Tevatron reach: G_{KK}, k/M_{Pl} =0.1: 1050 (ee+γγ) & 921 (μμ) GeV; Z'_{SSM}: 1023 (ee) & 1030 GeV (μμ)







Channel	μμ	ee	Combined
Z_{SSM}	1027 GeV	958 GeV	1140 GeV
Z_{ψ}	792 GeV	731 GeV	887 GeV
G_{KK}, k/M_{Pl} = 0.05	778 GeV	729 GeV	855 GeV
G_{KK}, k/M_{Pl} = 0.10	987 GeV	931 GeV	1079 GeV

Searches for Long-Lived Particles

Search for Long-Lived Particles

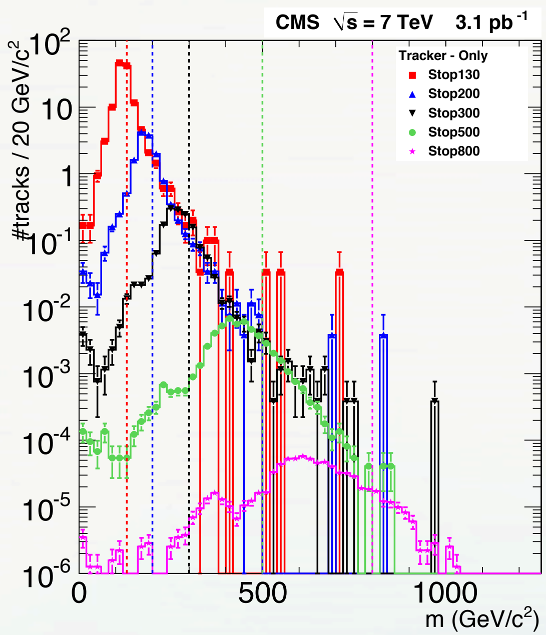
- Predicted in many extensions of the SM: SUSY, hidden valley, etc.
- Two type of searches pursued with 2010 data:
  - Massive charged long-lived particles leaving highly ionizing tracks in the tracker (and the muon system)
  - Long-lived strongly interacting particles stopping in the detector and decaying out-of-time with the collisions
- Excellent dE/dx resolution of the CMS detector as well as the thick calorimeters allow us to pursue these analyses very rapidly
- Complicated LHC beam structure with a number of gaps in the bunch sequence allows for a large coverage in terms of stopped particle lifetime
- Complementarity between these two searches: only slow particles ($\beta \lesssim 0.4$) stop in the detector; for those the efficiency of the dE/dx search is too low due to the minimum track p_T requirement

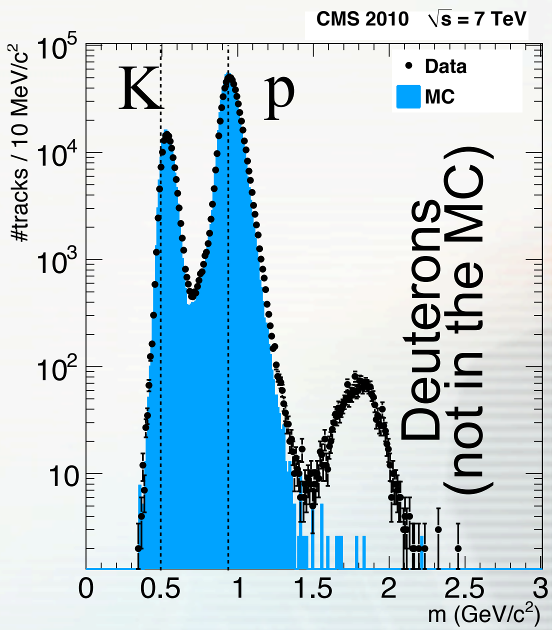
Heavy Stable Charged Particles

- Two types of analyses:
  - Tracker + Muon (μ+Tr): easy to trigger and low background, but requires HSCP to be sufficiently long-lived and hadronize into a charged R-hadron with high enough probability
  - Tracker-only (Tr): sensitive to the charge suppression scenario, where R-hadrons become neutral after traversing enough material; ideal for stau (but not enough sensitivity yet)
- Mass estimated from dE/dx and p using approximate Bethe-Bloch formula:

$$I_h = K\frac{m^2}{p^2} + C$$

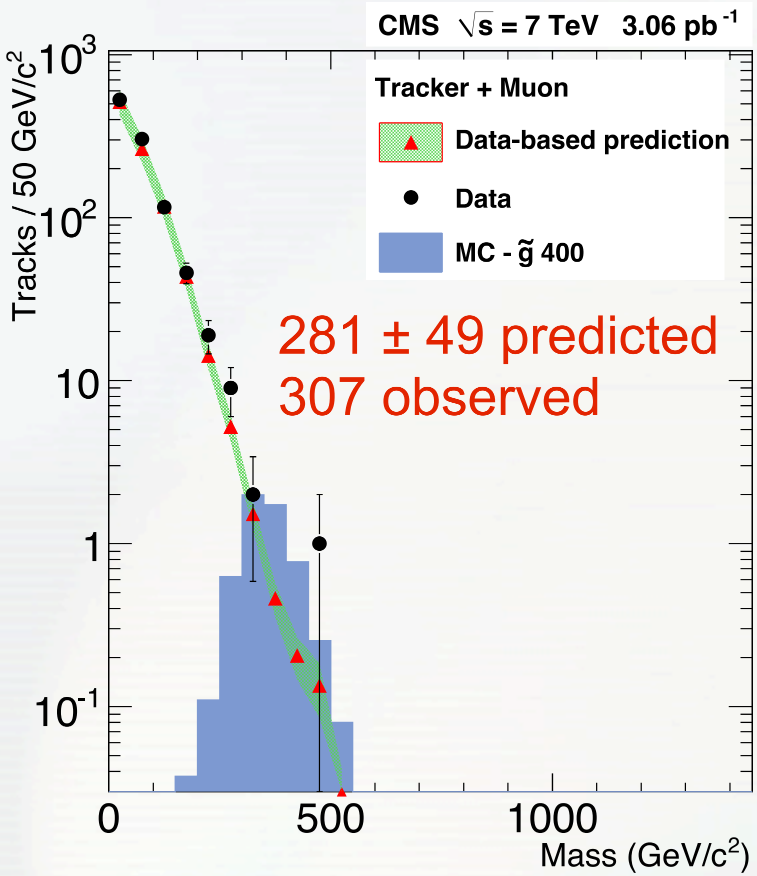
- Constants K and C are determined from proton data:
  - $K = 2.579$ MeV c^2/cm
  - $C = 2.557$ MeV/cm



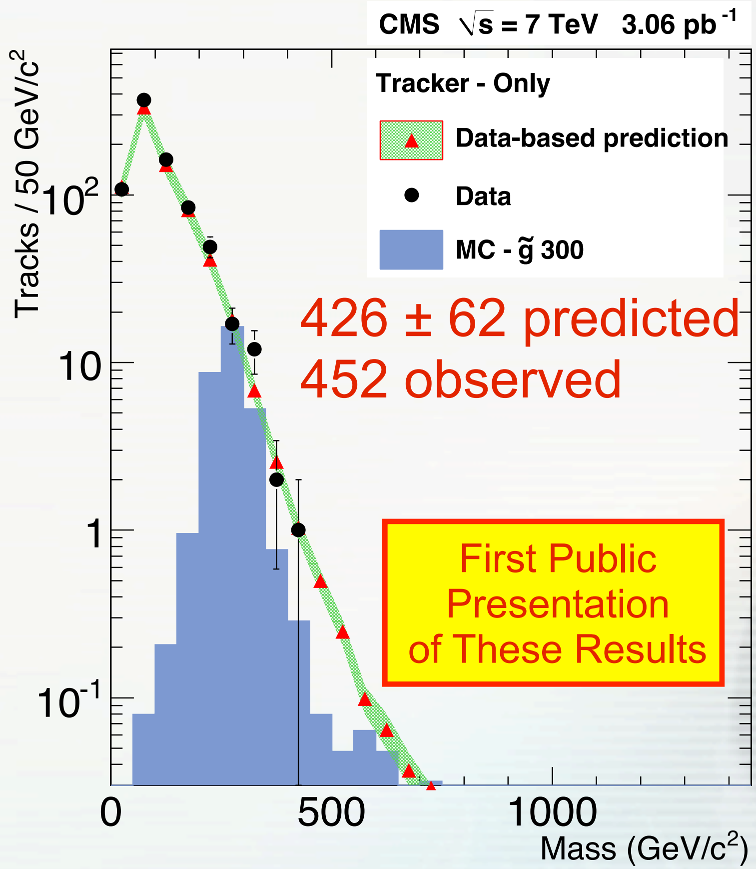


Background Estimation

- Estimate background by exploring independence of the track "mass" on its transverse momentum
- Loose sample with low track p_T and relaxed hit discriminant
  - p_T > 34-36 GeV, μ+Tr and 59-62 GeV, Tr-only
- Good agreement in a "loose" sample; proceed with the tight one



arXiv:1101.1645, submitted to JHEP



Limits on Gluinos and Stops

- Tight sample is picked to have very low background (discovery optimization), optimal for low-statistics dataset
  - B = 0.025 ± 0.004 (0.074 ± 0.011) events for μ+Tr (Tr-only)
- Use tracker-only analysis for the charge suppression scenario (R-hadron emerges as a neutral object); μ+Tr for the other ones
- Set limits on the gluino mass of 357-398 GeV for the fraction f of gg hadronization between 0.5 and 0.1 (μ+Tr)
  - In the charge suppression scenario, the limit is 311 GeV (for f = 0.1)
  - These are the most restrictive limits to date
- The analogous stop limit is 202 GeV - still a bit below the Tevatron's 249 GeV limit

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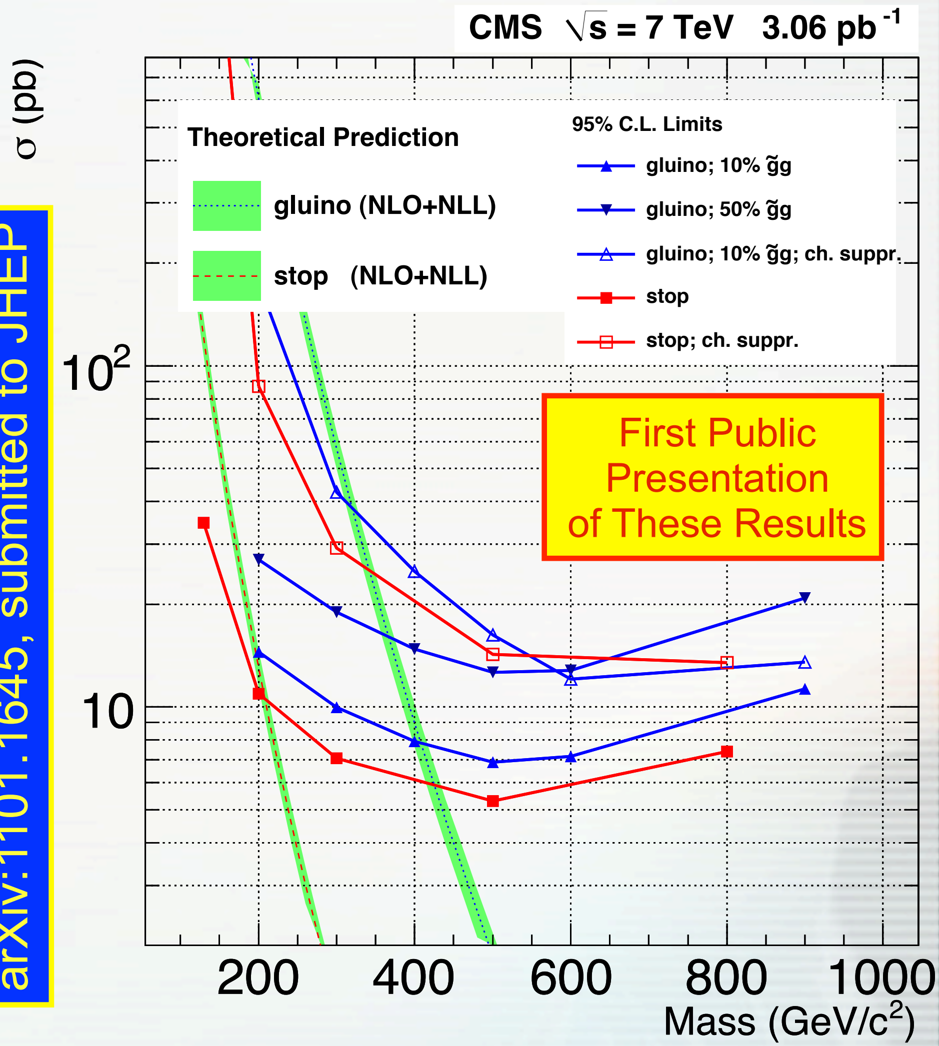
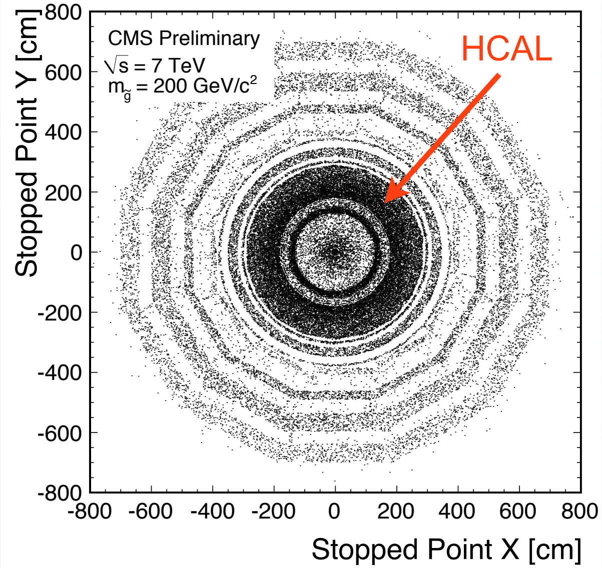


Search for Stopped Gluinos

- Sensitive to slow-moving ($\beta < 0.4$) long-lived particles that hadronize and then stop in the dense material of the CMS detector
- Once stopped, they can decay microseconds, seconds, or days later, potentially giving a spectacular signal when there is no beam passing through CMS
- Designed and commissioned special no-beam trigger using BPTX in anti-coincidence
- Routinely run after the end of the fill to get sensitivity to long lifetimes
- Main background from cosmic rays, beam halo, and HCAL noise

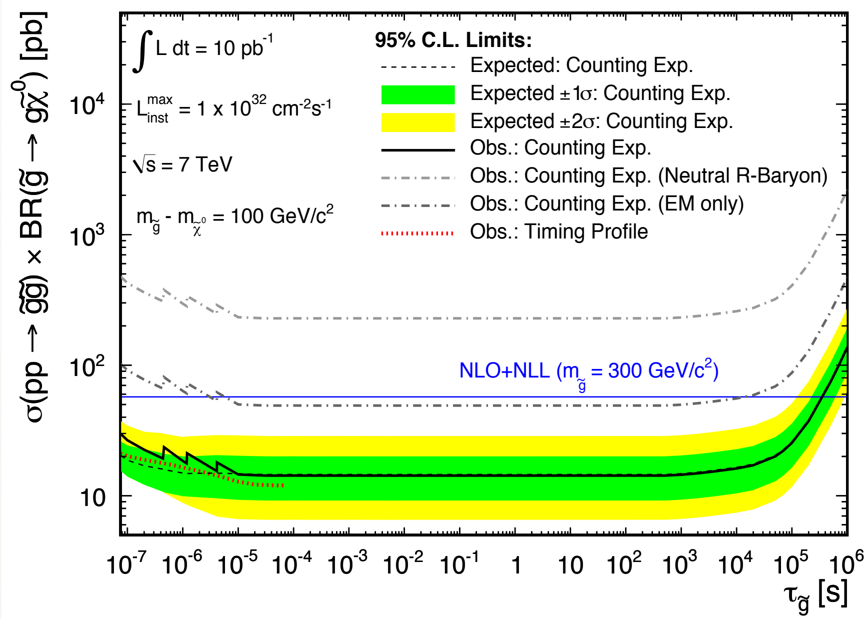


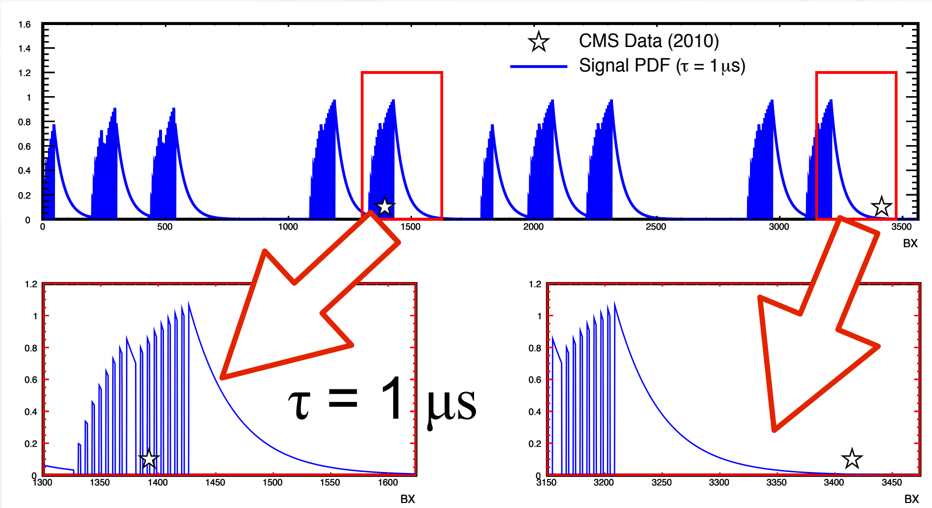
Search based on ~10 pb^{-1} of data corresponding to an instantaneous luminosity up to 10^{31} $cm^{-2}s^{-1}$

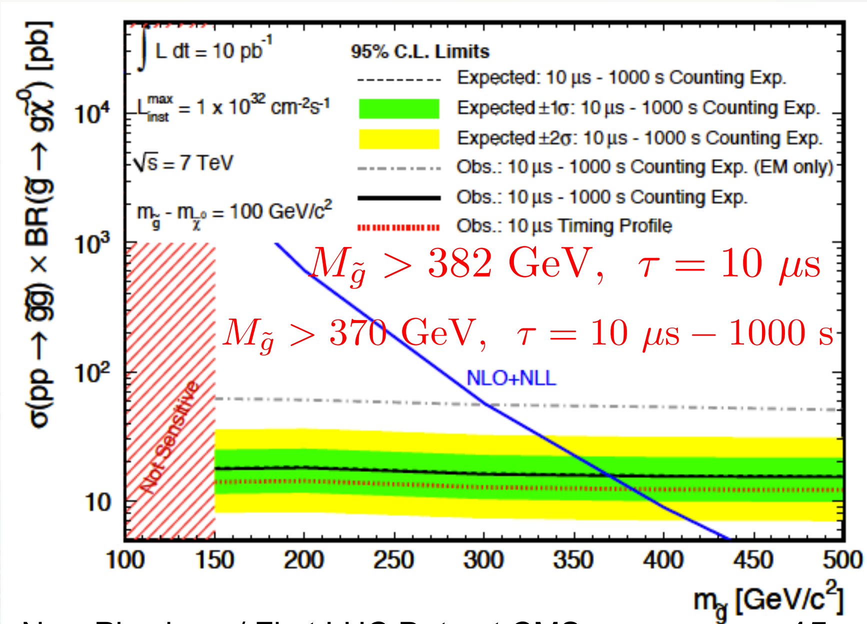
Search for Stopped Gluinos

- Search optimized separately for various lifetimes; spans many orders of magnitude in τ
- Set most stringent limits to date both on mass and lifetime

Lifetime [s]	Expected Background (± stat. ± syst.)	Observed
1×10^{-7}	$0.8 \pm 0.2 \pm 0.2$	2
1×10^{-6}	$1.9 \pm 0.4 \pm 0.5$	3
1×10^{-5}	$4.9 \pm 1.0 \pm 1.3$	5
1×10^{6}	$4.9 \pm 1.0 \pm 1.3$	5





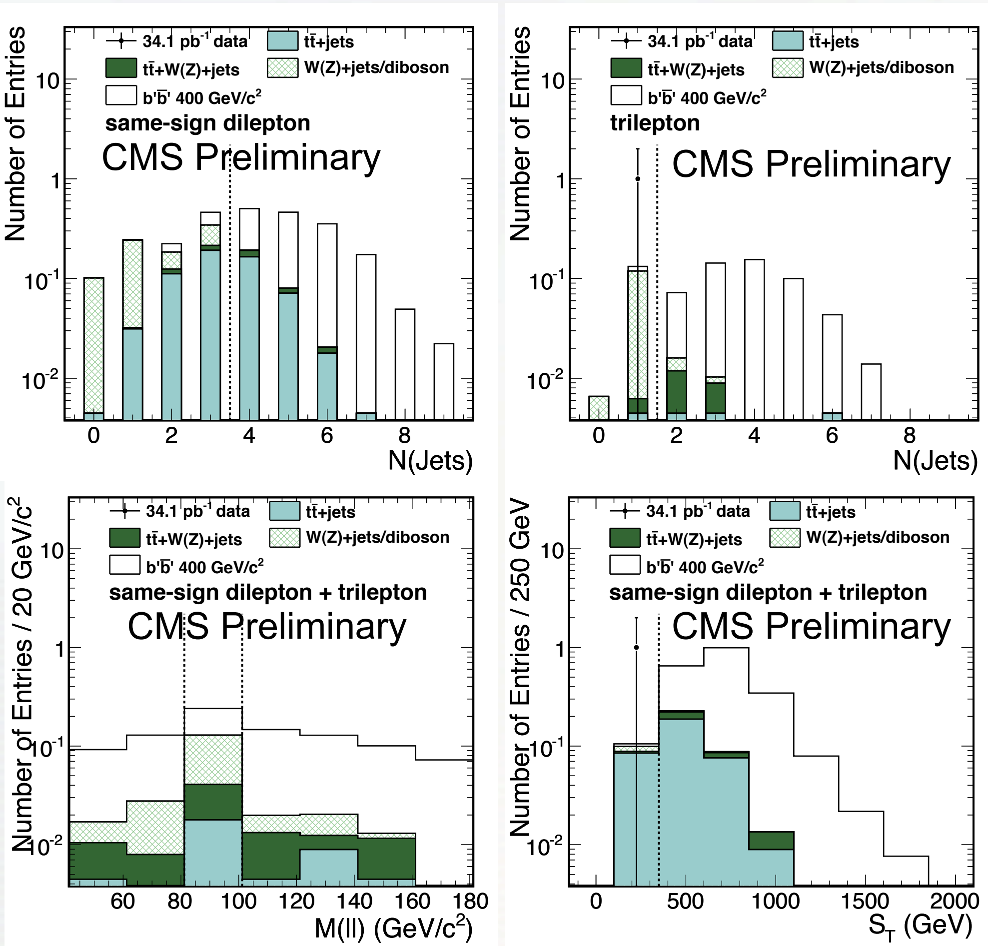


Phys. Rev. Lett. **106**, 011801 (2011)

Search for the Fourth Generation

Search for b'

- Renewed interest to fourth generation searches
- Look for heavy, pair-produced b′ → tW → WWb in low-background like-sign dilepton and trilepton channels with jets

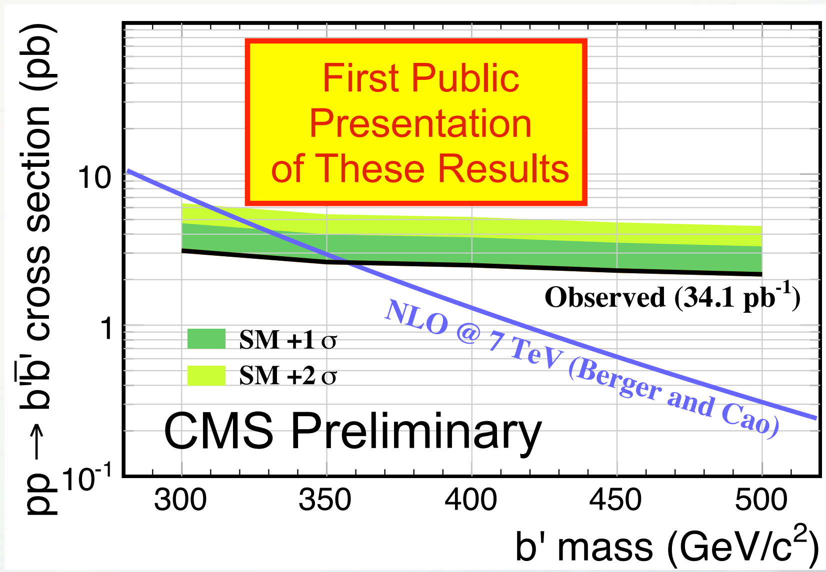


$N_B = 0.32 \pm 0.21$ (tt+jets)

Zero events observed

M(b′) > 357 GeV @ 95% CL

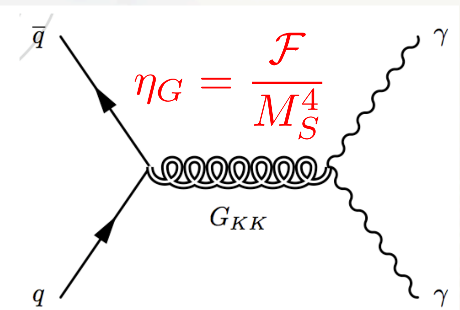
Exceeds CDF limit of 338 GeV



Search for Large Extra Dimensions

Search for Virtual Graviton Effects

- Probe models with Large Extra Dimensions (ADD) where gravity alone is allowed to propagate
  - Offers a solution to the hierarchy problem by "lowering" and apparent Planck scale $M_{Pl} \sim 10^{16}$ TeV to $M_D \sim 1$ TeV
- Non-resonant enhancement of DY and diphoton cross section due to virtual graviton exchange
- The sum over the Kaluza-Klein modes is divergent; introduce a UV cutoff $M_S \sim M_D$: $\sigma_{\rm ADD} = \sigma_{\rm SM} + A\eta_G\, \sigma_{\rm int} + B\eta_G^2\, \sigma_{\rm ED},$
  - Complementary to, e.g., monojet searches, as probes M_S, not M_D directly



$$\mathcal{F} = 1, \text{ (GRW [6]);}$$

Nucl. Phys. **B544** (1999) 3

$$\mathcal{F} = \begin{cases} \log\left(\frac{M_S^2}{M^2}\right), & n = 2 \\ \frac{2}{n-2}, & n > 2 \end{cases}, \text{ (HLZ [30]);}$$

Phys. Rev. **D59** (1999) 105006

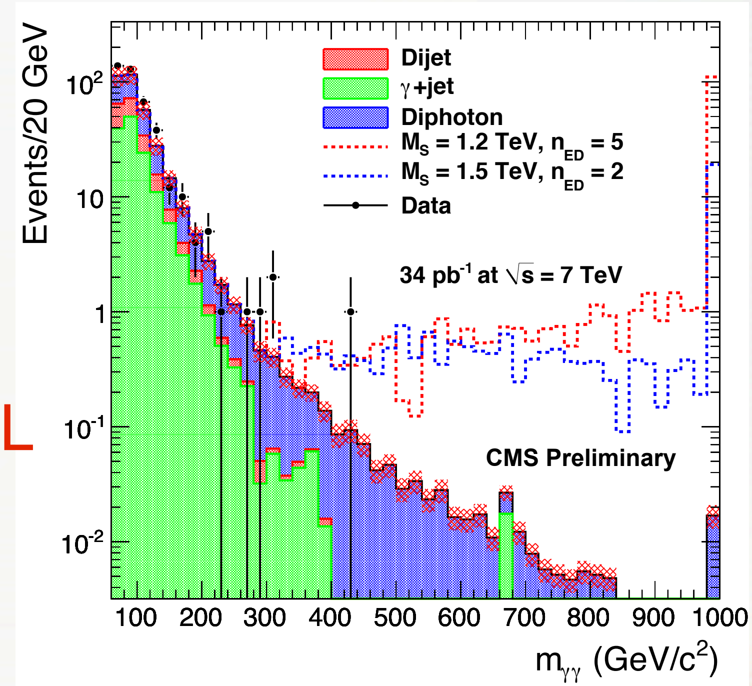
$$\mathcal{F} = \frac{2\lambda}{\pi} = \pm\frac{2}{\pi}, \text{ (Hewett [29]).}$$

Phys. Rev. Lett. **82** (1999) 4765

- Several conventions exist on how to truncate the sum

Diphoton Mass Spectrum & Limits

- Instrumental background from jets determined from data
- Main background at high masses is irreducible diphoton production
  - Assign ~20% systematics due to the K-factor
- Optimized cuts: $M_{\gamma\gamma} > 500$ GeV, $|\eta_\gamma| < 1.442$ (Barrel)
- B = 0.28 ± 0.06, 0 events observed
- σ < 0.118 (0.135 exp.) pb @ 95% CL
- Produce limits with and w/o perturbativity truncation
  - $\sigma(M_{\gamma\gamma} > M_S) = 0$ conservatively
- Limits highlighted in lime are the tightest to date



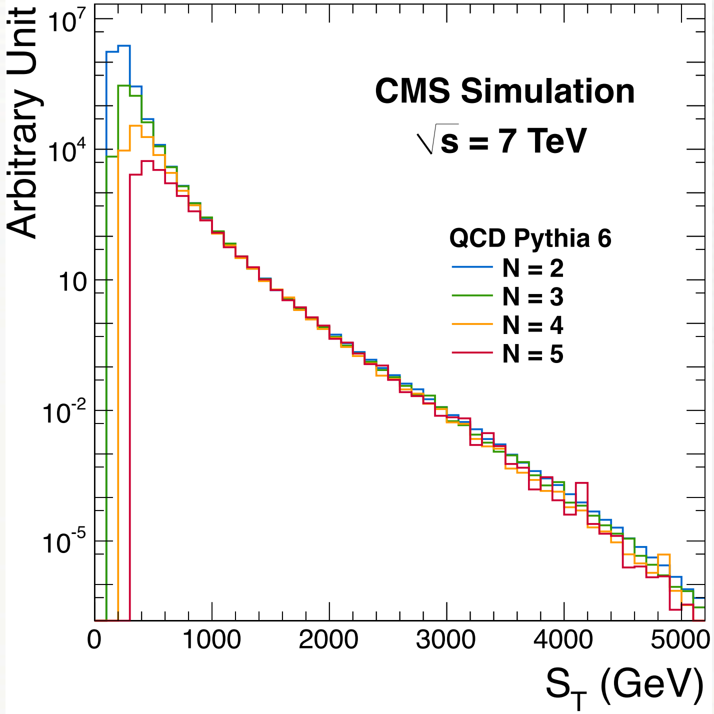
GRW	Hewett		HLZ (limits in TeV)					
	λ > 0	λ < 0	n=2	n=3	n=4	n=5	n=6	n=7
1.93	1.72	1.70	1.88	2.29	1.93	1.74	1.62	1.53
1.82			1.79	2.22	1.82	1.61	1.45	1.29

$M < M_S$

Searches for Black Holes at CMS

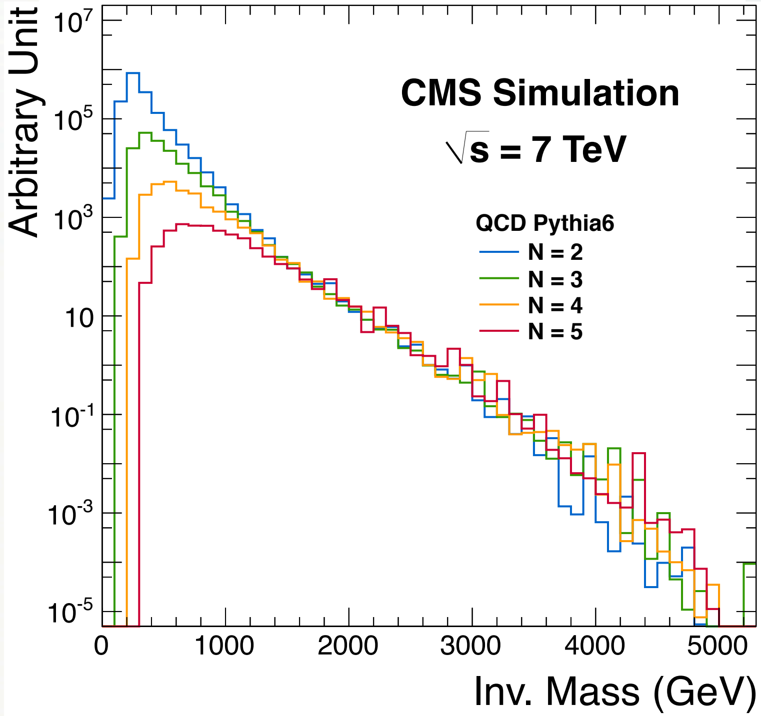
- Ultimate, smoking-gun signature of low-scale quantum gravity ($M_D << M_{Pl}$)
- Gravitational collapse is possible when the two partons from colliding beams pass each other at the distance smaller than approximately the Schwarzschild radius R_S, corresponding to their invariant mass $M = \sqrt{\hat{s}}$
- The cross section is given by the black-disk approximation, $\sigma = \pi R_S^2 \sim TeV^{-2}$ and could be as large as ~100 pb
- Black holes instantaneously decay via Hawking evaporation with an emission of large number of energetic objects, dominated (75%) by quark and gluons, with the rest going into leptons, photons, W/Z, h, etc.
- Generally, graviton emission is suppressed, so expect little MET, but this can be changed in more specific models
- Search largely based on the original papers [Dimopoulos, GL, PRL **87**, 161602 (2001) and Giddings, Thomas, PRD **65**, 050610 (2002)], with a few modifications, as captured by the CHARYBDIS 2 and BlackMax generators ([partial] grey-body factors, spinning Kerr black holes, formation of a stable non-interacting remnant, etc.)
- Caveat: rely on semi-classical approximation, which is expected to be modified for black hole masses less than ~5 x M_D

Search for Black Holes in CMS



- First dedicated collider search
- Based on $S_T = \Sigma E_T$, where the sum is over all the objects with $E_T > 50$ GeV, including ME_T
- Completely data-driven QCD background determination using a novel technique: S_T-invariance of the final state multiplicity
- Empirically found and tested with various MC generators (PYTHIA, ALPGEN) up to high jet multiplicity
- "Easy" to understand after the fact: FSR and ISR splitting does not change the S_T in the event appreciably due to its collinear nature
  - Nevertheless came as an initial surprise to all the theorists we mentioned it to!
  - Note that one naively would expect such scaling for the invariant mass, which is simply the sum of total energy in the detector
    - Does work as well: object minimum E_T thresholds, pile-up!

Search for Black Holes in CMS



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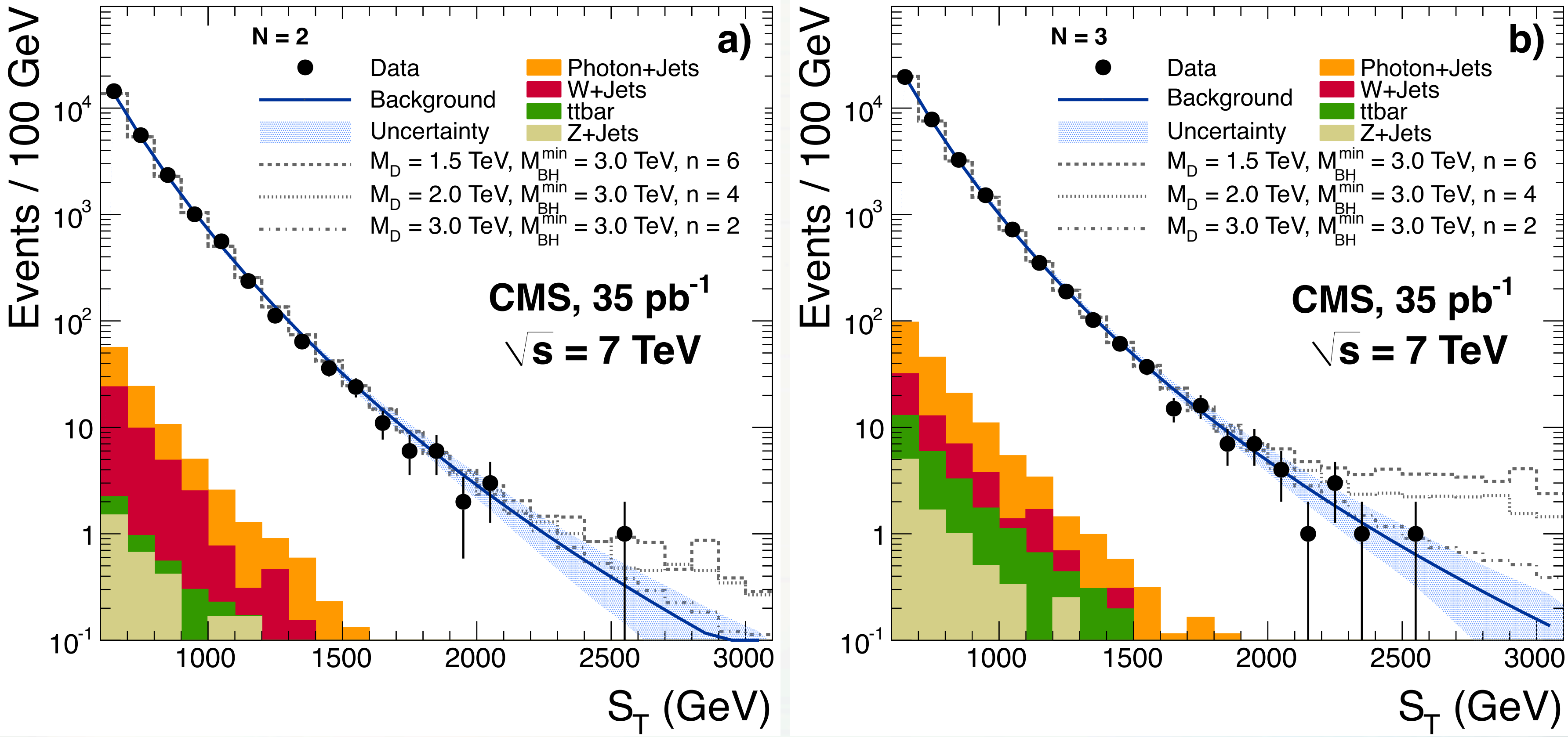
QCD Background Prediction

- Established the empirical scaling with the data, using exclusive N = 2 and 3 multiplicities
- Assign shape uncertainty due to fit parameter variation and template function choice

arXiv:1012.3375, submitted to PLB



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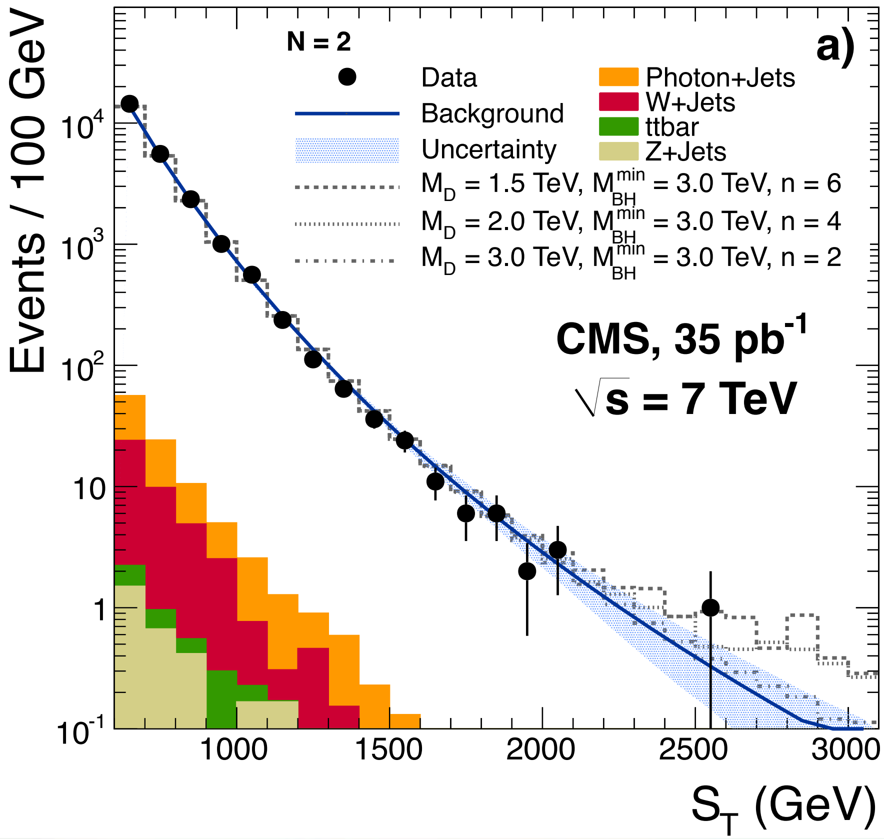
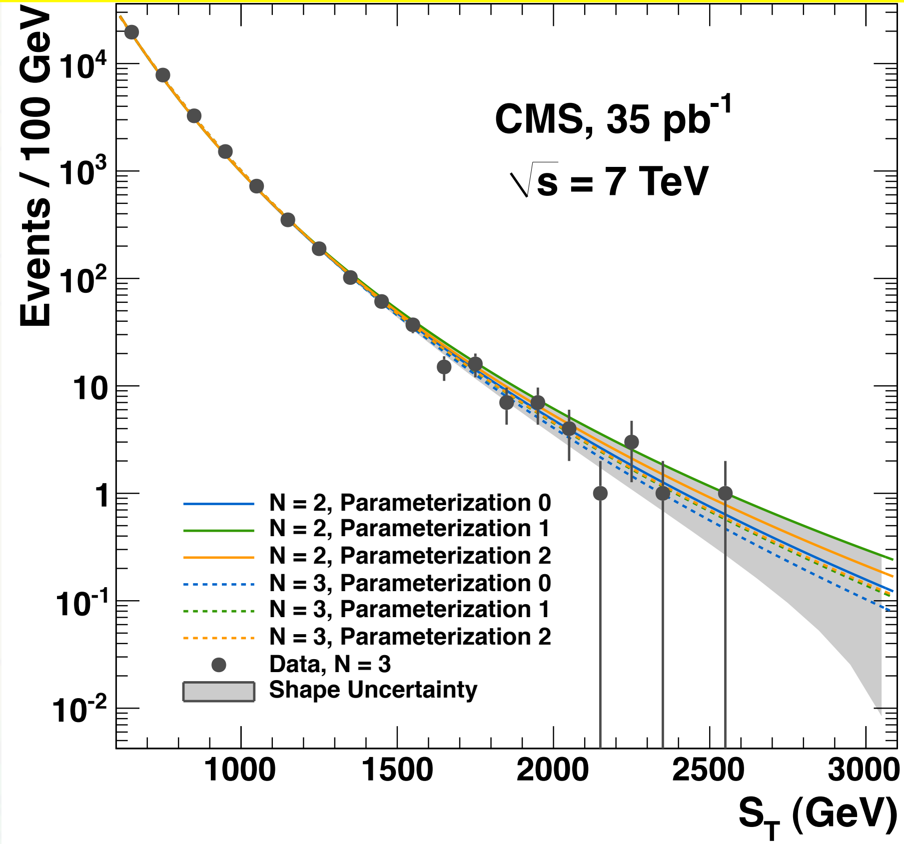
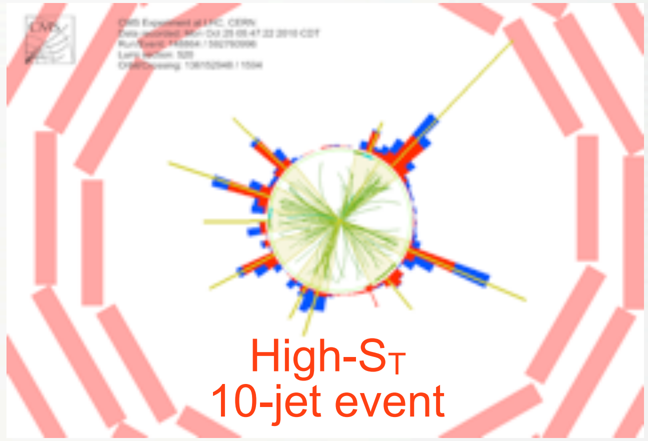




Limits on Black Holes

- Used the N=2 shape with its uncertainties, to fit higher multiplicities, where the signal is expected to be most prominent
- Given no excess, set limits on the minimum BH mass of 3.5-4.5 TeV in semi-classical approximation
- First direct limits at colliders



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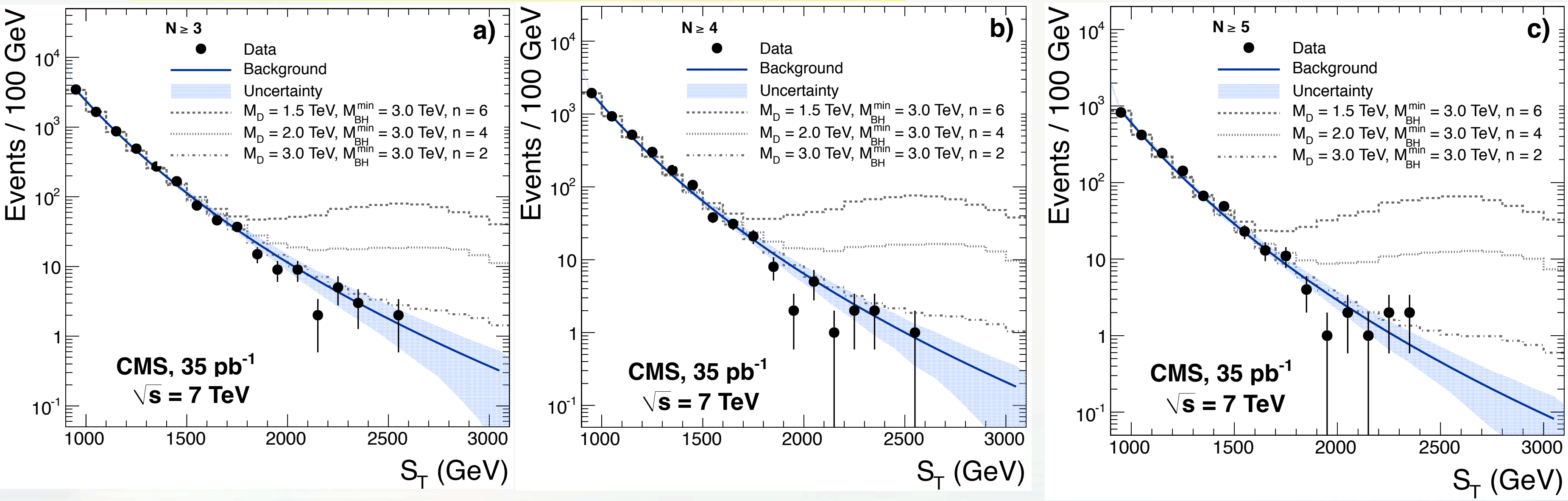

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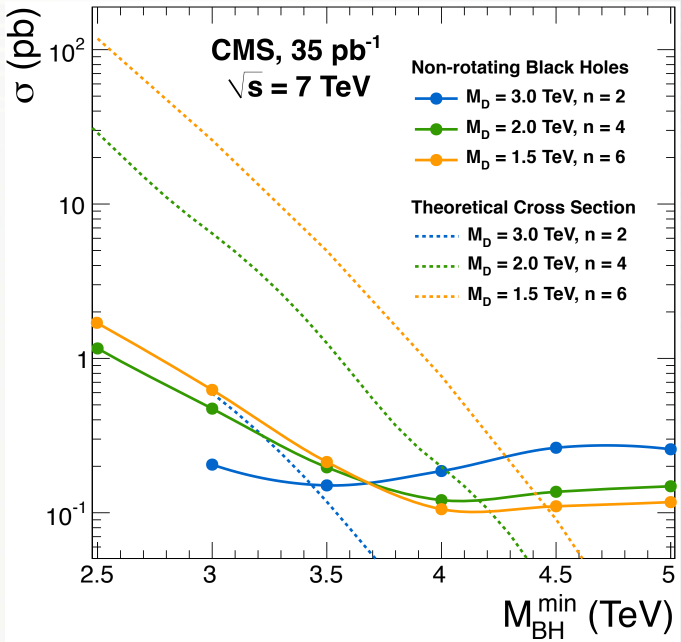

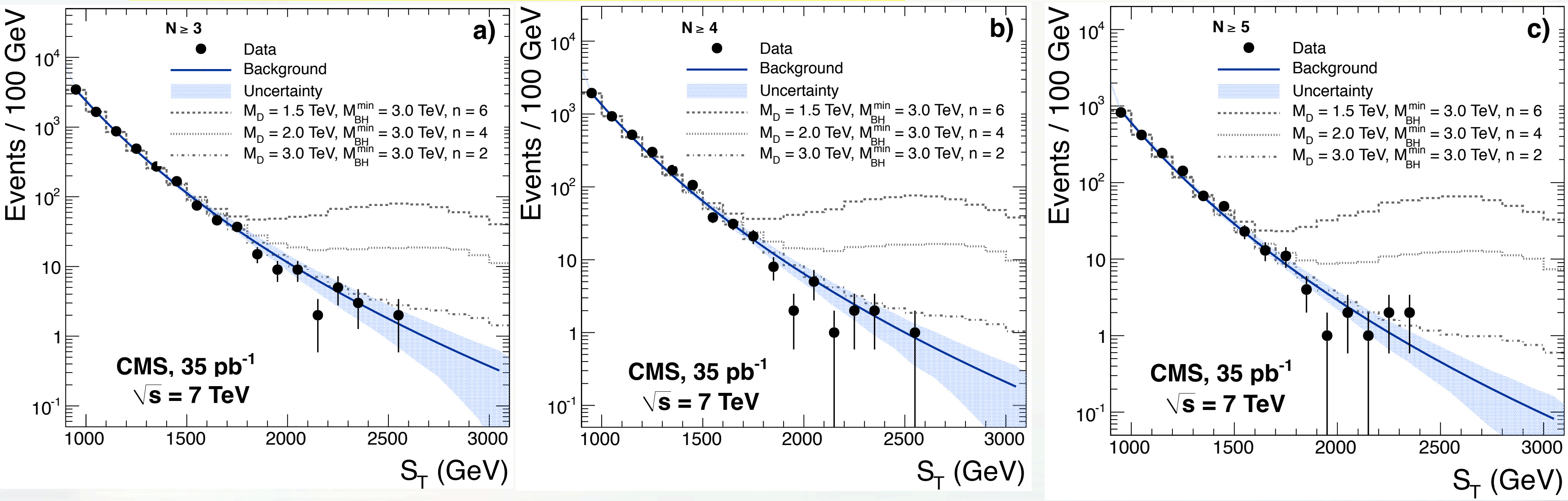

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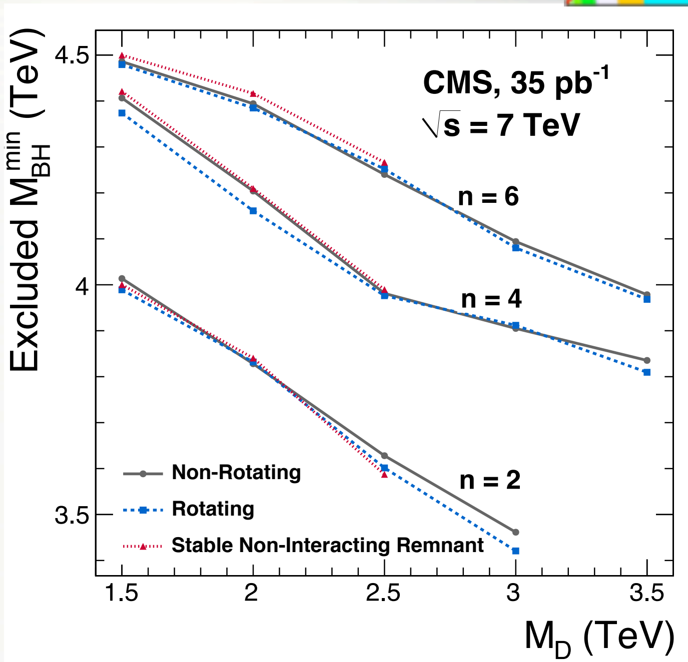

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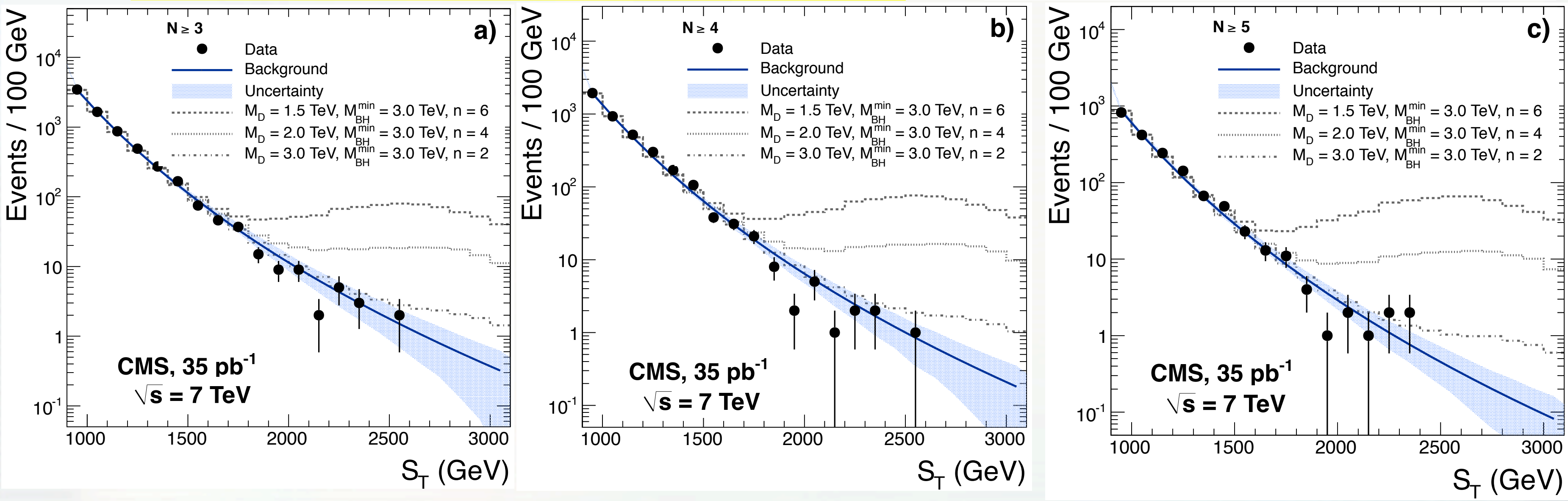

Model-Independent Limits

- Can also set generic model-independent limits on new physics decaying to high-mass, high-multiplicity final states, with $S_T > S_T^{min}$
- These limits, as a function of S_T^{min} are in a 0.1-1 pb range and can be used to probe more generic black hole models, including trapped surface losses, bulk radiation, etc.
- They are also useful for other models of new physics, e.g. heavy resonances decaying into multijet states

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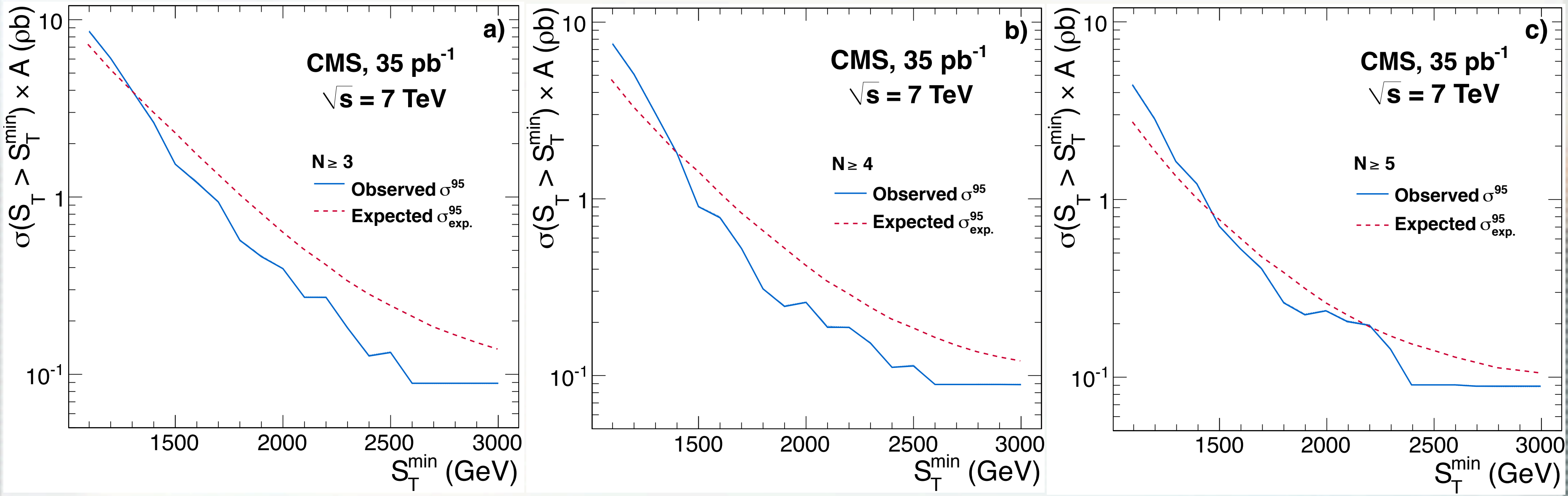
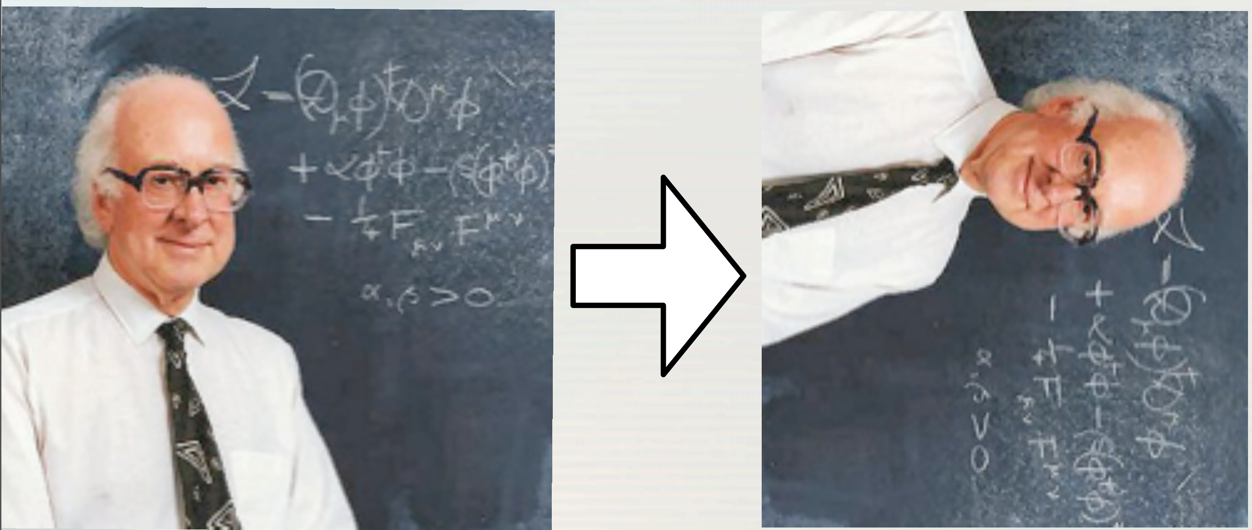
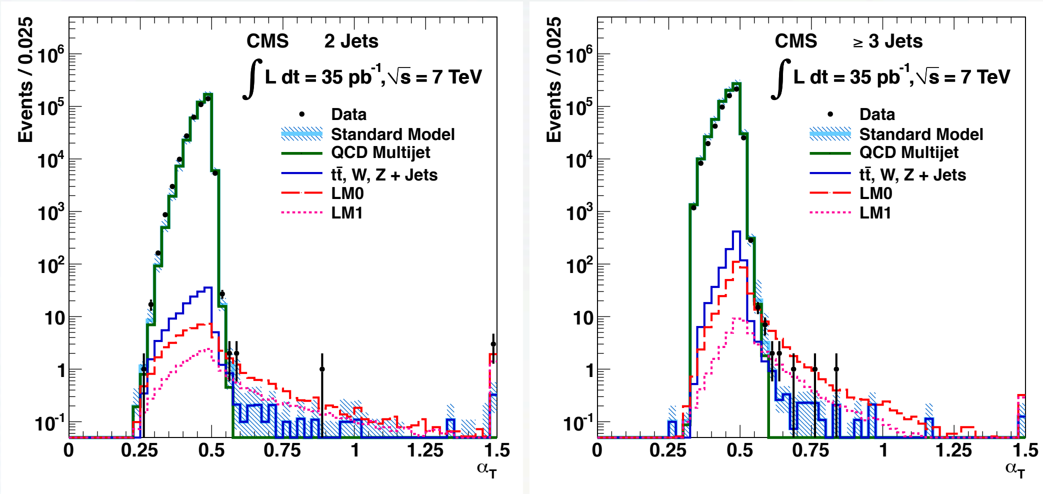


Toward SUSY and Higgs



First SUSY Limits from the LHC

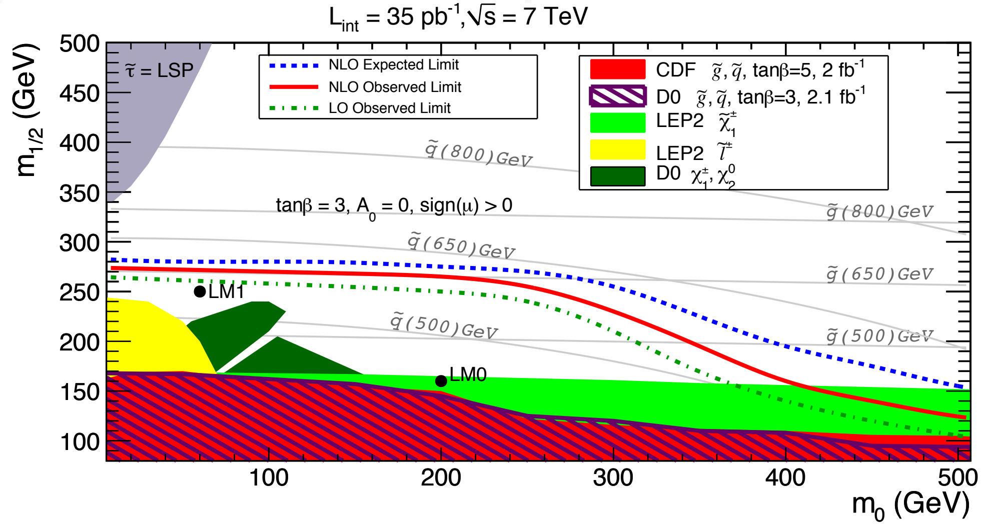
- The jet-only search using α_T variable, with little reliance on ME_T
- Already extended the Tevatron limits significantly
- Plan a separate EP/PP/LPCC seminar on SUSY & Higgs later this year



$$\alpha_T = \frac{1}{2}\frac{H_T - \Delta H_T}{\sqrt{H_T^2 - (MHT)^2}}.$$

$$H_T = \sum_{\text{jets } j} p_{Tj}$$

$$\Delta H_T = p_{T\text{pseudojet }1} - p_{T\text{pseudojet }2}$$



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- Some dozen new results on searches; many more to follow
- Exciting discoveries can happen as early as this year, and by the end of the next year a lot of still uncharted territory will be mapped
- This is just the beginning: the LHC will deliver beautiful physics for the entire decade and we are here to catch it!

The Future is Bright!

Thank You!

The Future is Bright!