Physics Reach of LHC with 1 fb^{-1} at 7 TeV

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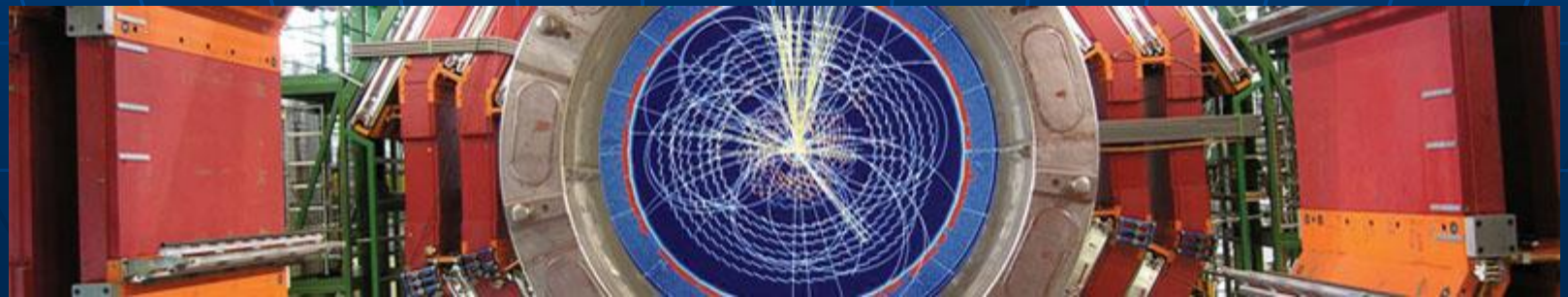
On behalf of the ATLAS and CMS Collaborations

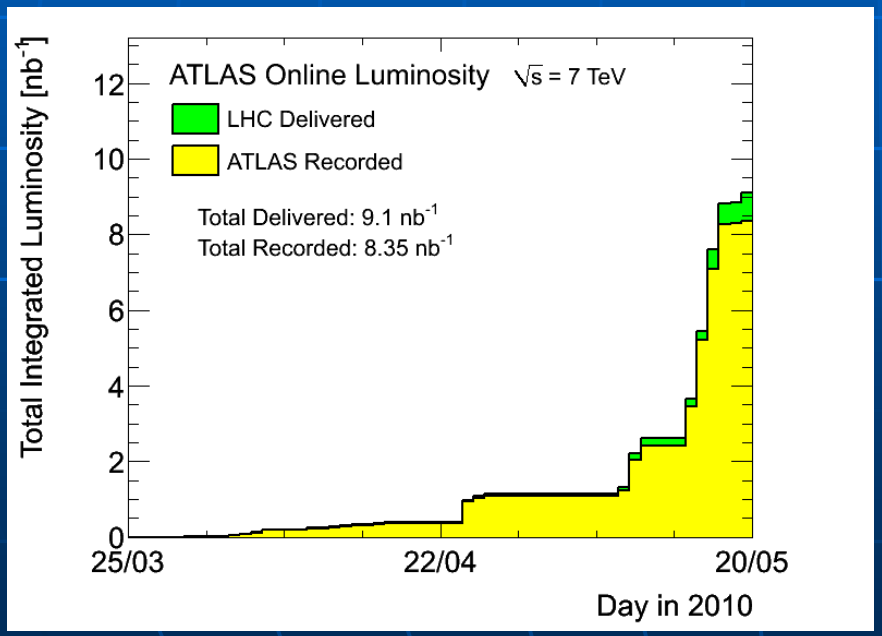


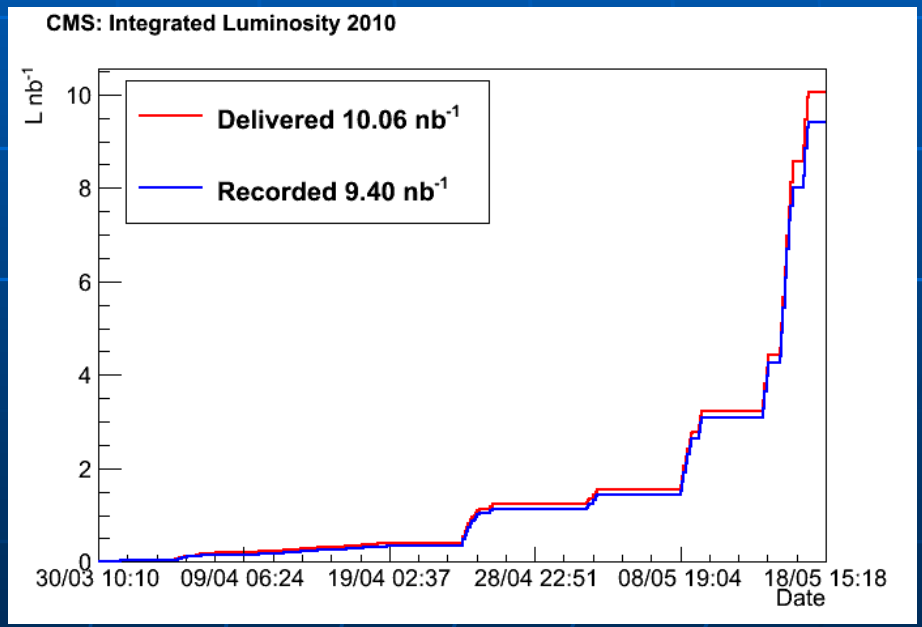
Outline

- Introduction
- Standard Model
  - Physics analysis with early data
- Higgs
  - Higgs expectation at 7 TeV with 1 fb^{-1}
- Beyond the Standard Model (BSM)
  - BSM expectation at 7 TeV with 1 fb^{-1}

LHC at 7 TeV

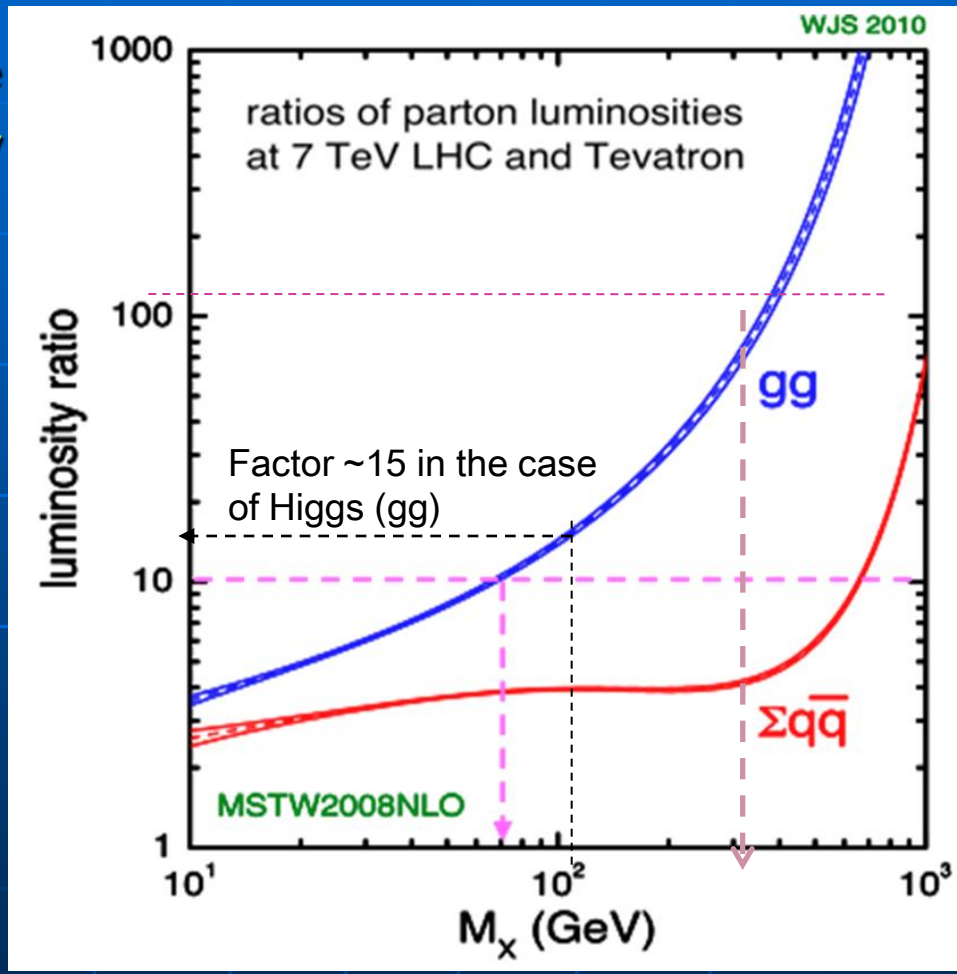
- LHC will run at 7 TeV with the goal to reach an instantaneous luminosity of 1.2×10^{32} during 2010 and 2011
  - Collect up to 1 fb^{-1} data before the end of 2011





7 TeV at LHC vs. Tevatron

- Gain a factor 10 or more
  - LHC can reach same sensitivity with the factor of 10 or less integrated luminosity than Tevatron approximately
- Examples
  - Higgs (gg): pp → H, H→WW and ZZ
    - Factor ~15
  - Top: (85% $q\bar{q}$, 15% gg at Tevatron)
    - Factor: 0.85 x 5 + 0.15 x 100
    - → ~ 20
  - Squarks: ~350 GeV (assume top):
    - Factor: 0.85 x 10 + 0.15 x 1000
    - ~ 150 to 200
  - Z': ~1 TeV ($q\bar{q}$)
    - Factor: ~ 50 to 100
- We will show plots for √s = 7 TeV
  - But some plots are for √s = 10 TeV or 14 TeV

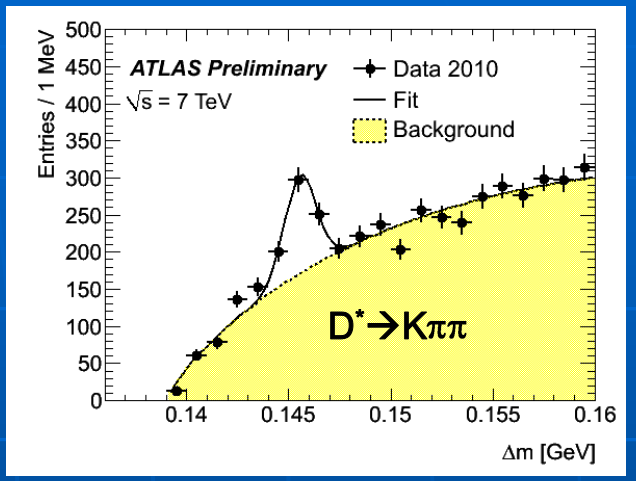


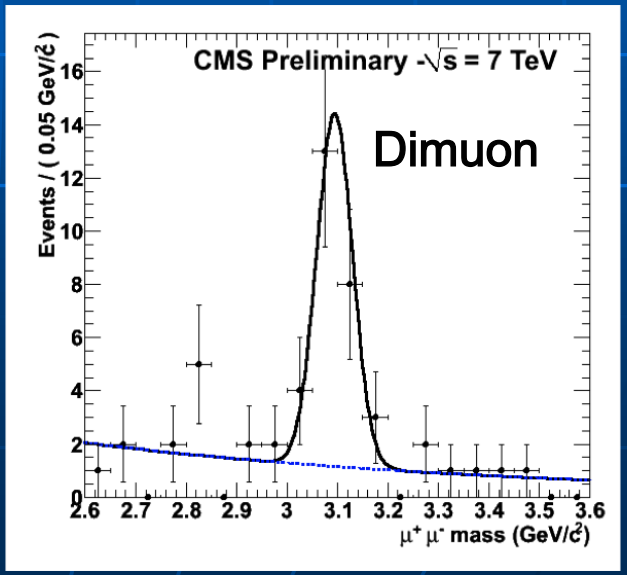
Standard Model

- Physics analysis with early data
- Heavy Flavor
- W and Z
- Top

Heavy Flavor Measurement

- We can understand our detector with small amount of early data
- Early heavy-flavor physics measurements at 7 TeV
  - Tracking performance study using low mass resonances
  - $J/\psi \rightarrow \mu^+\mu^-$ cross-section
    - Clean observation possible with only 1 nb^{-1} of data
    - $\sim 10^8$ / fb^{-1} at 7 TeV
  - $\Upsilon \rightarrow \mu^+\mu^-$ cross-section
    - We expect ~10K / pb^{-1} in $\Upsilon(1S)+\Upsilon(2S)+\Upsilon(3S) \rightarrow \mu^+\mu^-$
    - $\sim 10^7$ / fb^{-1} at 7 TeV
  - $b\bar{b}$ cross-section
    - MC simulation indicates feasibility with 5-10 pb^{-1} (~150 events/pb^{-1})

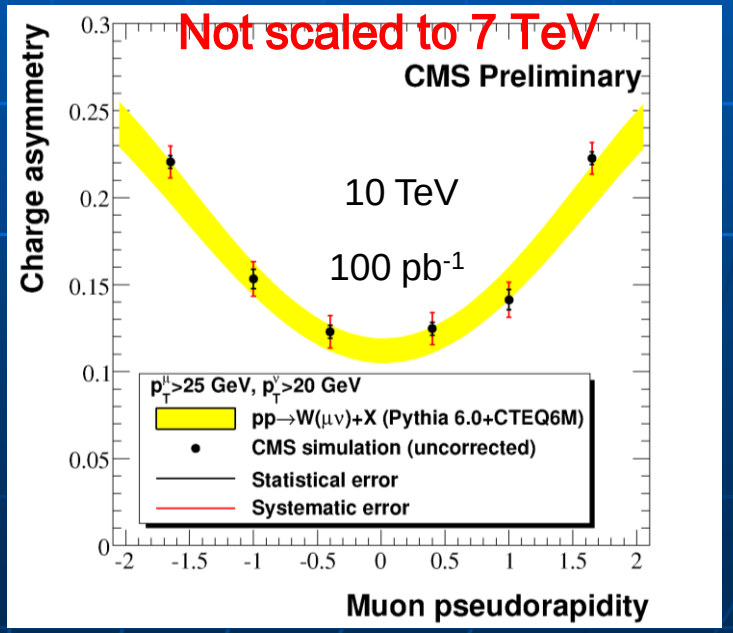




W and Z

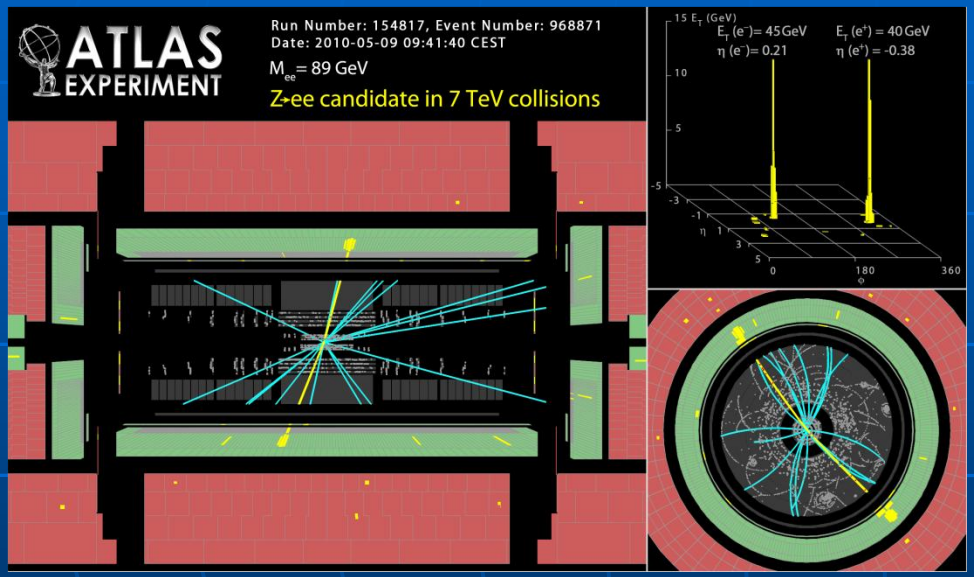
- W / Z cross section
  - ATLAS and CMS expect ~25,000 Z→ll (e,μ) and ~250,000 W→lν (e,μ) per 100 pb^{-1} individually.
  - Very important for physics calibration with early data
- W asymmetry
  - At 7 TeV, we need ~150 pb^{-1} to get the same W yield as 100 pb^{-1} at 10 TeV
  - With this statistics, the total error is comparable to the PDF uncertainty

W	ATLAS 1 fb^{-1}	CMS 1 fb^{-1}
Stat.	0.04%	0.04%
Sys.	2.4%	3.3%
Z	ATLAS 1 fb^{-1}	CMS 1 fb^{-1}
Stat.	0.2%	0.13%
Sys.	1.3%	2.3%



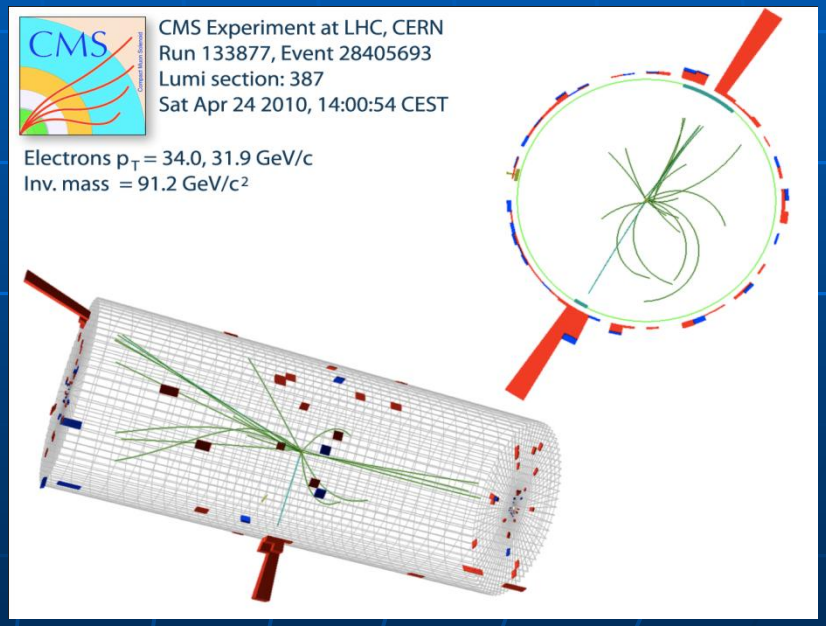
W and Z – First Data

- ATLAS



Z → ee candidate

- CMS
  - Data observed: 6 Ws and 1 Z with 1 nb^{-1}
  - MC expectation: 8 Ws and 0.8 Z



Top Perspectives at 7 TeV

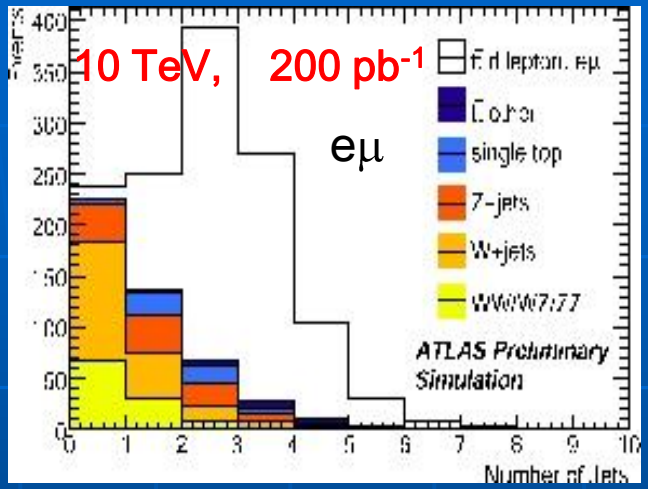
- Signatures of top pair signal will come fast
- By the end of 2010, the LHC experiments expect to collect samples comparable to the Tevatron experiments

	CDF	LHC at 7 TeV	Ratio
σ_{ttbar} (NLO)	5.5 pb	160 pb	× 30
Luminosity for evidence	20 pb^{-1}	1 pb^{-1}	1 / 20
Main background W + ≥3 jets	6.5 pb	240 pb	× 37

~160 k $t\bar{t}$ pairs are expected with 1 fb^{-1}

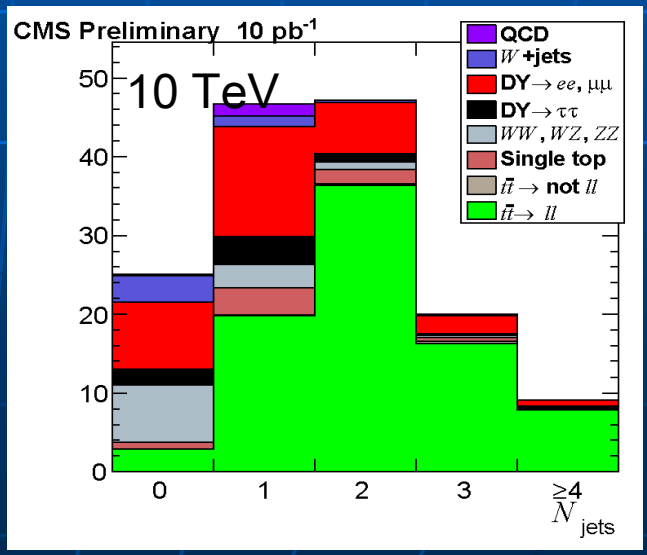
Top: dilepton channel

- Signature: 2 leptons + 2 jets + MET
  - 9% branching fraction
  - Clean signal
  - Most likely 1st channel to be observed
- With ~10 pb^{-1}, we expect a convincing signal
  - Each experiment will have ~30 events with an expected background of 5 or 6.



ATL-PHYS-PUB-2009-086
(Scaled to 7 TeV)

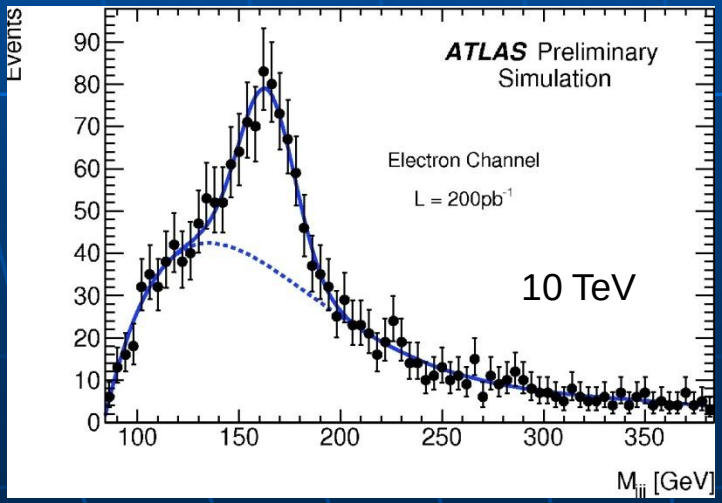
Channel	N (Sig)	N (Bkg)
$e-\mu$	14	2.5
$e-e$	4.3	1.1
$\mu-\mu$	6.6	1.9
Total	**25**	**5.5**

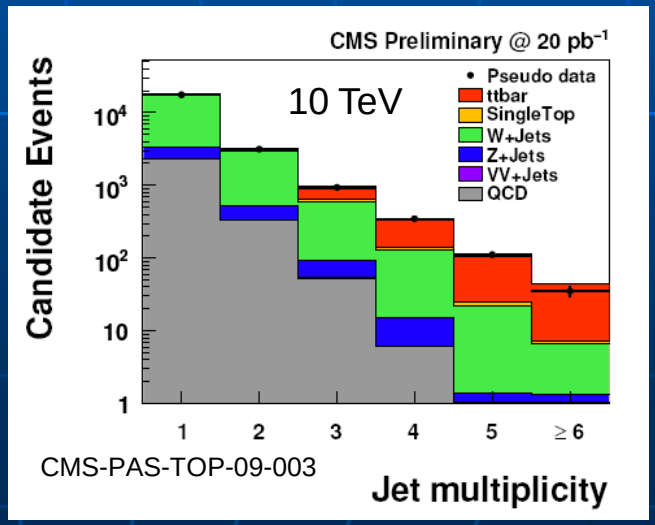


- With 100 pb^{-1}, ~400 events

Top: lepton+jets channel

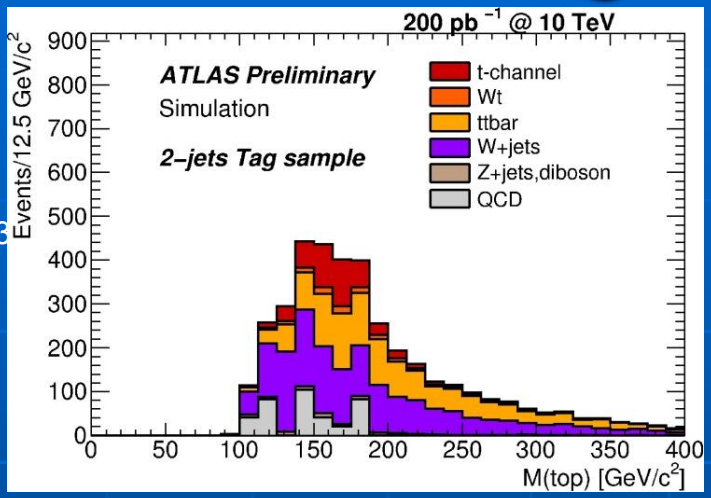
- Signature: one lepton + 4 jets
  - 45% branching fraction
  - More statistics than dilepton channel
- At 7 TeV with 10 pb^{-1}, we expect ~60 top events per lepton flavour over a background of ~40 events in the 4 jet, 5 jet and 6+ jet bins per experiment
- ~1400 events per 100 pb^{-1}
  - With large variations depending on selection requirements

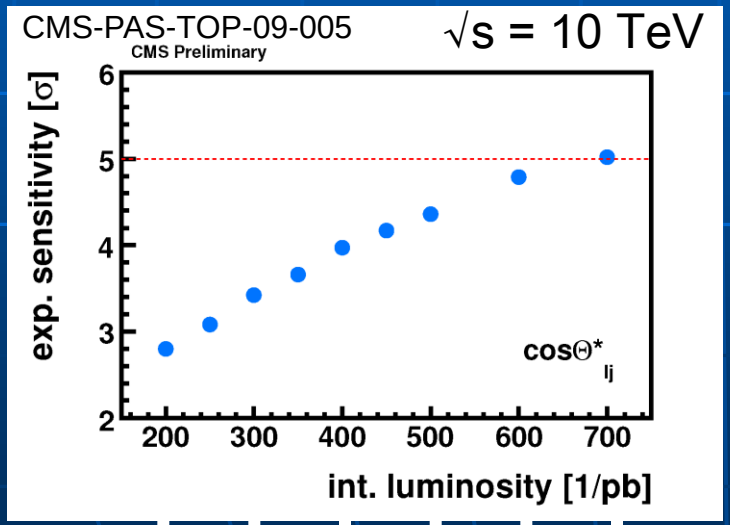




Single Top

ATL-PHYS-PUB-2010-003





Scale to 7 TeV

400 1000 1400 (1/pb)

10 TeV → 7 TeV

Process	$\sigma_{7TeV}/\sigma_{10TeV}$
t channel	0.48
s channel	0.92
top pair	0.43
W+jets	0.65
QCD	0.58

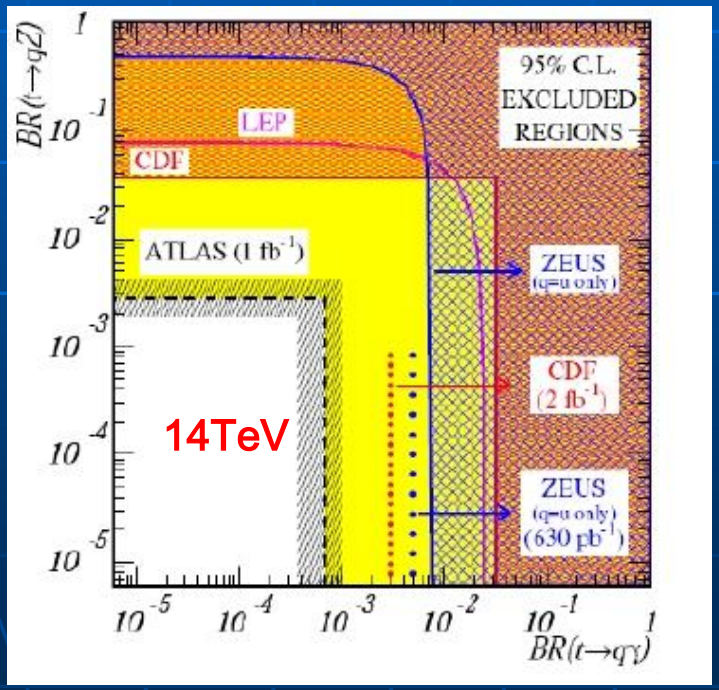
Need ~2 times more integrated luminosity to obtain the same expected sensitivity as 10 TeV

- 1.4 fb^{-1} is needed for 5σ discovery at 7 TeV
- ~4.5σ with 1 fb^{-1}

Branching Ratio

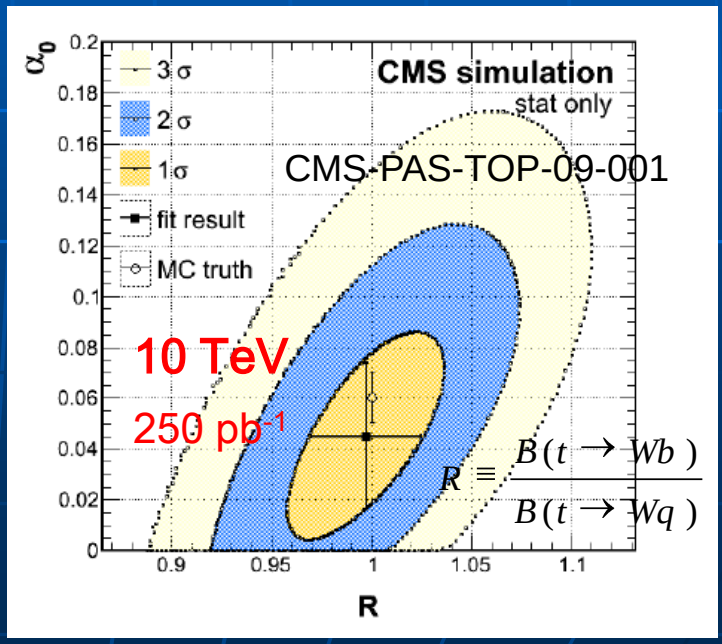
- $R = B(t \to Wb)/B(t \to Wq)$

The limits on the FCNC (flavour changing neutral current) decays $t \to qZ$ and $t \to q\gamma$



To reach current PDG precision

- CMS expects a ±9% measurement of R
- ~600 pb^{-1} of 7 TeV data



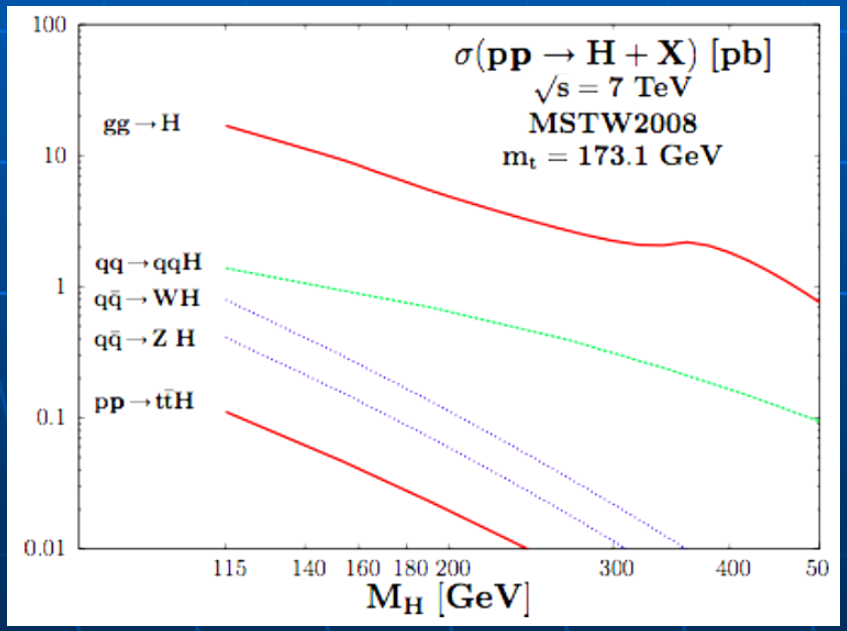
Higgs

- SM Higgs: H→WW, ZZ, $\gamma\gamma$
- SM Higgs: Combined
- SM Higgs: 2 Experiments
- MSSM Higgs

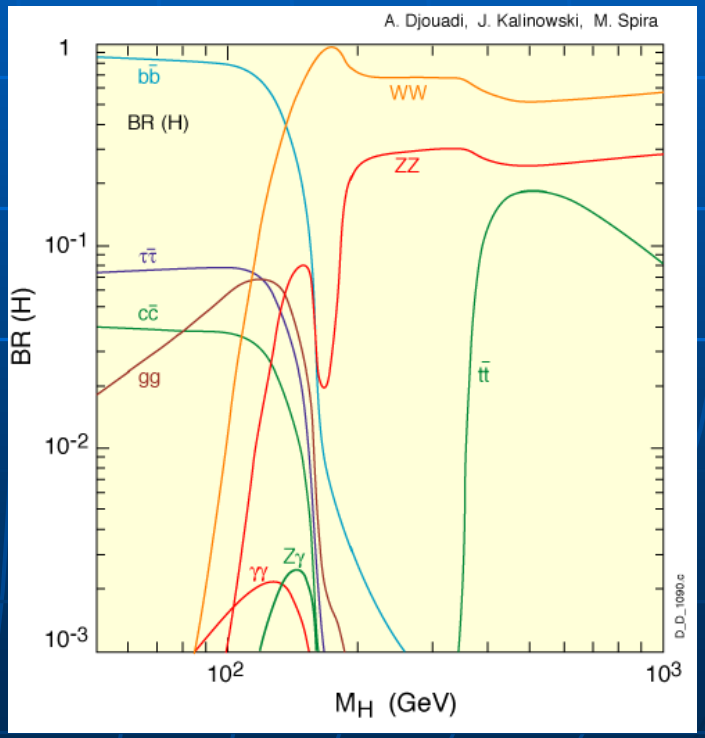
SM Higgs

- gg→H is the dominant production mode at √s = 7 TeV
- H→WW is the dominant decay mode (in high mass)

Production cross section

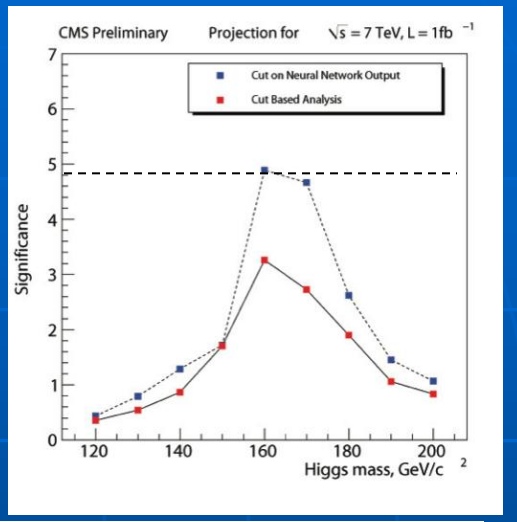


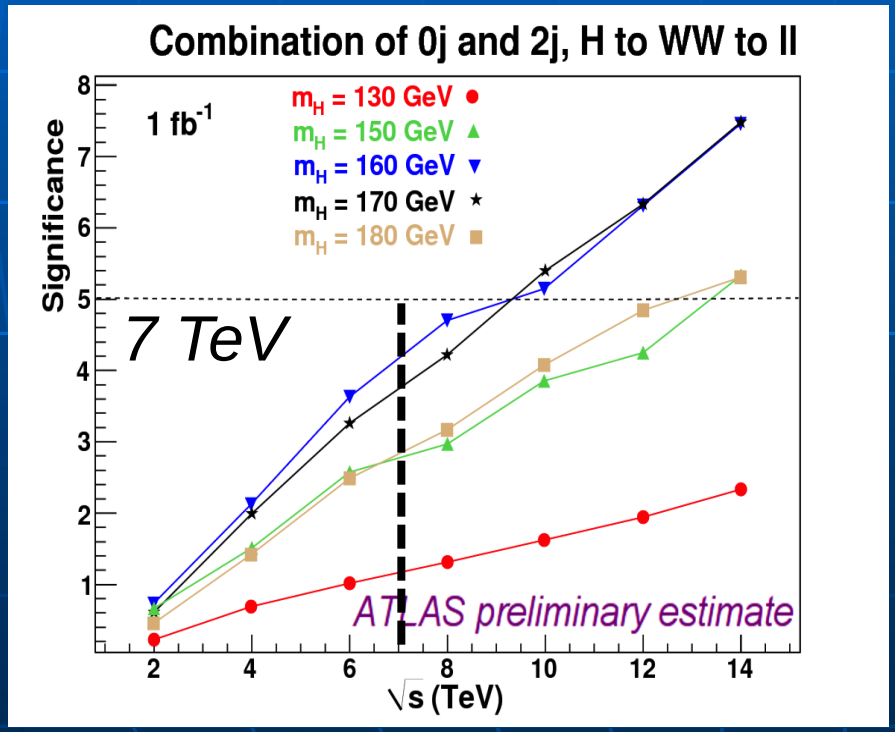
Branching ratio

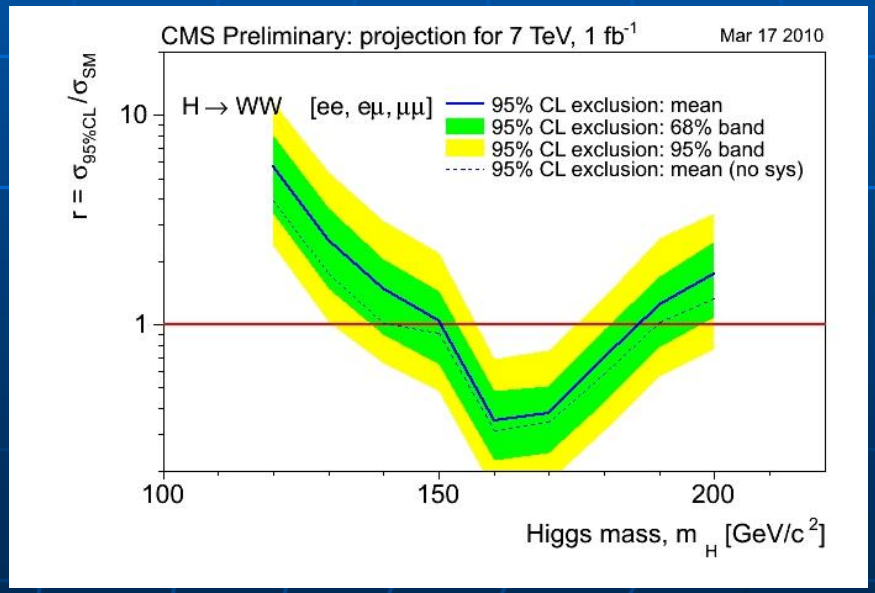


SM Higgs: H→WW

- Single experiment
- The expected exclusion mass range is $150 < m_H < 185$ GeV with 1 fb^{-1}
- The discovery level sensitivity (~5σ) is expected for the mass range $160 < m_H < 170$ GeV

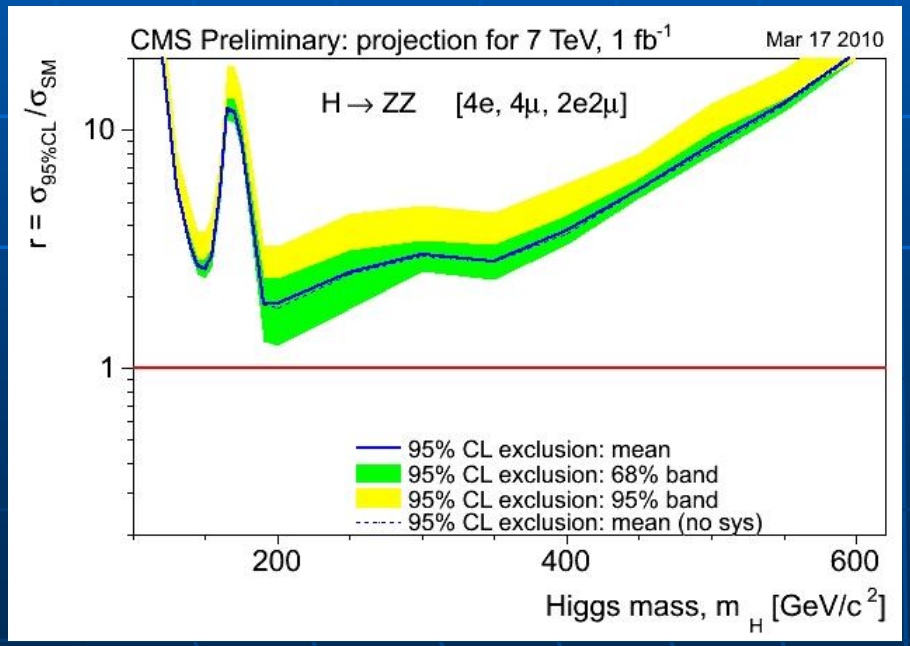


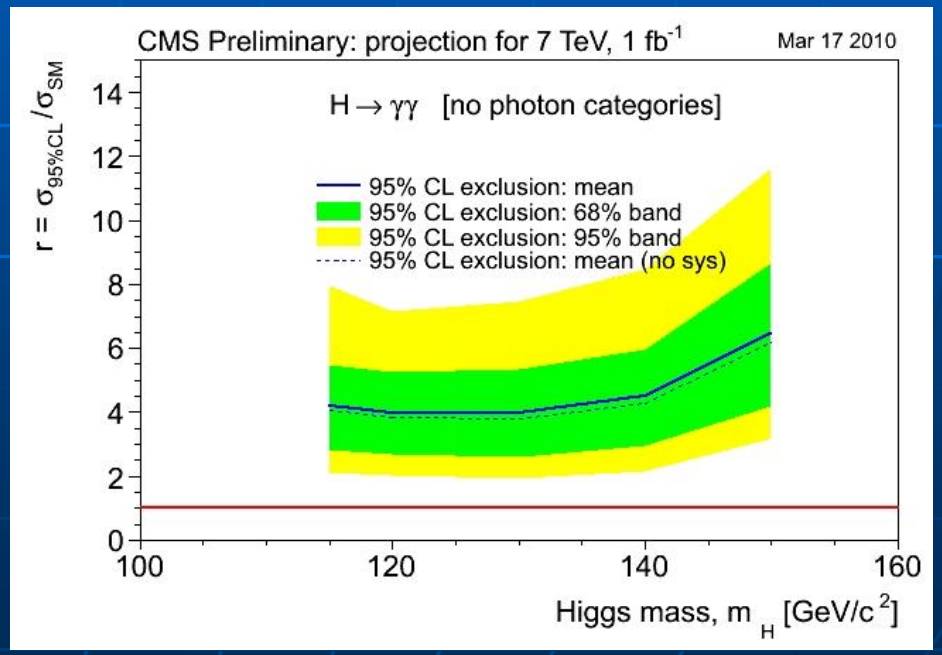




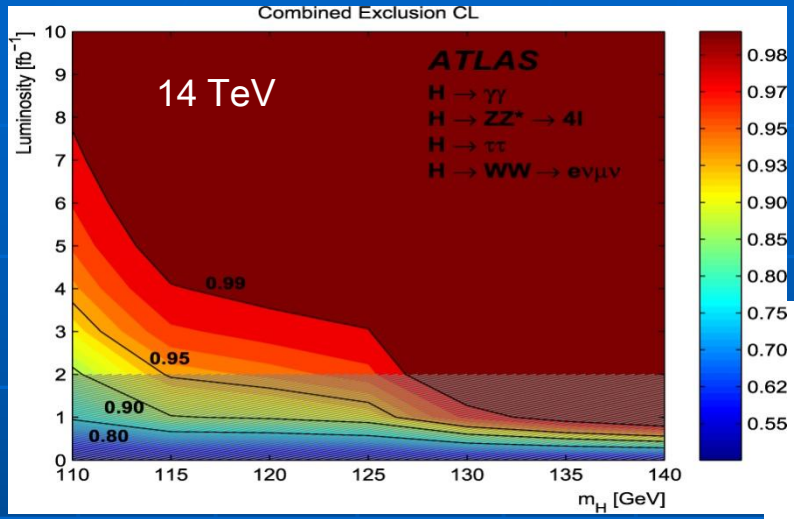
SM Higgs: H→ZZ, H→ γγ

- Single experiment
- The SM Higgs (H→ZZ, H→ γγ) can not be excluded anywhere in the entire mass range with 1 fb^{-1} at 7 TeV
  - Have similar sensitivity for m_H ~ 200 GeV to compare with H → WW in H →ZZ

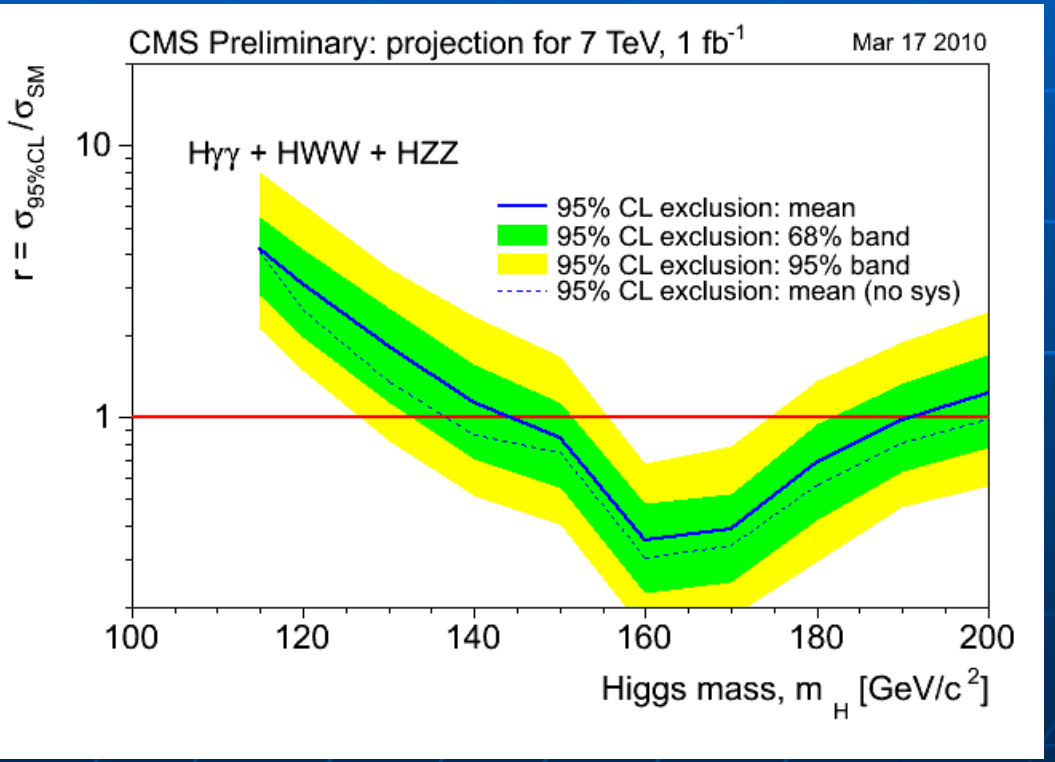




SM Higgs: combined



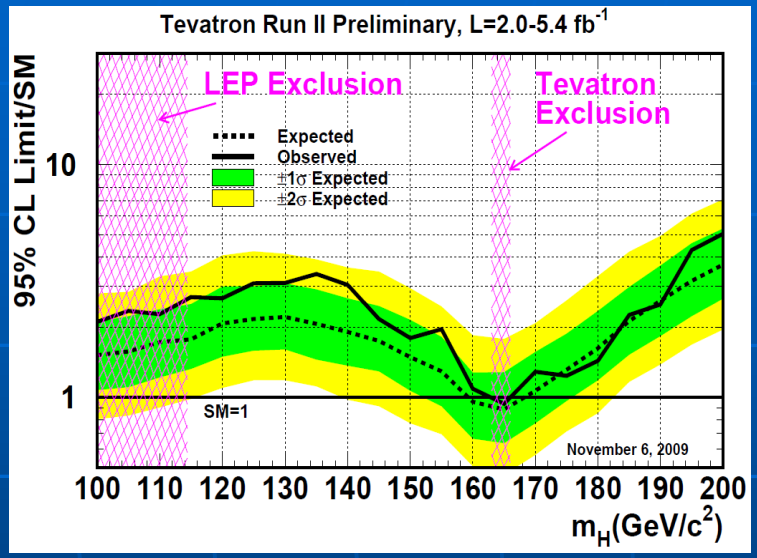
- 95% C.L. exclusion: 145-190 GeV
- Discovery sensitivity: ~160 GeV



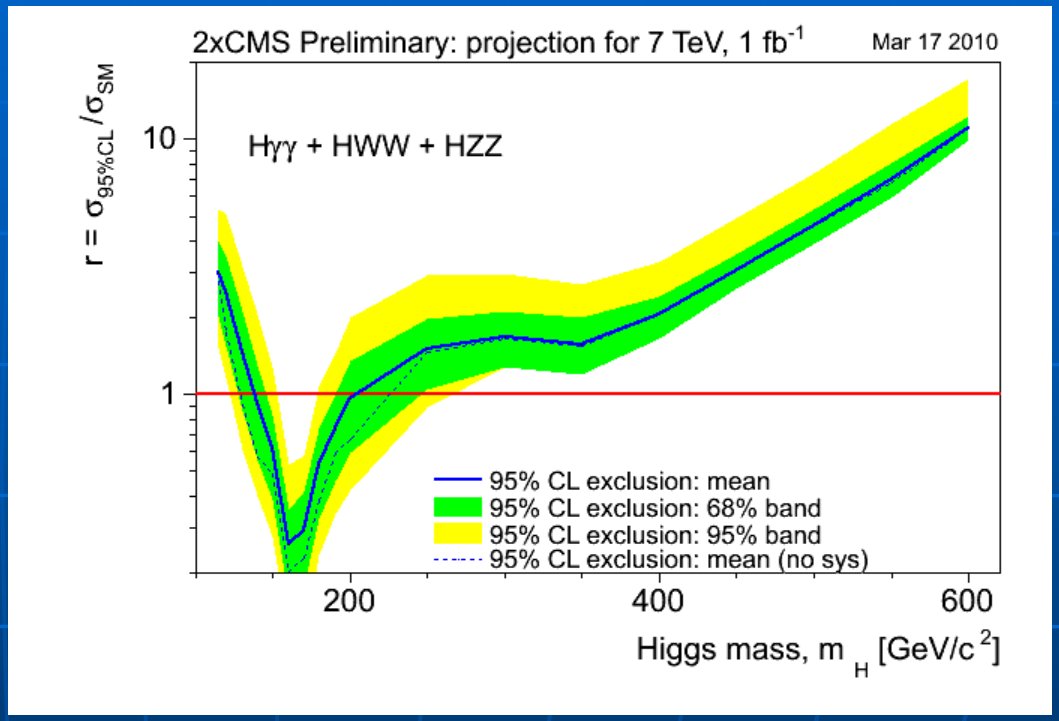
- All channels combined for single experiment

SM Higgs: 2 experiments

Tevatron CDF+D0

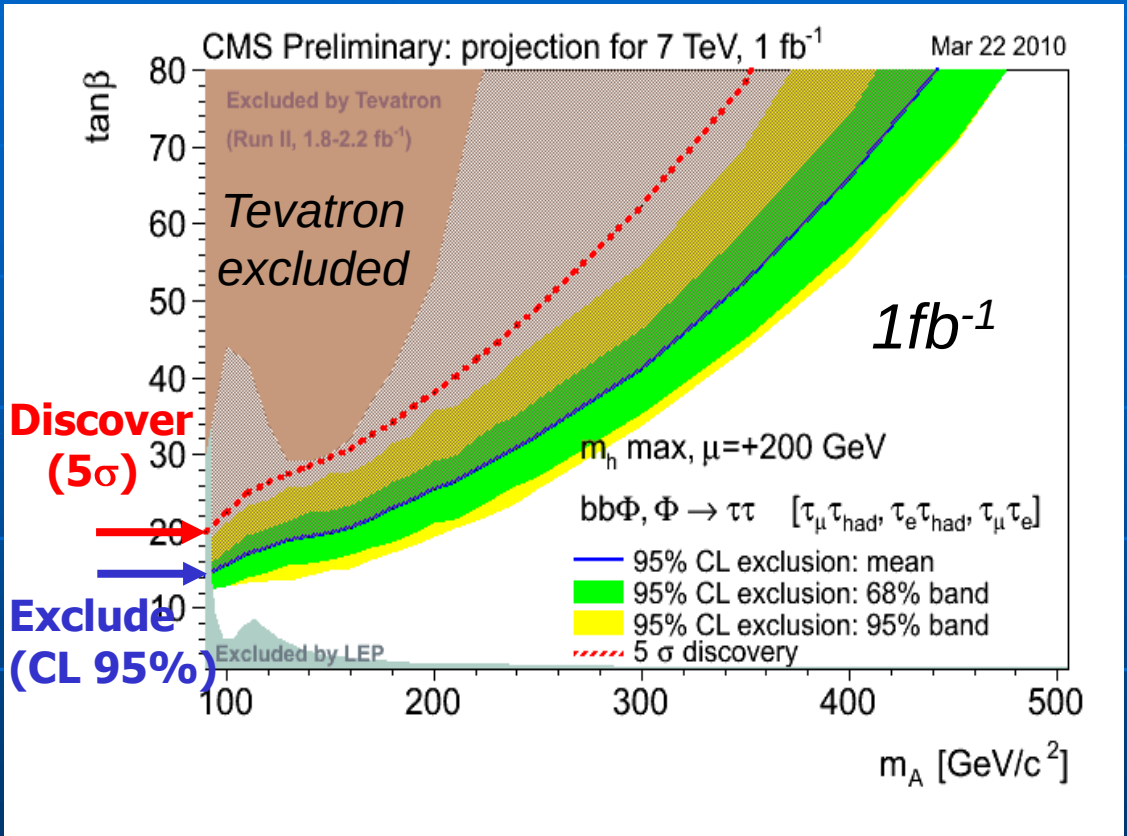


Tevatron excluded 162-166GeV with CL 95%



- 95% C.L. exclusion: 140-200 GeV
- Discovery sensitivity: 160~170 GeV

MSSM Neutral Higgs



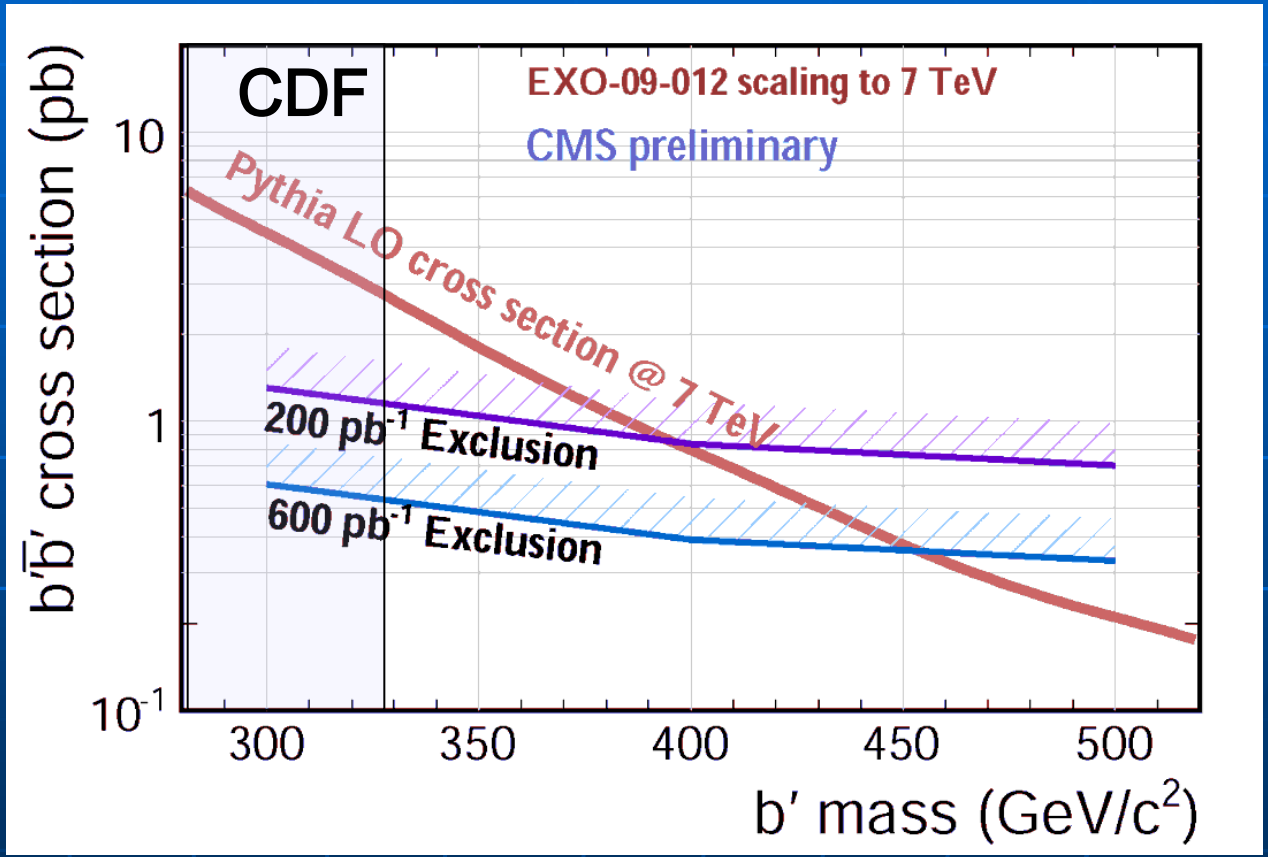
Expect to reach discovery level covering: tanβ ~ 20 at low m_A
Exclusion range without signal: down to tanβ ~15 at low m_A

Beyond the Standard Model

- b‘ Search
- Large Extra Dimensions
- Randall-Sundrum Gravitons
- W‘ and String Balls
- Heavy Stable Charge Particles
- Z‘ Resonances
- Long-lived Heavy Gluino
- Leptoquarks
- SUSY

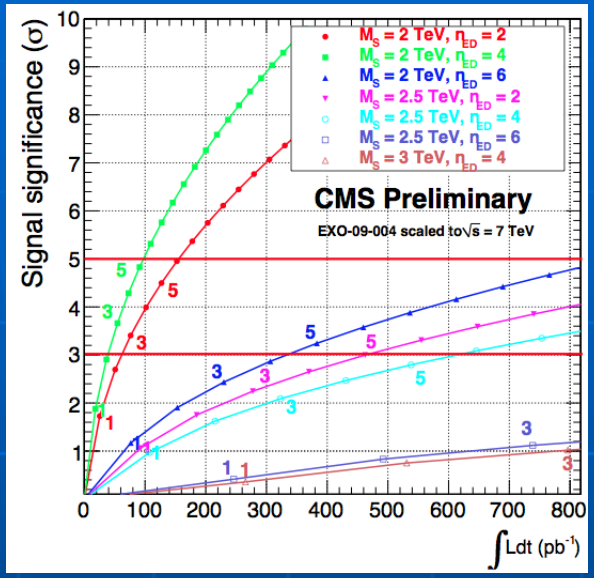
b' Search

- b‘ → Wt
- Scale using LO PYTHIA cross section for signal and background
- Our sensitivity is expected to surpass the current Tevatron lower b‘ mass limit of 325 GeV (CL 95%)

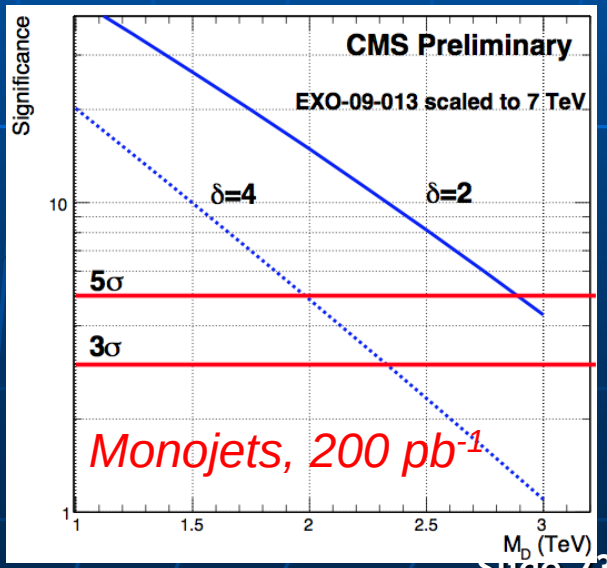


Large Extra Dimensions

- Diphoton channel
  - Sensitivity of the search surpasses the current Tevatron limits with 50 pb^{-1}
  - M_s = 2 TeV, ED = 2, 4 reach 5σ discovery level with 100, 150 pb^{-1}
  - We expect to probe M_S up to ~3 TeV with 1 fb^{-1}



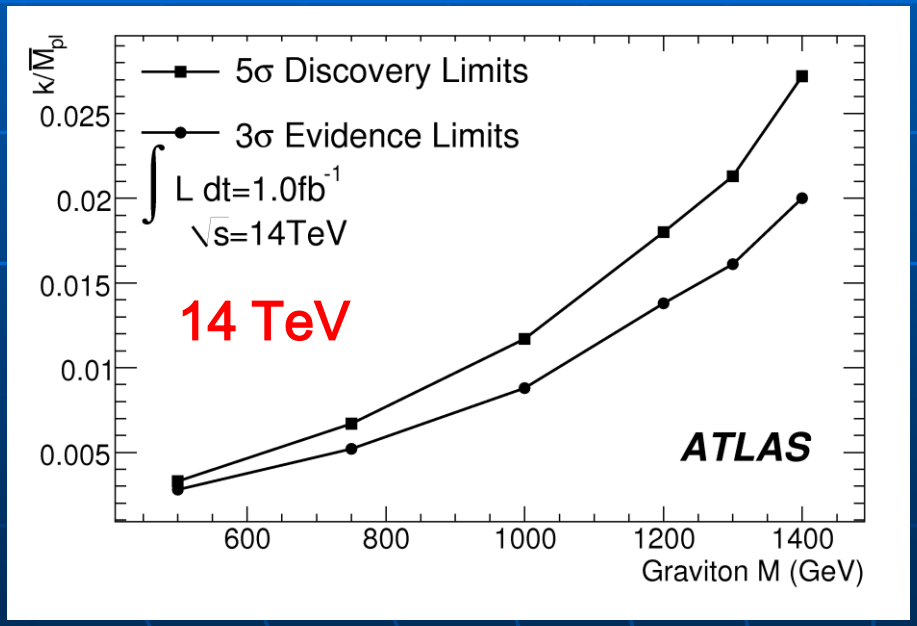
- Monojets channel
  - Missing ET + single-jet
  - We can probe the search with same sensitivity at the Tevatron if we have 10 pb^{-1} of integrated luminosity
  - With 200 pb^{-1} data, M = 2 TeV, δ = 4 reaches 5σ discovery sensitivity



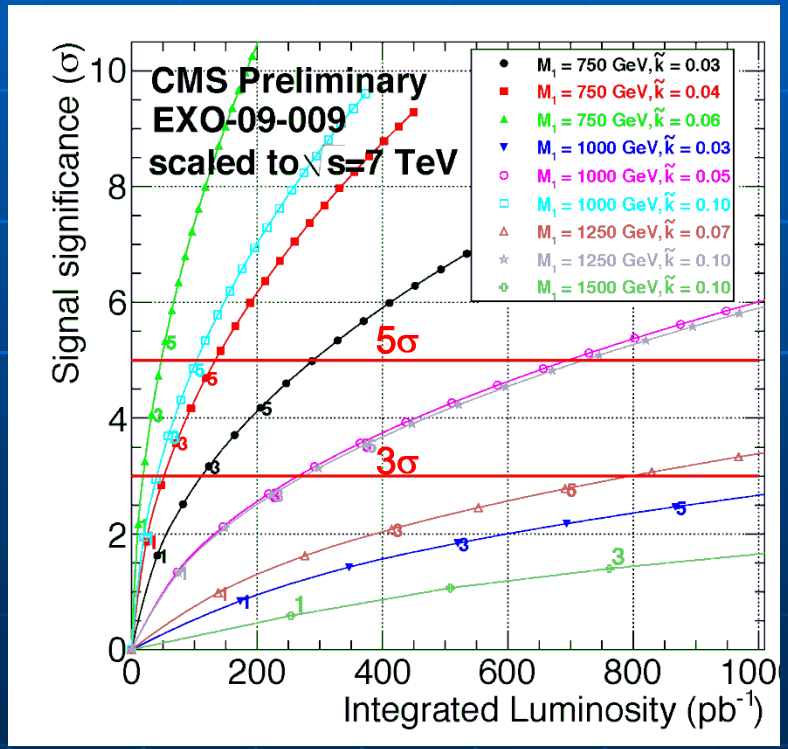
Randall-Sundrum Gravitons

- 50 pb^{-1} of 7 TeV data is required to surpass the sensitivity of the search at the Tevatron
- We expect 5σ discovery with M = 750 GeV with 300 pb^{-1}

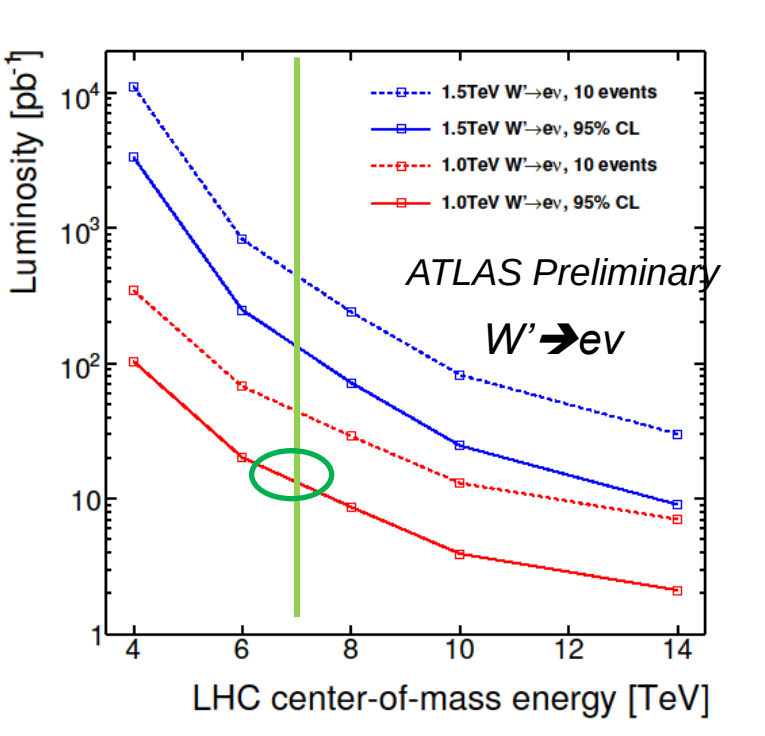
G→ee, discovery reach as function of m(G) and coupling constant



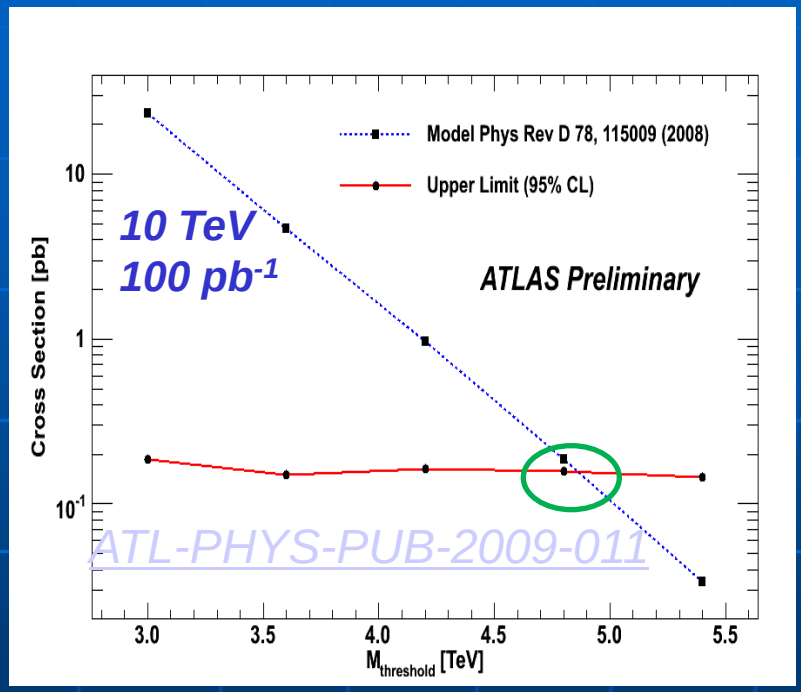
G → γγ



W' and String Balls



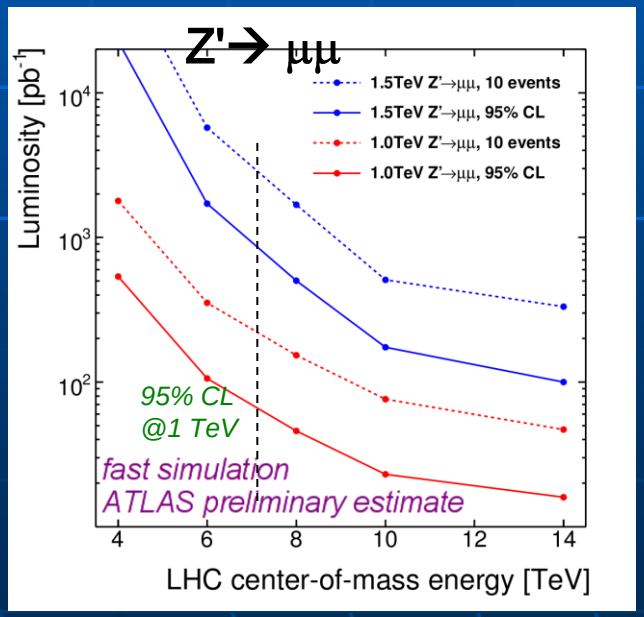
95% CL limit per channel:
O(10/pb) at M =1 TeV @ 7 TeV

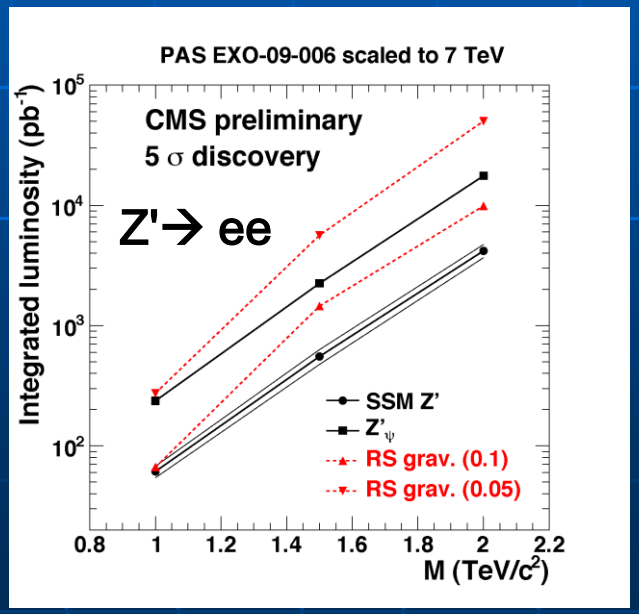


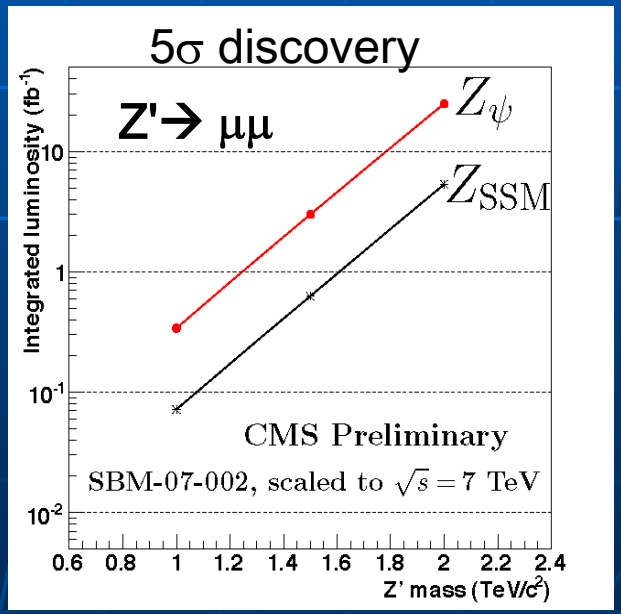
For 10 TeV: exclude M_{th} below 4.8 TeV
For 7 TeV: exclude M_{th} below ca. 4 TeV

Dilepton Resonances (Z')

- Predicted in many SM extensions (Extra Dimensions, Technicolour, Little Higgs)
  - Background dominated by DY
- 95% CL exclusion O(100/pb) at 1 TeV
- Sensitivity beyond the Tevatron (1 TeV SSM Z') with ~100 pb^{-1}

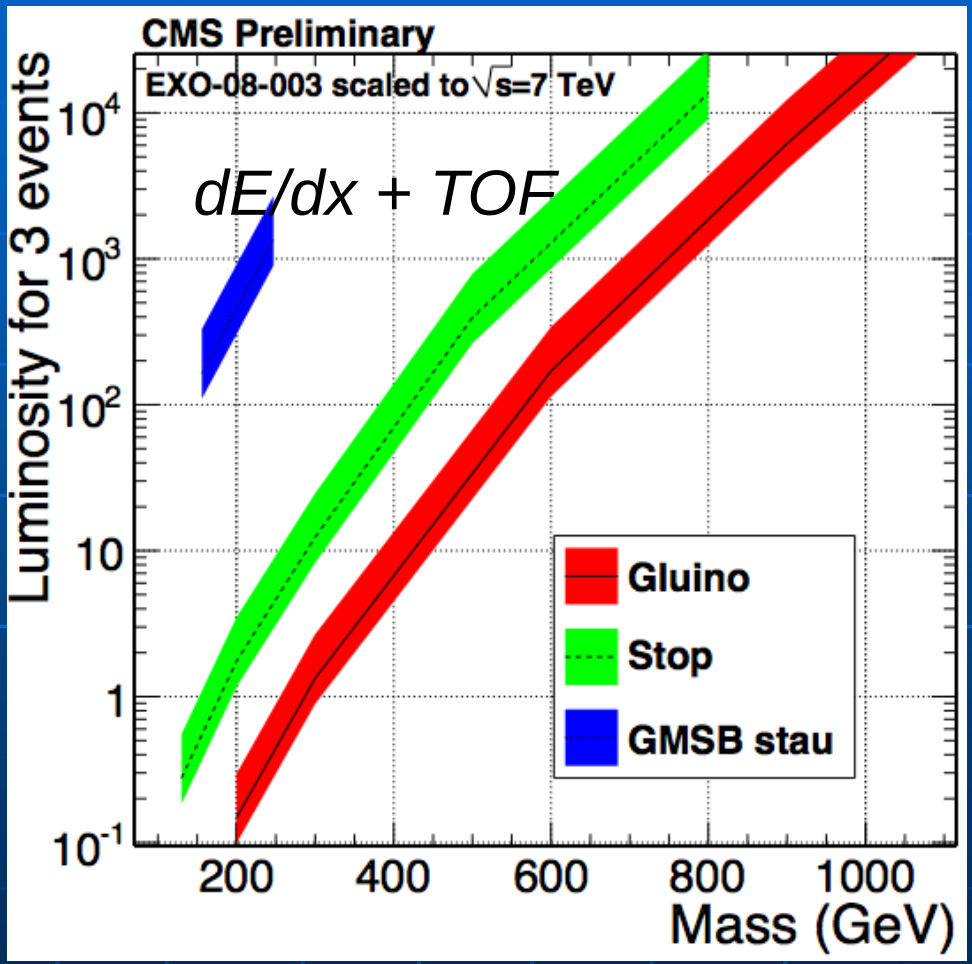






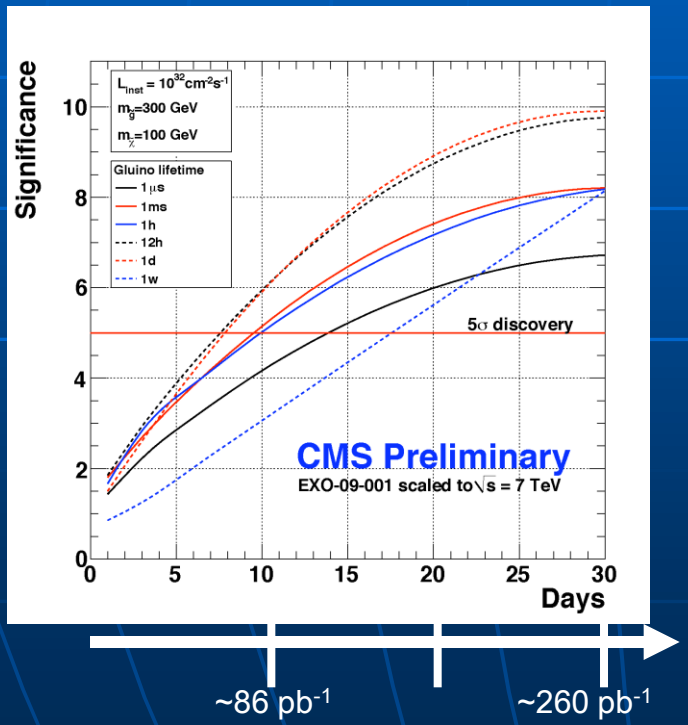
Heavy Stable Charge Particles

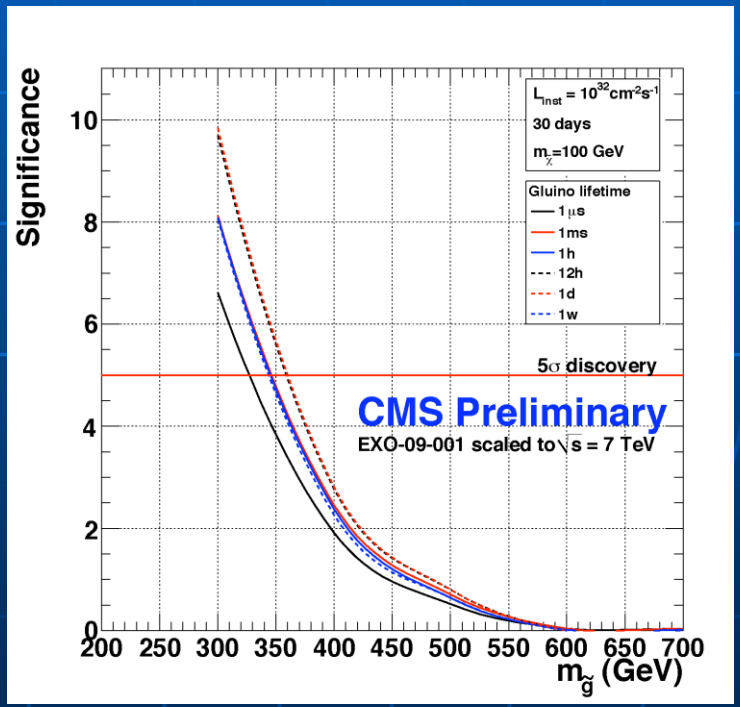
- Long lived particles predicted by several models
  - e.g. GMSB, split SUSY
- Scale using LO PYTHIA cross section for signal
  - Background is not scaled because it is almost negligible
- The reach beyond the Tevatron limits is achieved with just a few pb^{-1} of 7 TeV data



Long-lived Heavy Gluino

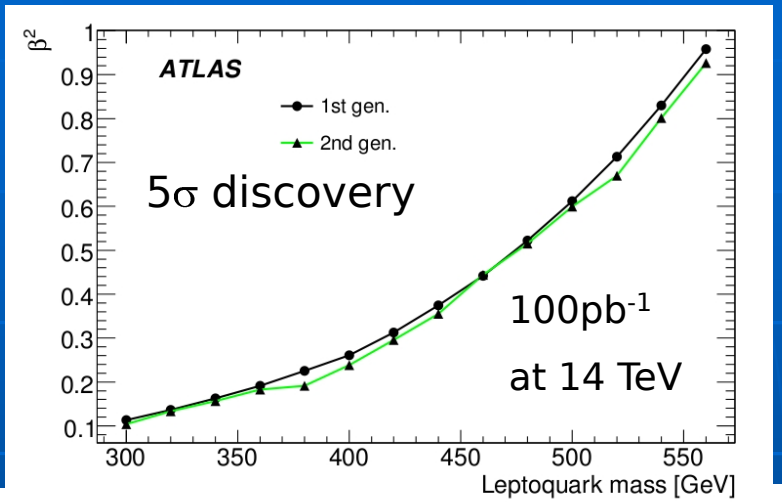
- Look for gluino decays during periods of no beam including
- 30-day long (~260 pb^{-1}) 7 TeV run at instantaneous luminosity of 10^{32} $cm^{-2}s^{-1}$
  - We can expect 5σ discovery with all lifetime senarios with M_g = 300 GeV
  - The discovery beyond the Tevatron limits is possible with just a couple of weeks of data



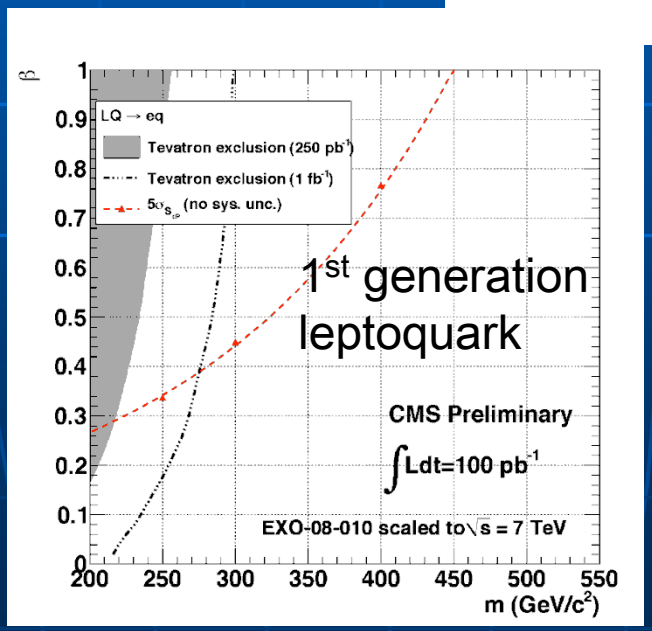


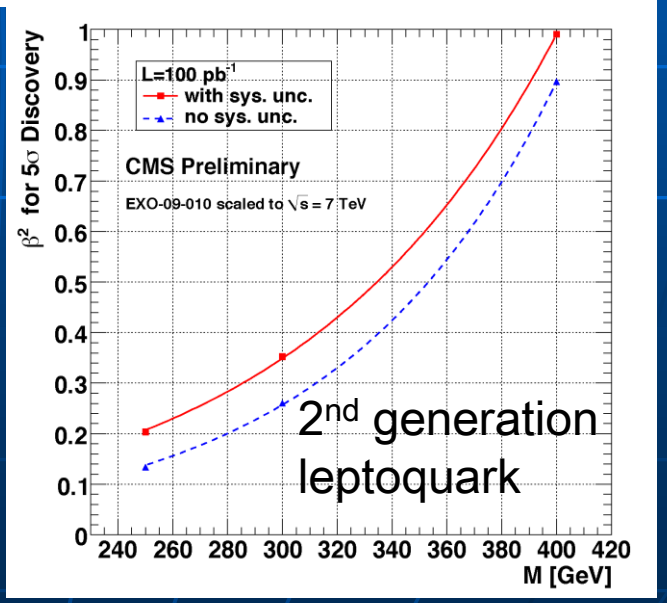
Leptoquarks

- Signature of leptoquarks
  - Two opposite charge leptons with same flavour + two jets
- Limit and discovery reach for 100 pb^{-1} of the LHC data at 7 TeV
- With ~10 pb^{-1} the LHC sensitivity at 7 TeV is expected to surpass at the Tevatron for both generations



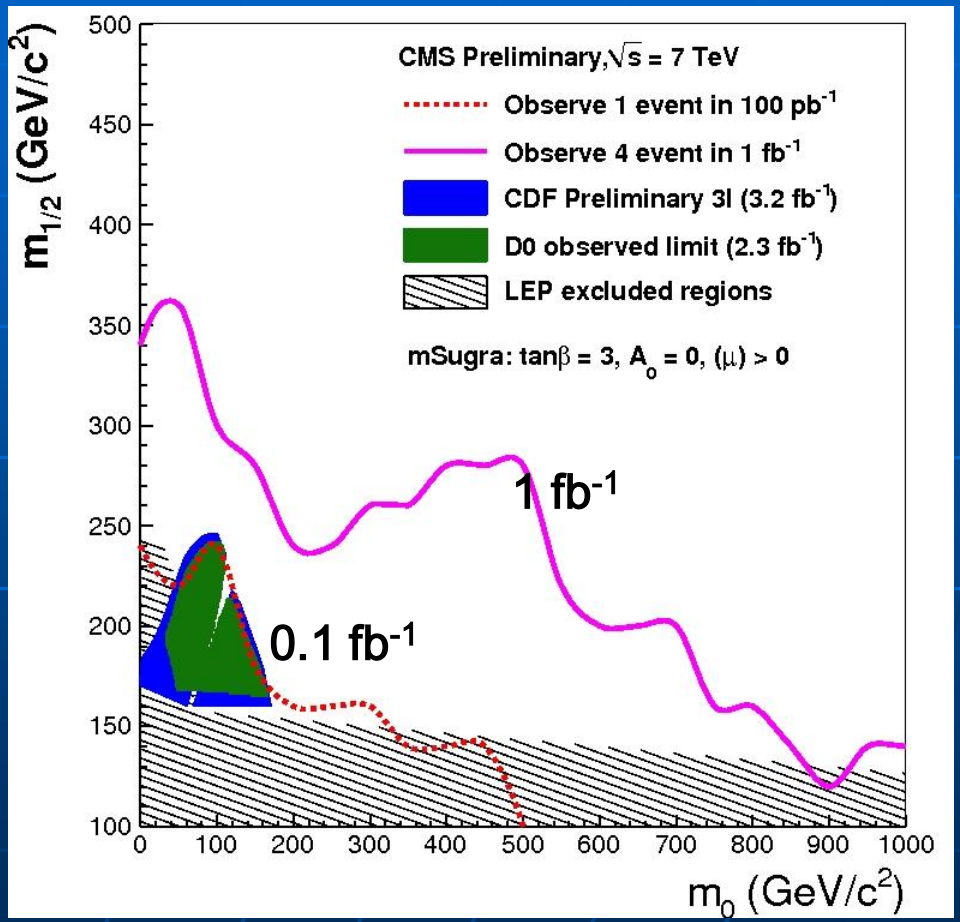
β Is branching ratio, LQ → lq





SUSY: like-sign dileptons

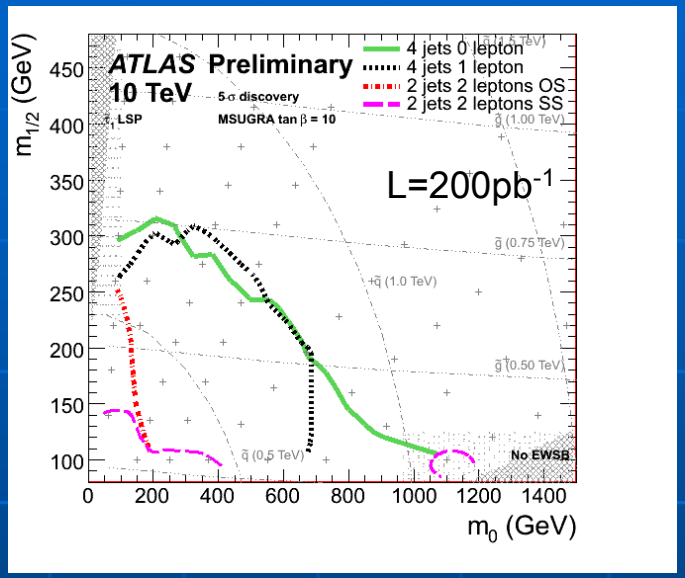
- Perform in ee, μμ, eμ channels
  - Total estimated SM background is less than 1 event with 100 pb^{-1}
- Expect 1 event in 100 pb^{-1}
  - Similar sensitivity with the Tevatron limits
- Expect 4 events in 1 fb^{-1}

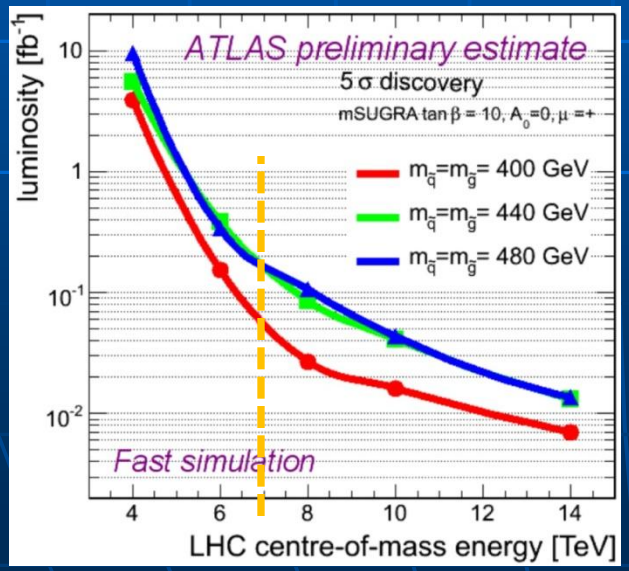


SUSY: jets+leptons+missing E_T

- Search in 0-lepton, 1-lepton and 2-lepton +Njets with missing Et channels (Meff= ∑Pt_jets + ∑ Pt_lep +Et_miss)
  - Sys. uncertainty on SM background ~50%
- R-parity conserving SUSY signals with squark and gluino masses less than 600 - 700 GeV can be discovered at √s=10 TeV , L=200 pb^{-1}

mSUGRA Discovery reach



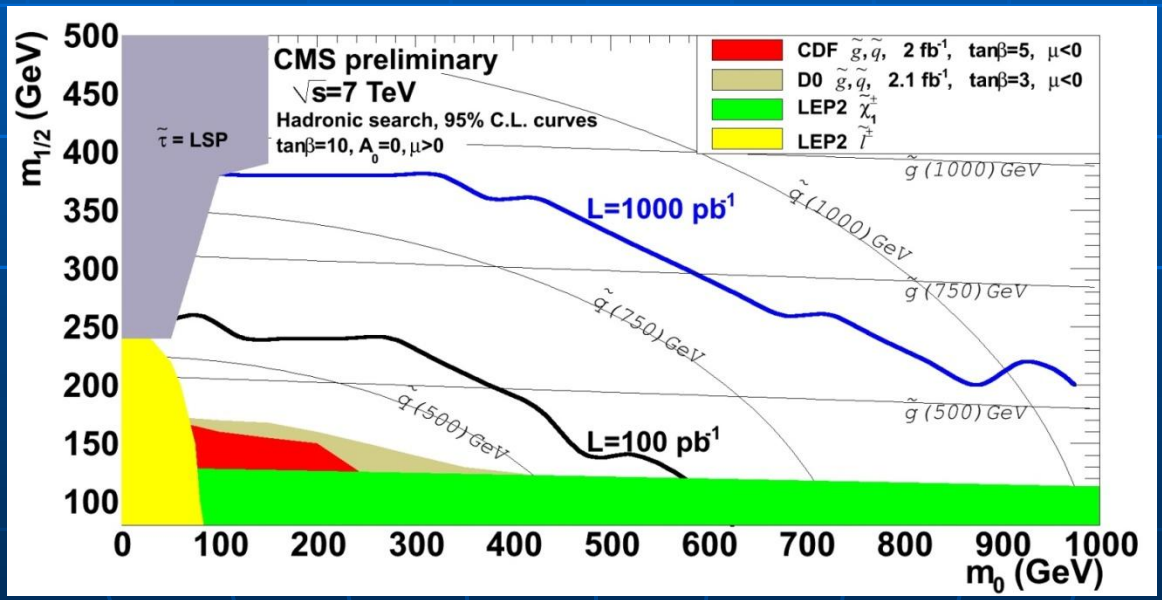


- For 7 TeV need a factor 2.5-3 more integrated luminosty to achieve similar reach

√s energy scan
(SUSY points close to Tevatron bound)

SUSY: jets + missing E_T

- "Classic" all hadronic search
- Systematic uncertainty of 50% assumed on Standard Model background
- Sensitivity significantly beyond previous experiments (~50/pb to surpass Tevatron)

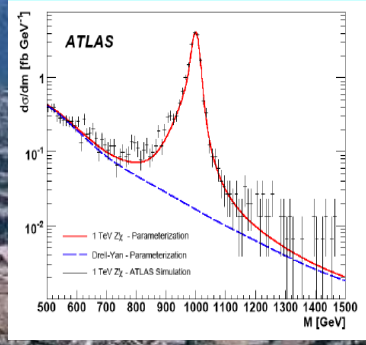


Summary

- At the LHC at 7 TeV, we get a gain of a factor of 10 or more compared with Tevatron
- Standard Model physics is observable with very early data
- Top quark can be rediscovered with only 10 pb^{-1}
- The LHC will surpass Tevatron's sensitivity for several SM and MSSM Higgs searches with 1 fb^{-1}
- The LHC will have discovery potential with as little as 10 to 100 pb^{-1} for many new physics models
- We still need more than 1 fb^{-1} in particular physics analysis
  - SM Higgs H→ZZ, $\gamma\gamma$ can not be excluded anywhere in the entire mass range

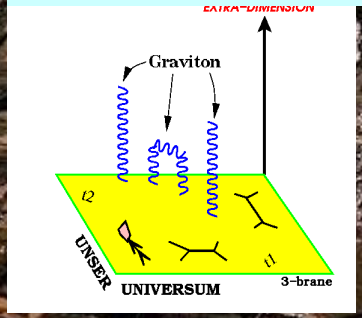
Higgs!

New Gauge Bosons?

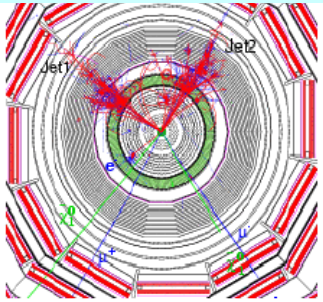


Stay tuned: We will be back with new discoveries soon!

Extra Dimensions?



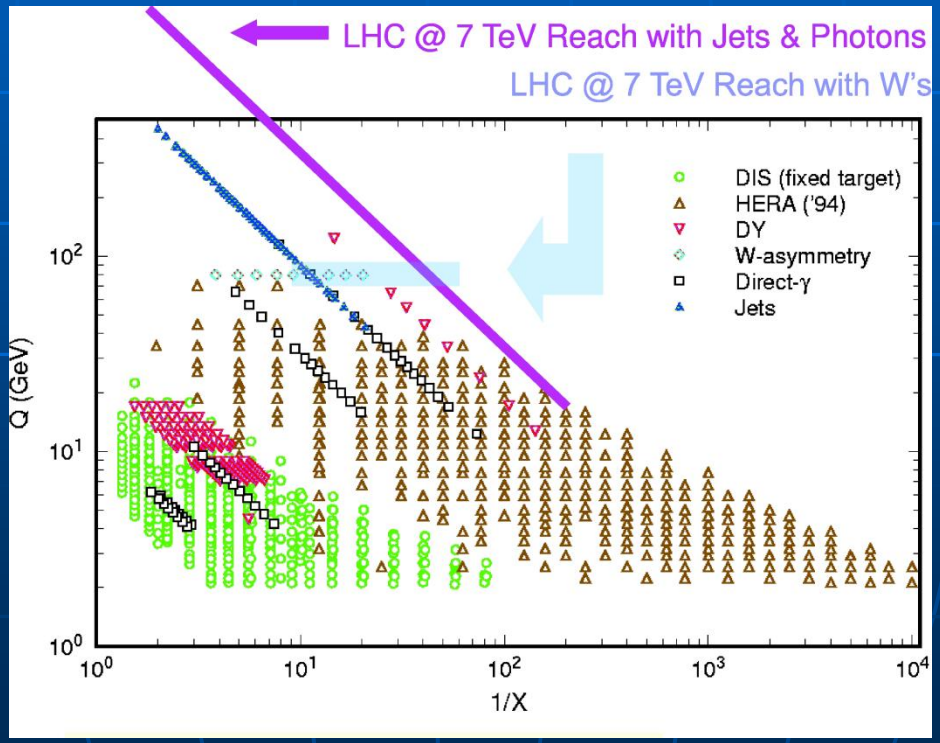
SuperSymmetry?



Backup

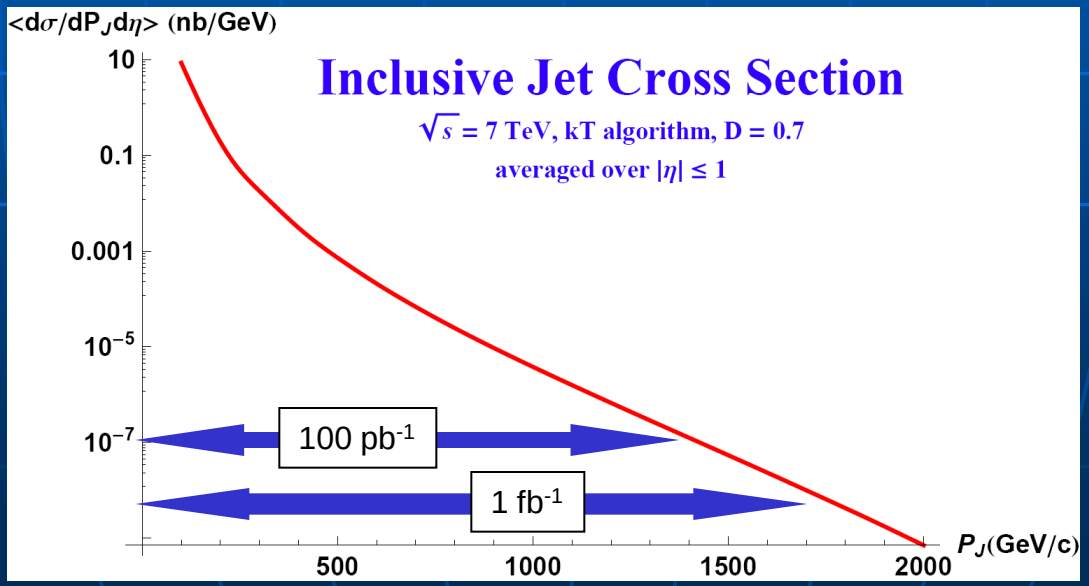
LHC Kinematic Reach

- 7 TeV LHC run will substantially increase the available kinematic range for physics analysis
  - e.g., QCD, EWK with jets and photons

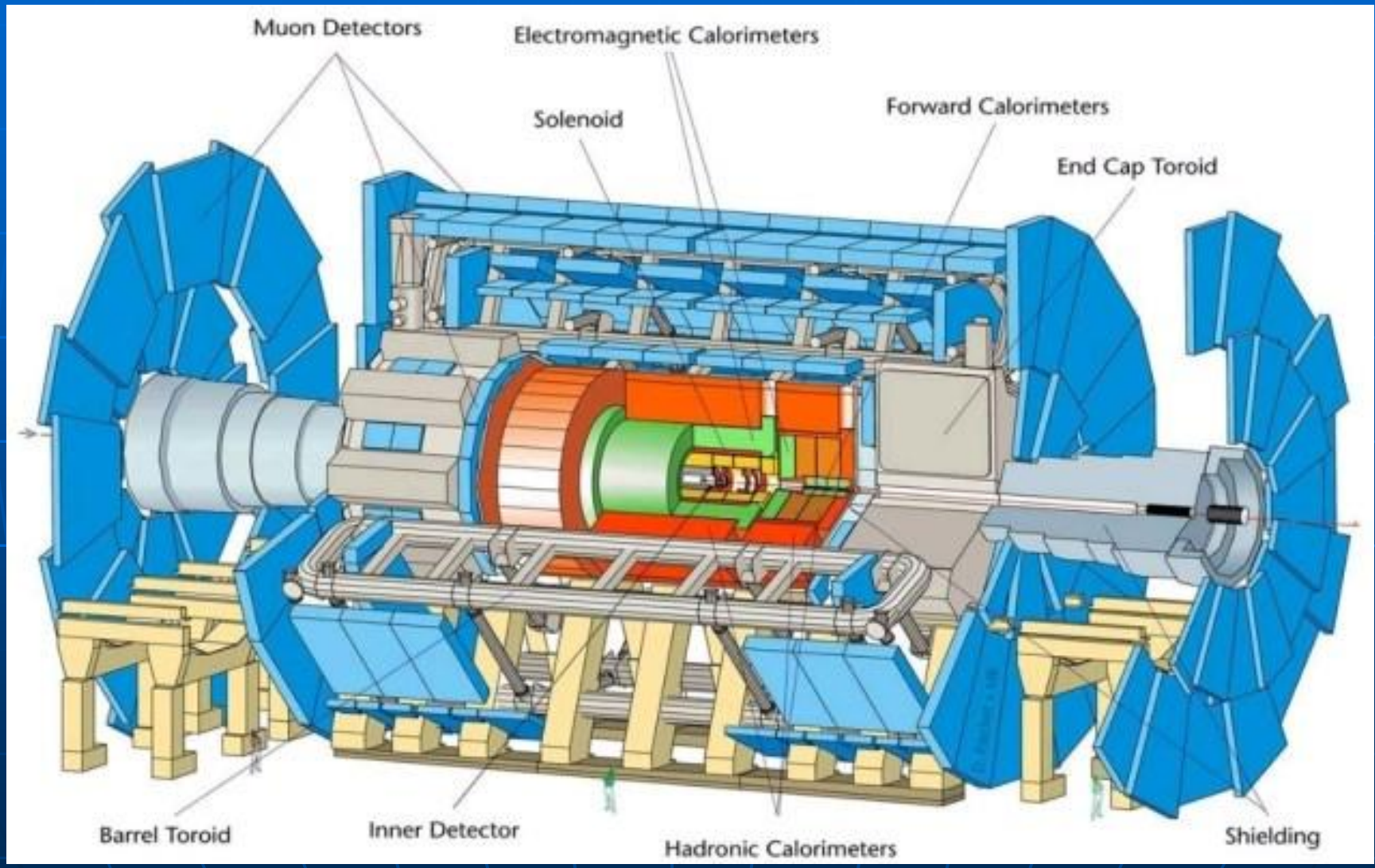


Inclusive Jet Cross Section

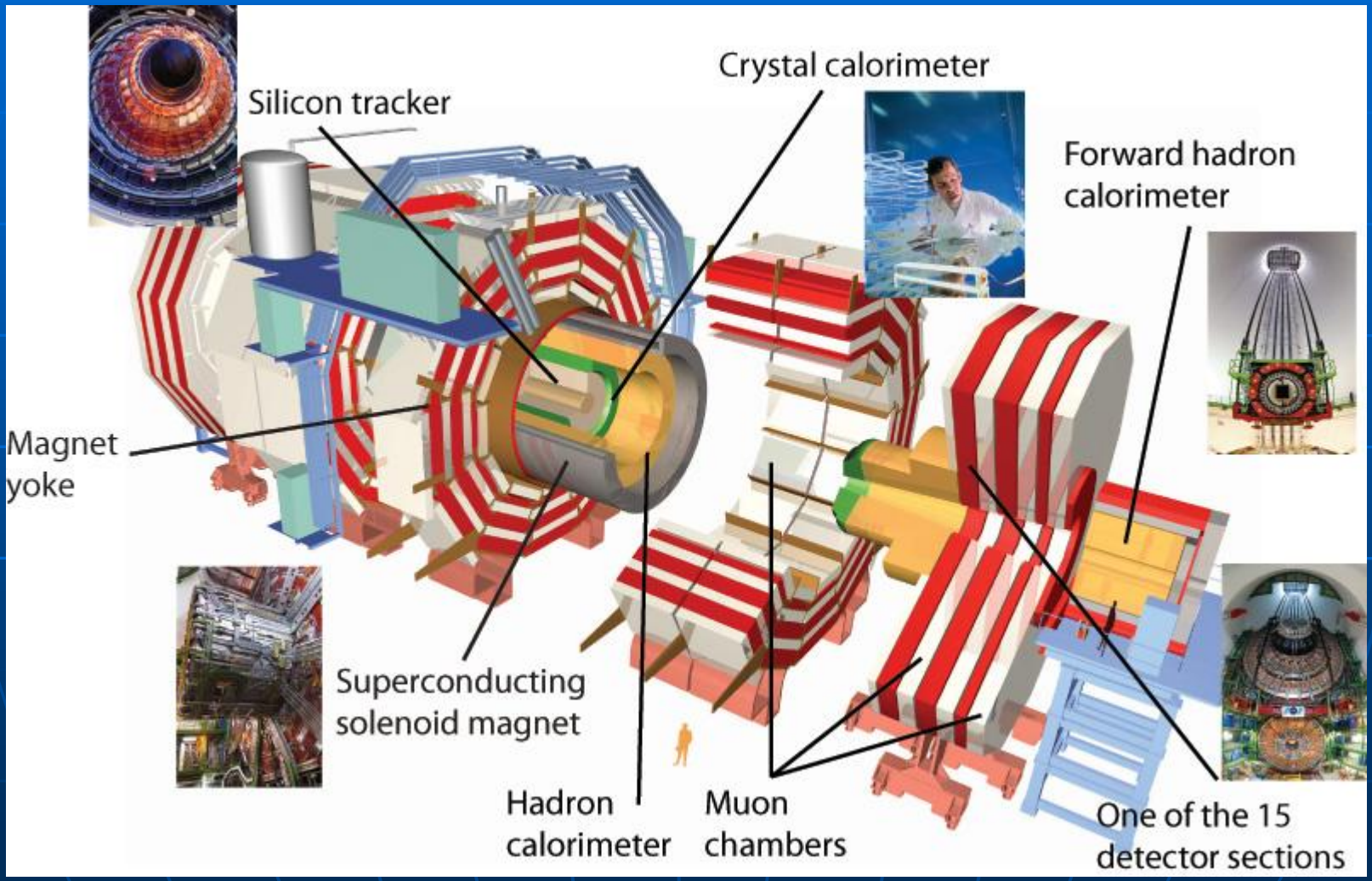
- NLO QCD jet spectrum – no detector effects included
- We expect to reach jets with E_T's of around 1.4 TeV after the first 100 pb^{-1}
- Also, jets with E_T's of around 1.7 TeV after the first fb^{-1}



ATLAS

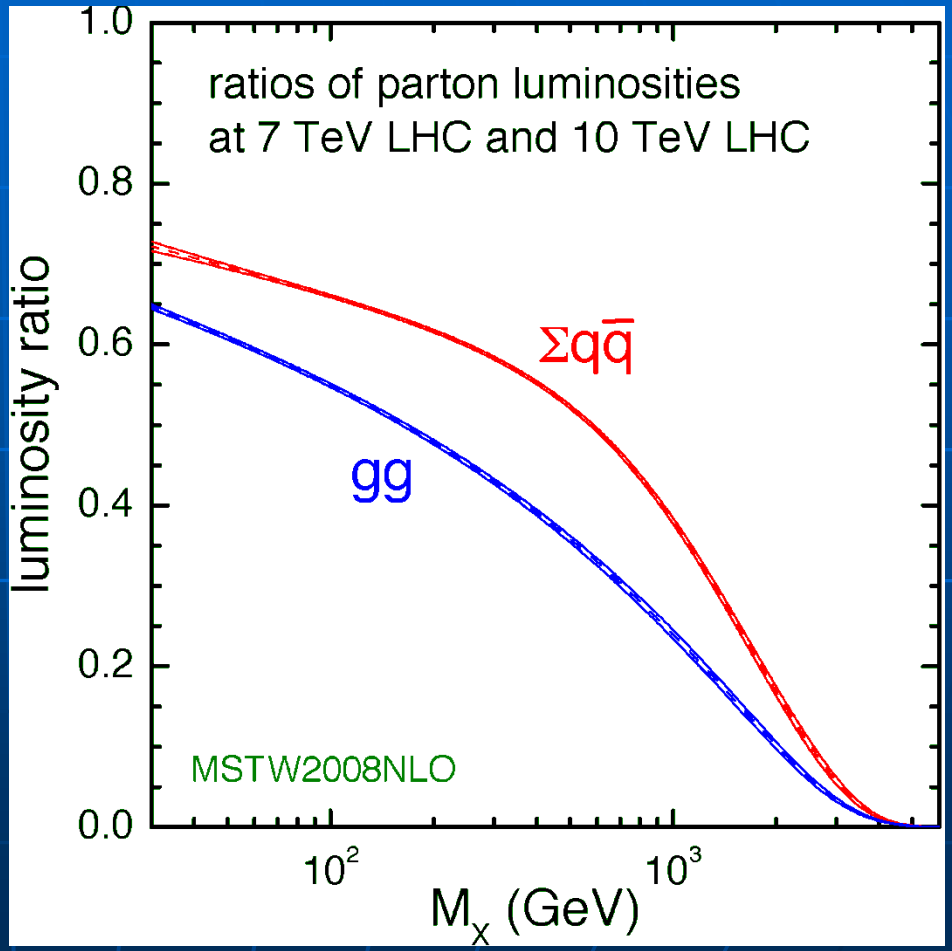

Muon Detectors
Electromagnetic Calorimeters
Solenoid
Forward Calorimeters
End Cap Toroid
Barrel Toroid
Inner Detector
Hadronic Calorimeters
Shielding

CMS


Silicon tracker
Crystal calorimeter
Forward hadron calorimeter
Magnet yoke
Superconducting solenoid magnet
Hadron calorimeter
Muon chambers
One of the 15 detector sections

Rescaling 10 TeV to 7 TeV

- Scaling of 10 TeV results to 7 TeV by using parton luminosities ratio for gg and qq
  - Obtain using MSTW2008NLO PDF
  - Should be considered as conservative rough estimates of the true reach at 7 TeV
- Use LO PYTHIA cross section for the scaling in some results
- ATLAS results scaled to 7 TeV work in progress



SM Expectation