XXX PHYSICS IN COLLISION

CMS results with collision data

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On behalf of the CMS Collaboration

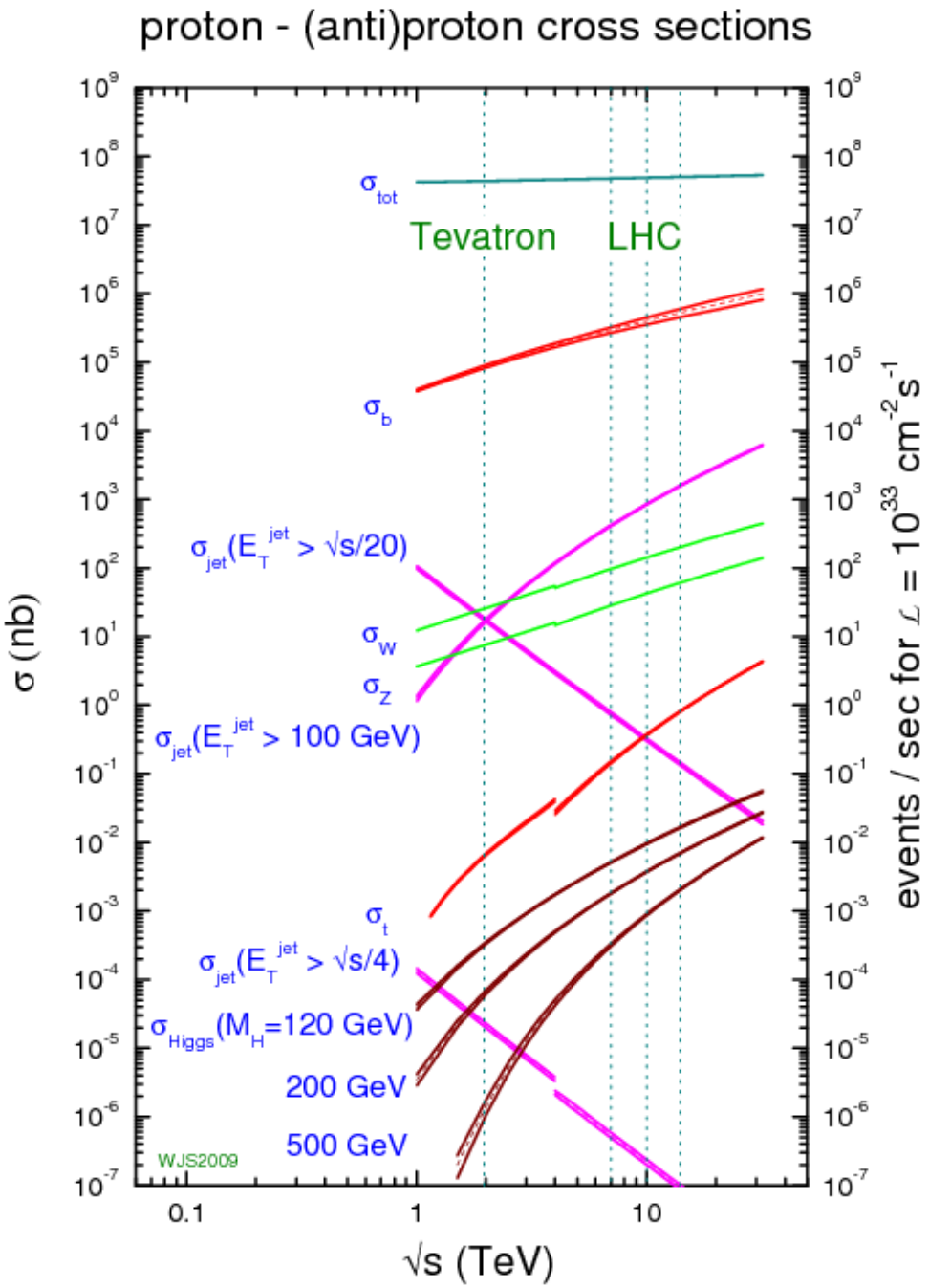
Karlsruhe, September 1 2010

Outline

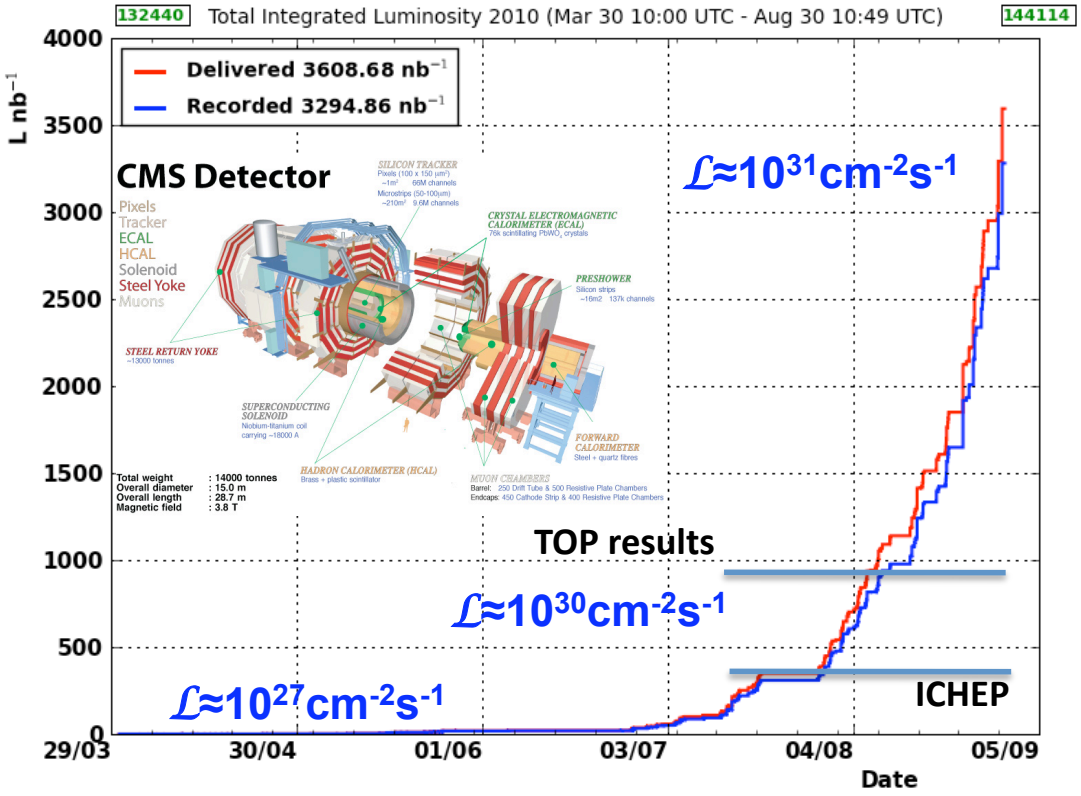
Study of **SM processes** with cross sections spanning several orders of magnitude:

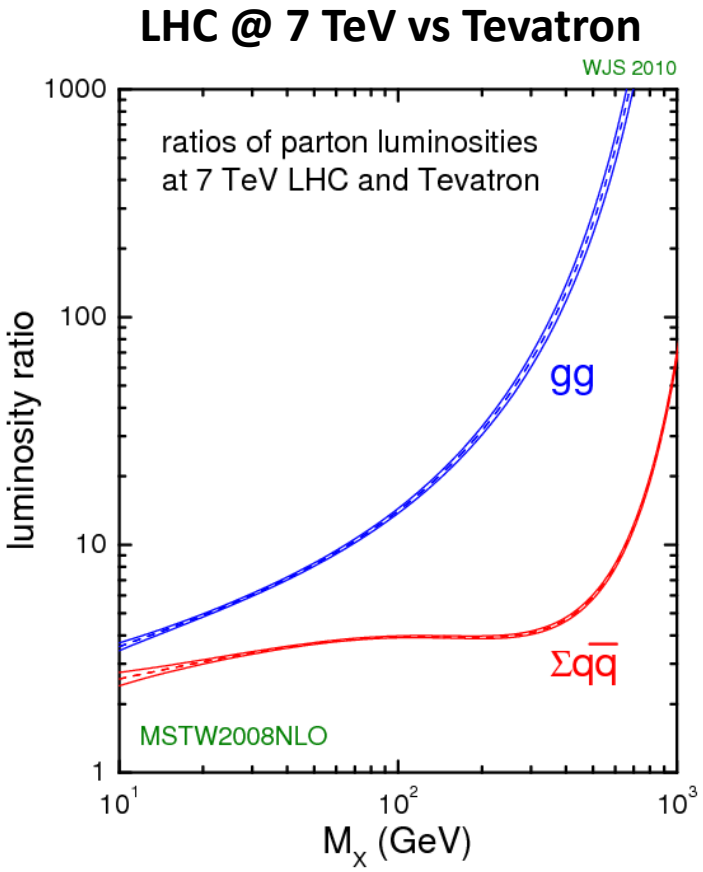
- ✓ **Minimum bias** for detector and physics object commissioning
- ✓ **W/Z** as standard candles
- ✓ **W/Z+jets** and **ttbar**
- ✓ first limits in **BSM searches**

ONLY APPROVED RESULTS ARE SHOWN:
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults



CMS data taking @ 7 TeV



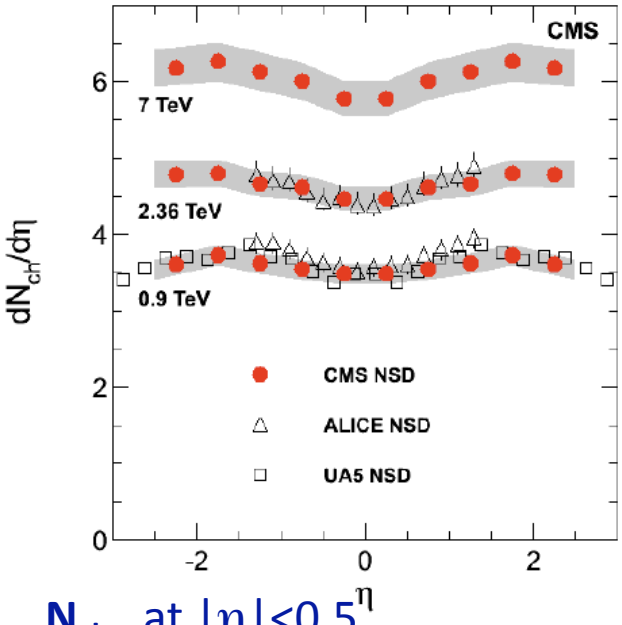


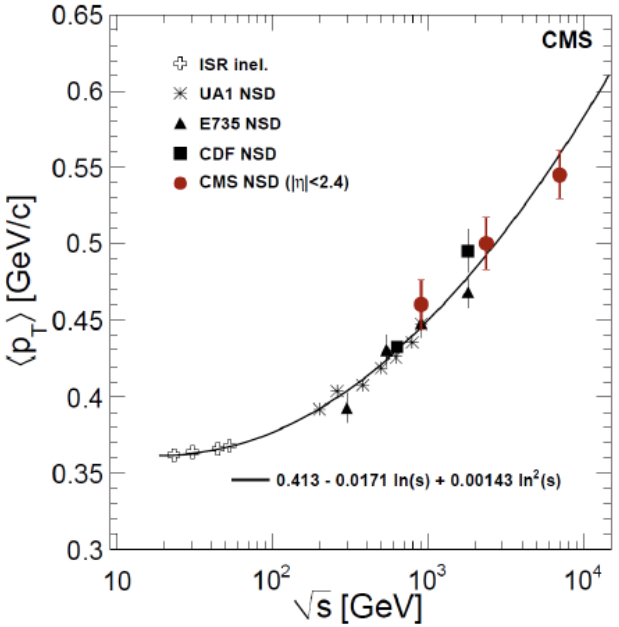
- ✓ **>98%** of each subdetector fully operational
- ✓ overall data taking efficiency **~ 92%**
- ✓ **3.3 pb^{-1}** data recorded **(>1 pb^{-1}** last week)

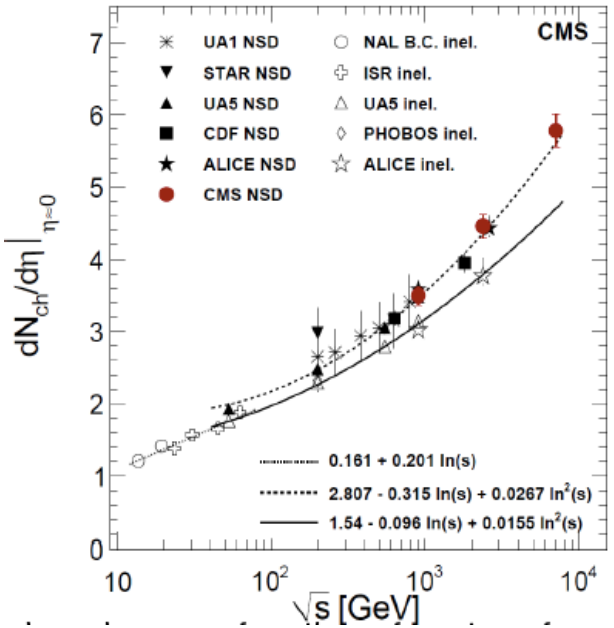
x 20 gain in luminosity @ M_{top}

Charged hadrons@ 0.9, 2.36 and 7 TeV

Minimum bias events: soft QCD (p_T tracks down to 50 MeV)
Non single-diffractive event selection (correction 6%→2.5% systematic error)







N_{ch} at $|\eta|<0.5$

0.9 TeV: $3.48 \pm 0.02\ (\text{stat.}) \pm 0.13\ (\text{syst.})$

2.36 TeV: $4.47 \pm 0.04\ (\text{stat.}) \pm 0.16\ (\text{syst.})$

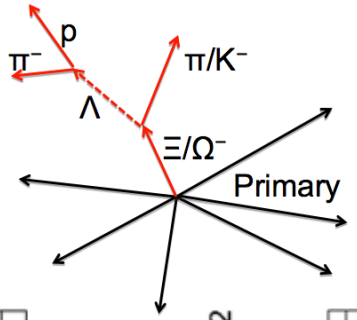
7 TeV: $5.78 \pm 0.01(\text{stat}) \pm 0.23(\text{syst})$

"Transverse Momentum and Pseudorapidity Distributions of Charged Hadrons in pp Collisions at √s=7TeV"
Phys. Rev. Lett. 105, 2010, 022002

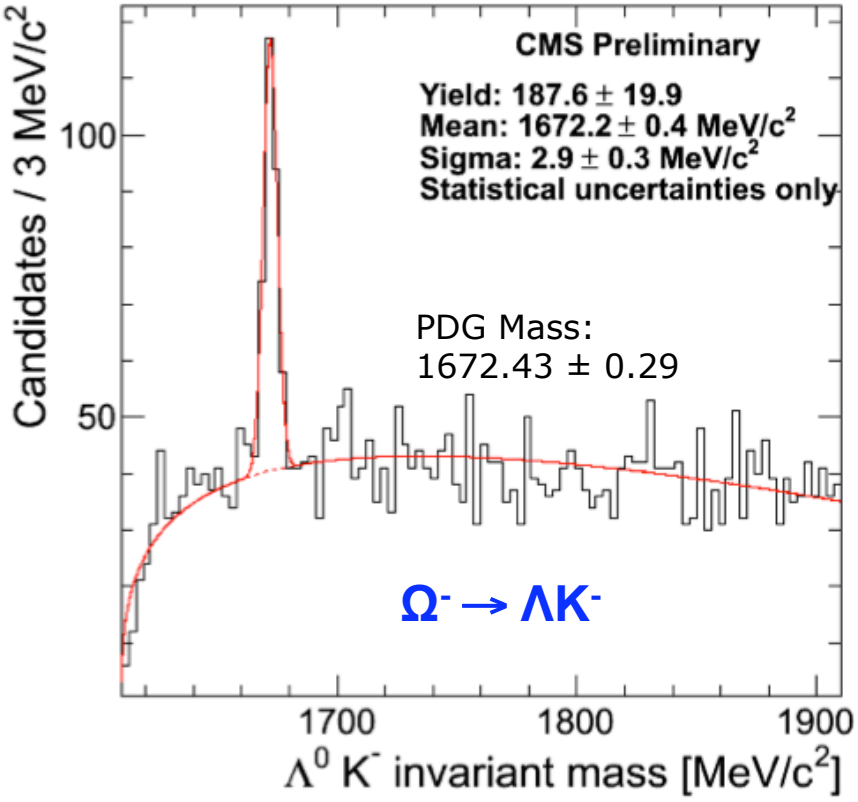
Careful tuning effort of the MC generators is ongoing. Marginal impact on high p_T physics

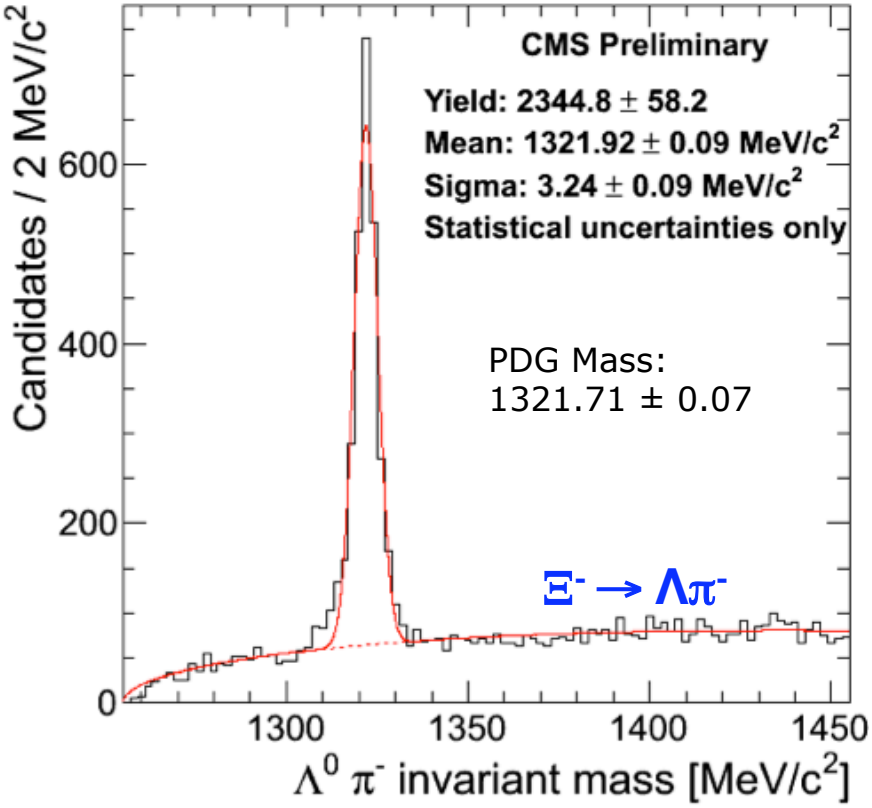
Low mass resonances

- Tracks displaced from primary vertex ($d_{3D} > 3\sigma$)
- Common displaced vertex ($L_{3D} > 10\sigma$)



Invariant mass distribution for different combinations ($\Omega^{\pm} \rightarrow \Lambda K^{\pm}$ or $\Xi^{\pm} \rightarrow \Lambda\pi^{\pm}$) fit to a common vertex.

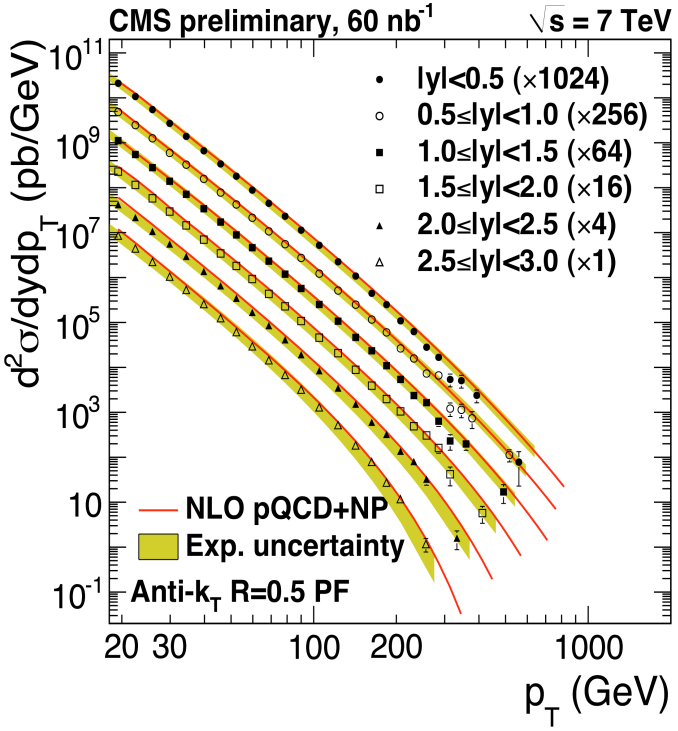




Mass accuracy at the level of 10^{-4} ➔ good alignment of Si-strip and pixels

Inclusive jet cross section

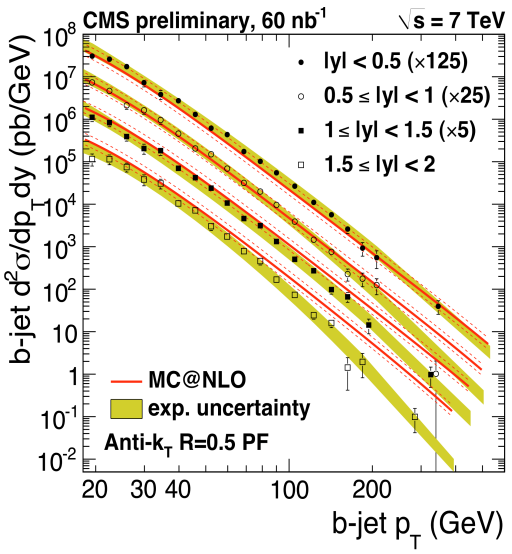
- ✓ Inclusive jet p_T spectra have been produced with three different jet approaches
- ✓ All results are in good agreement with NLO theory
- ✓ With Particle Flow approach distributions can be extended to a low p_T value of 18 GeV.

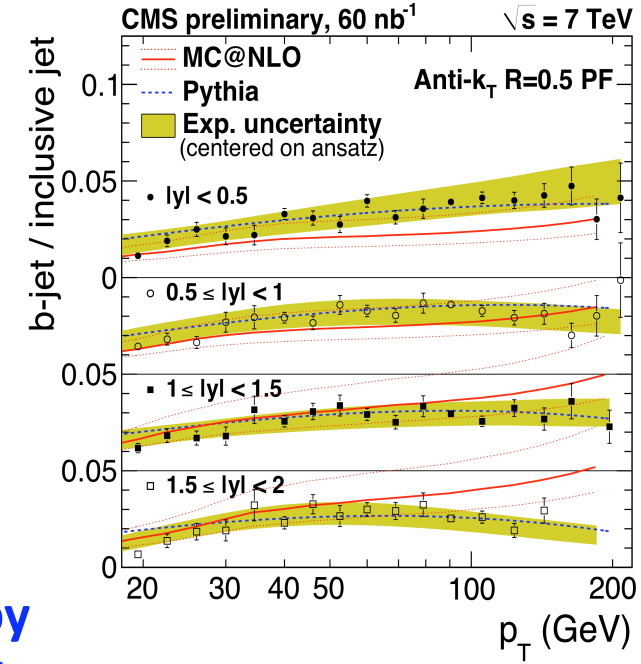


L=60 nb^{-1}

b-jets

High Purity ~ 0.7 using Secondary Vertex Tagger

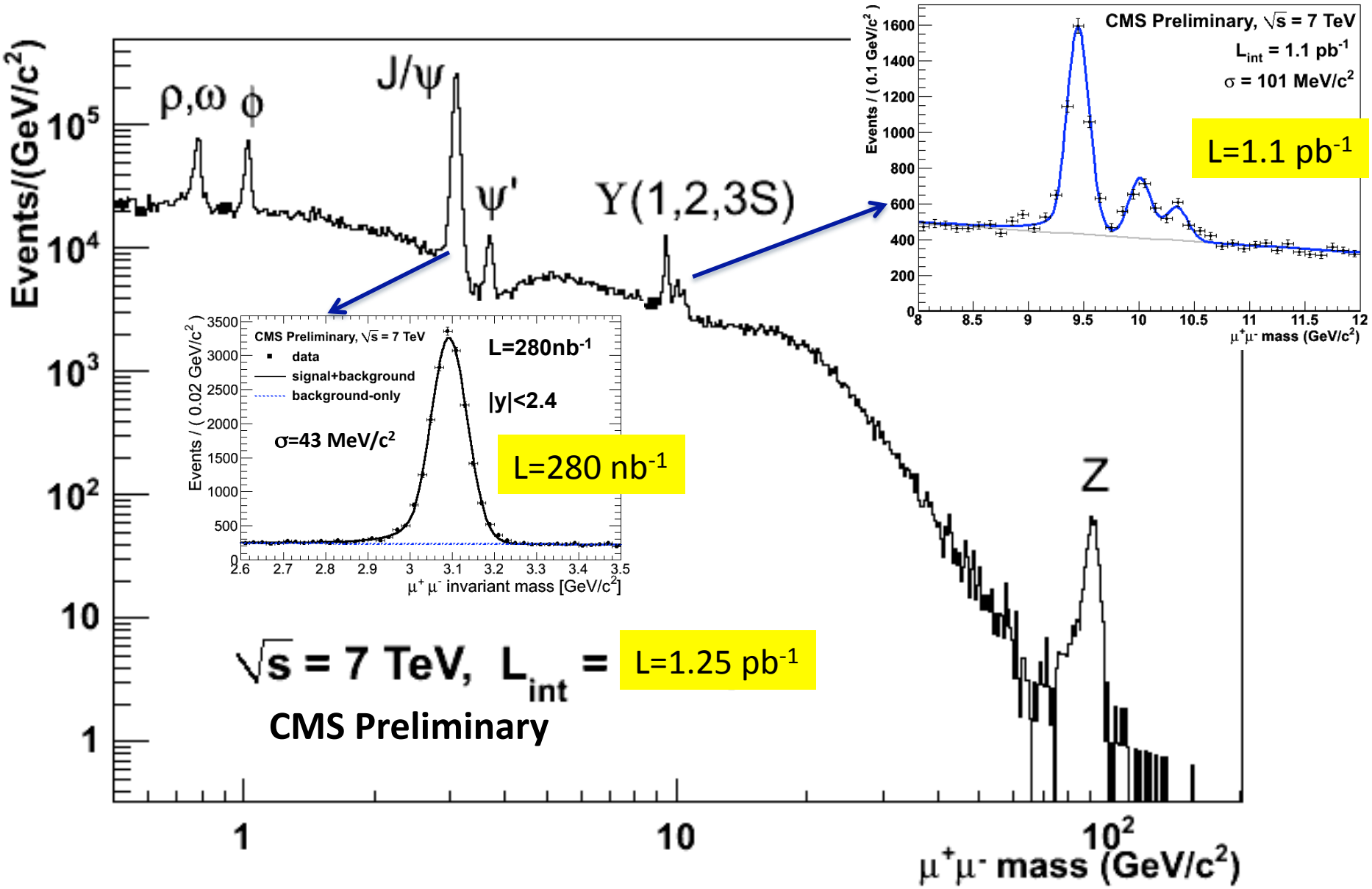




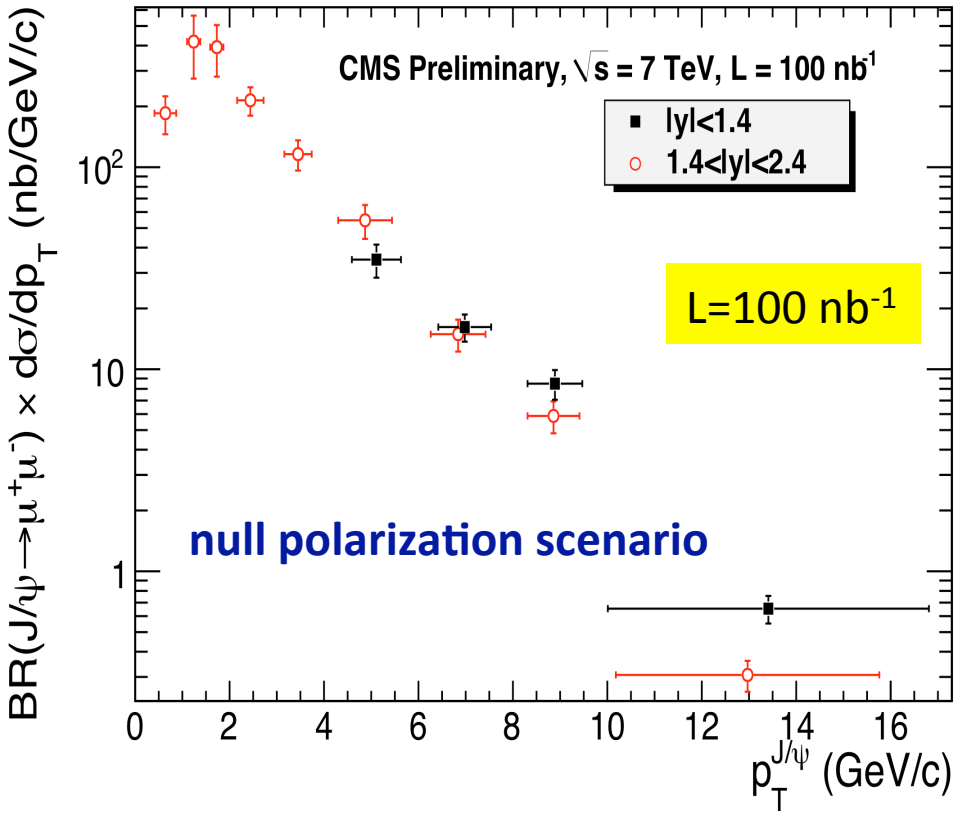
See also poster by Oliver Oberst

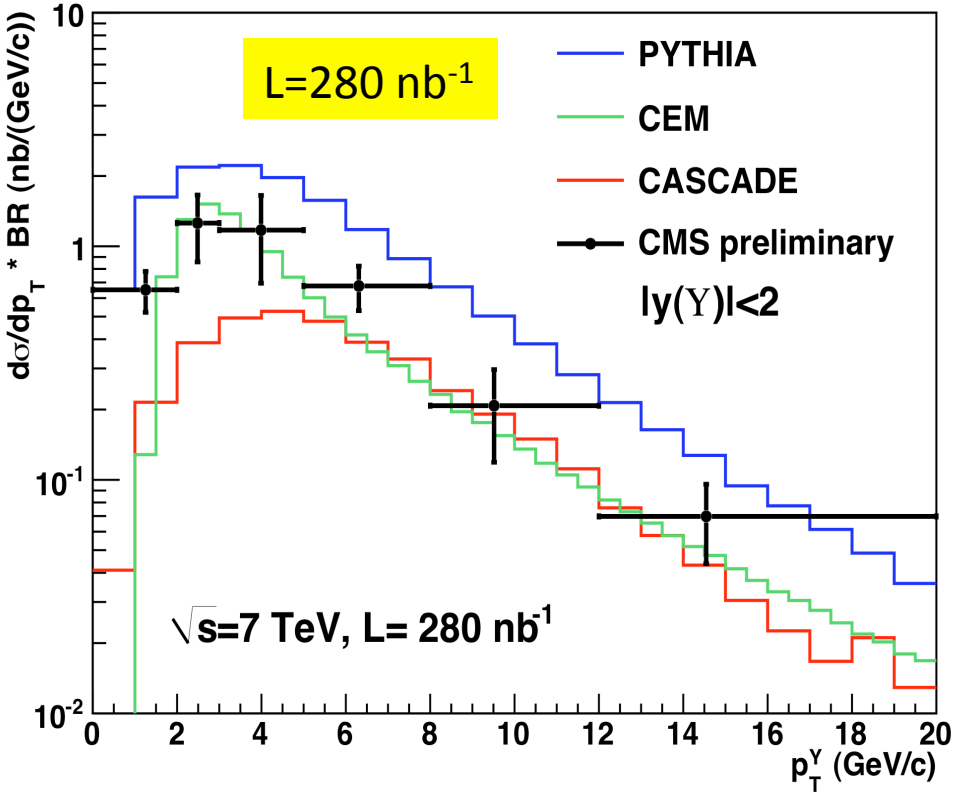
See also poster by Daniel Martschei

Di-muon spectrum



J/ψ(Υ)→μ+μ-
differential &total cross section



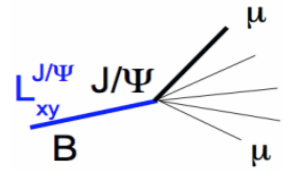


σ(pp→J/ψ + X)·BR(J/ψ→μ+μ−) = (289.1 ± 16.7(stat) ± 60.1(syst)) nb

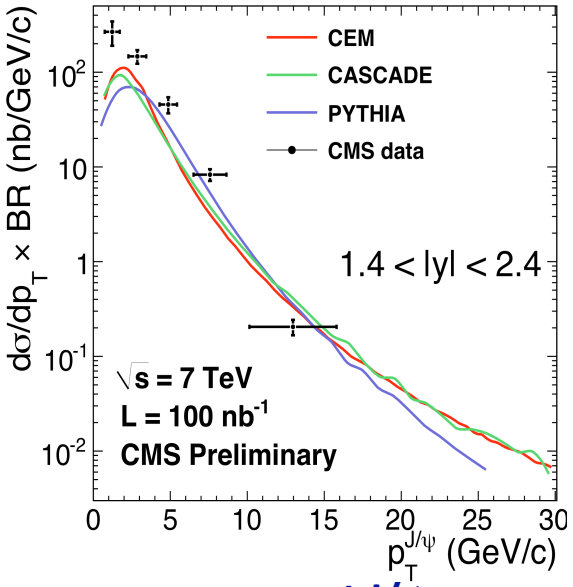
σ(pp →Υ(1S)+X)·B(Υ(1S)→μ+ μ−)=(8.3±0.5(stat)±0.9(syst) ±1.0(lum))nb

systematic uncertainties dominated by:
- **statistical precision of muon efficiency determination from data**
- **uncertainty on the luminosity.**

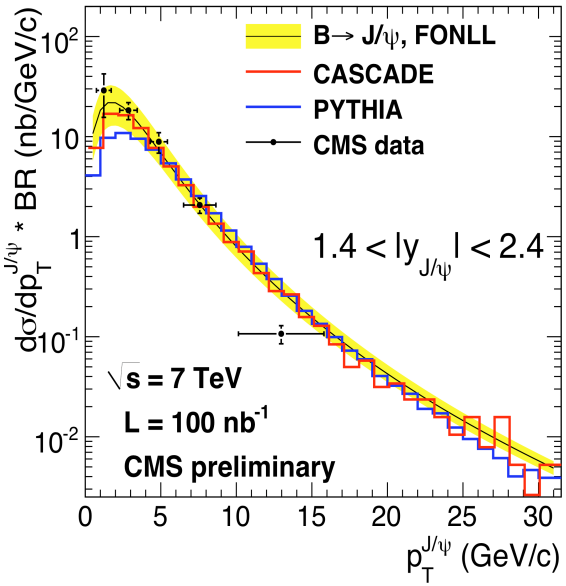
J/ψ from B hadron vs p_T



prompt J/ψ



non prompt J/ψ

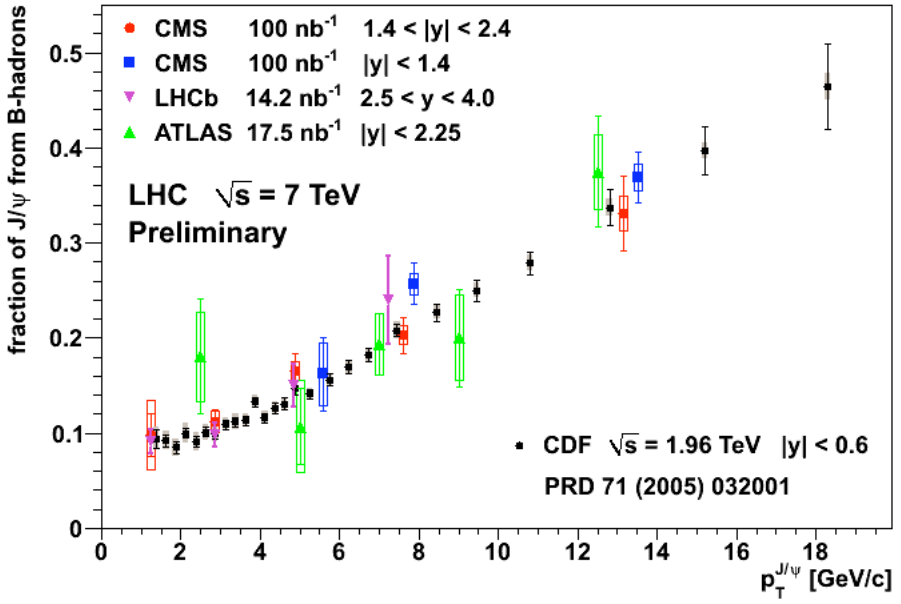


B transverse decay length used to separate the prompt from the non-prompt component

See also poster by Sarah Beranek

L=100 nb^{-1}

LHC and CDF data



Non prompt J/ψ :

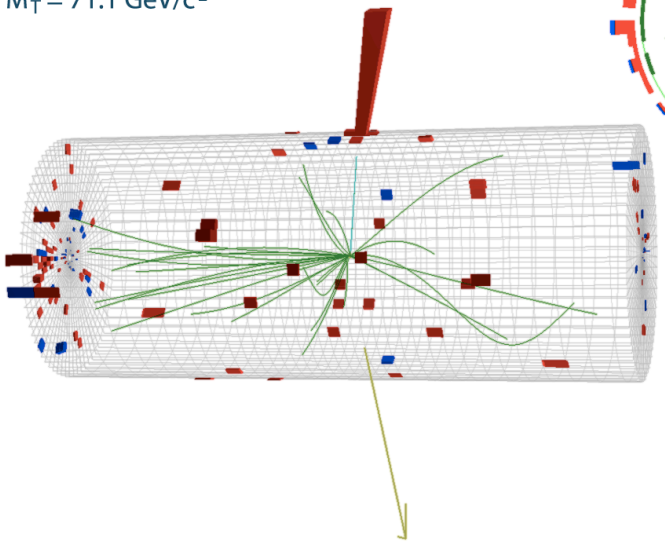
σ_{NP}* BR= **56.1±5.5(stat)±7.2(syst) nb**

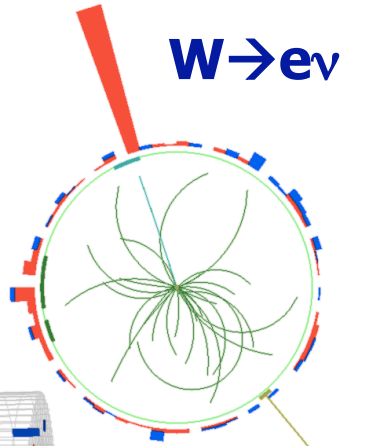
(p_T within 4-30 GeV/c, |η|<2.4)

W/Z candidates

CMS Experiment at LHC, CERN
Run 133874, Event 21466935
Lumi section: 301
Sat Apr 24 2010, 05:19:21 CEST

Electron $p_T = 35.6$ GeV/c
$ME_T = 36.9$ GeV
$M_T = 71.1$ GeV/c^2

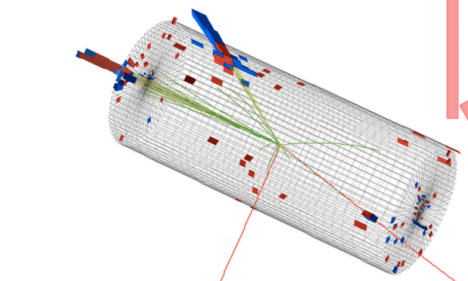


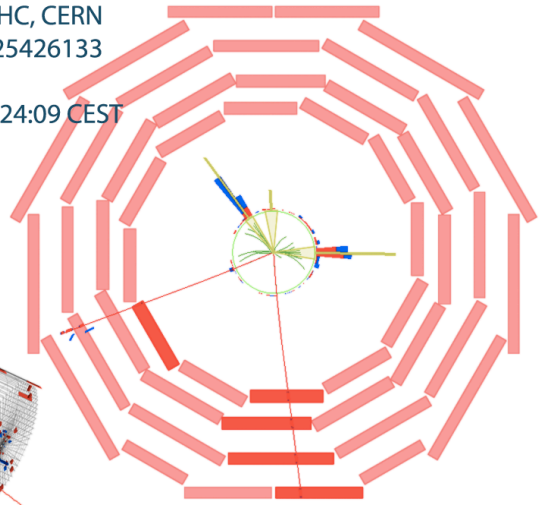


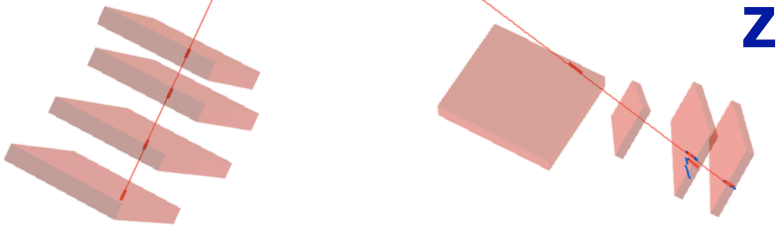
W→eν

CMS Experiment at LHC, CERN
Run 135149, Event 125426133
Lumi section: 1345
Sun May 09 2010, 05:24:09 CEST

Muon $p_T = 67.3, 50.6$ GeV/c
Inv. mass $= 93.2$ GeV/c^2







Z→μμ

See also poster by Manuel Zeise

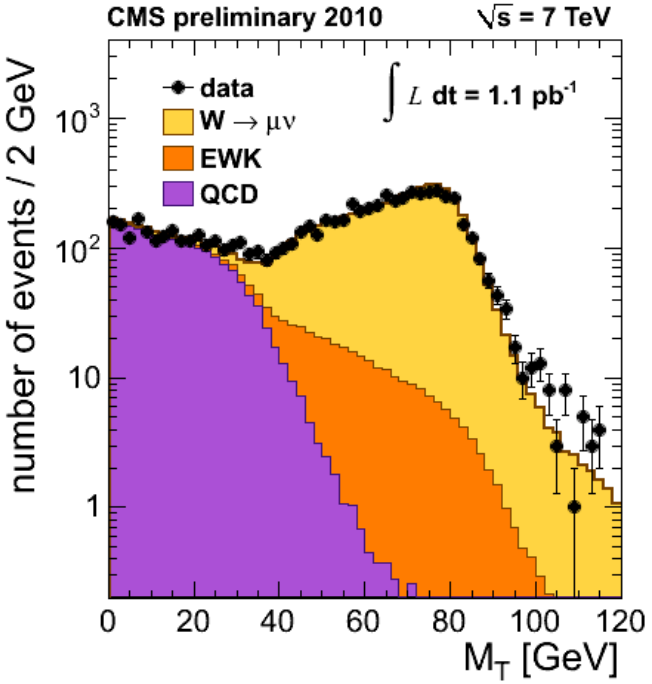
W and Z with μ selection

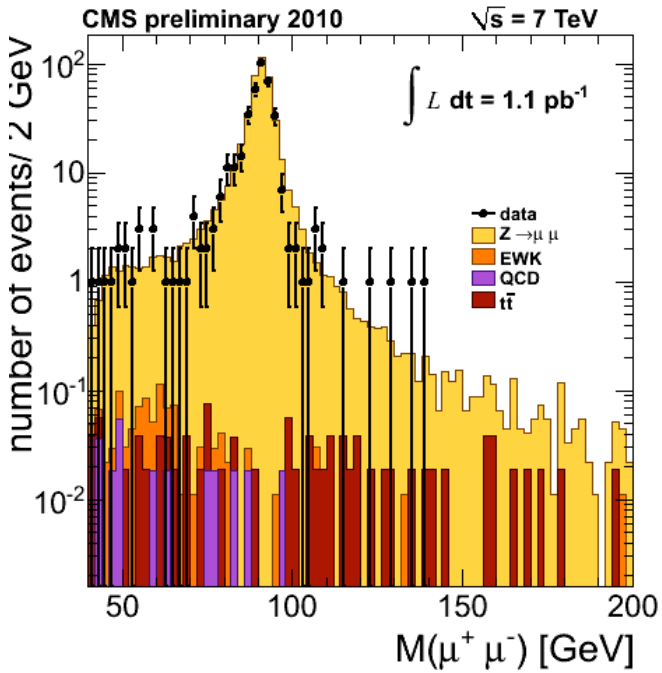
L=1.1 pb^{-1}

- Kinematics
  - For W, p_T > 9 GeV, $|\eta|$ < 2.1
  - For Z, p_T > 20 GeV, one $|\eta|$ < 2.4
- Good quality muon track
  - Hits in pixels, strip tracker, muon system)
  - χ^2/dof < 10
- Z measurement requires only track isolation of 3 GeV in a cone
- For W measurement, use a relative isolation in a cone of ΔR < 0.3:

Source	W channel (%)	Z channel (%)
Muon reconstruction/identification	3.0	2.5
Trigger efficiency	3.2	0.7
Isolation efficiency	0.5	1.0
Muon momentum scale/resolution	1.0	0.5
$\not\!\!E_T$ scale/resolution	1.0	-
Background subtraction	3.5	-
PDF uncertainty in acceptance	2.0	2.0
Other theoretical uncertainties	1.4	1.6
TOTAL (without luminosity uncertainty)	6.3	3.8
Luminosity	11.0	11.0

Simultaneous fits to backgrounds and signal contributions.
QCD background shapes obtained using data.
EWK background shapes and signal from MC.





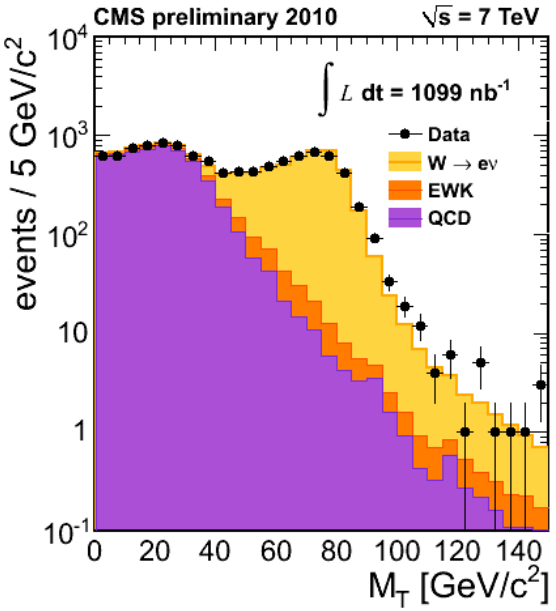
W and Z with e selection

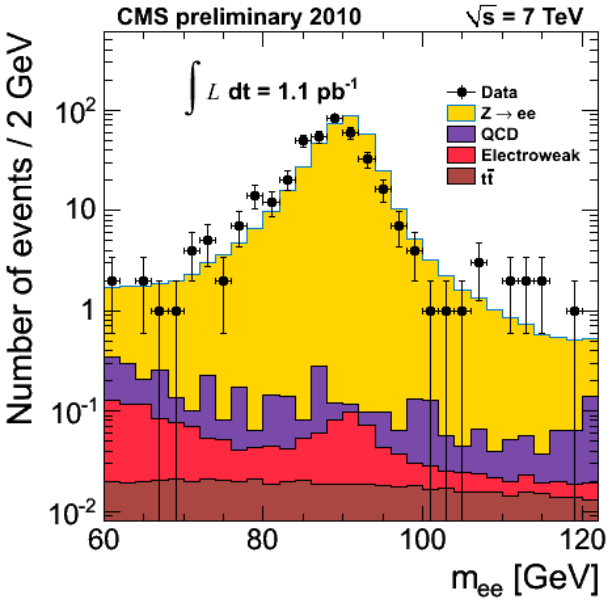
L=1.1 pb^{-1}

- Kinematics
  - p_T > 20 GeV
  - 0.0 < |η| < 1.442
  - 1.566< |η| < 2.5
- Specialized track reconstruction to deal with potential large bremsstrahlung
- Electron identification requirements on shower shape variables
- Isolation requirements in tracker ECAL, HCAL

W: 75% efficiency
Z: 90% efficiency
QCD background shapes from data, EWK background and signal shapes from MC

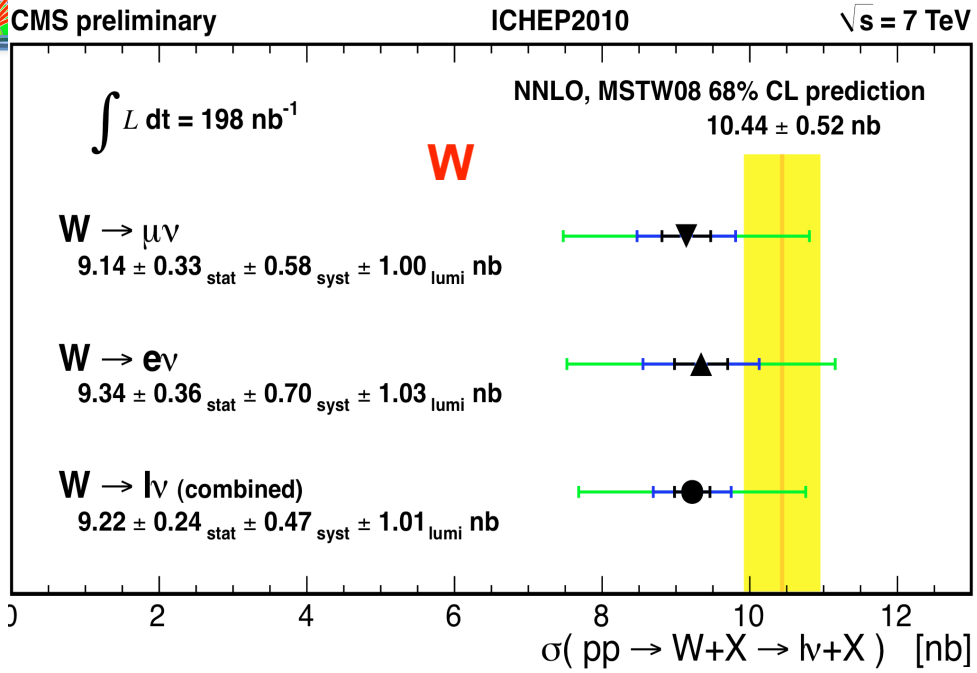
Source	W channel (%)	Z channel (%)
Electron reconstruction/identification	6.1	7.2
Trigger efficiency	0.6	-
Isolation efficiency	1.1	1.2
Electron momentum scale/resolution	2.7	-
$\not\!\!E_T$ scale/resolution	1.4	-
Background subtraction	2.2	-
PDF uncertainty in acceptance	2.0	2.0
Other theoretical uncertainties	1.3	1.3
TOTAL (without luminosity uncertainty)	7.7	7.7
Luminosity	11.0	11.0

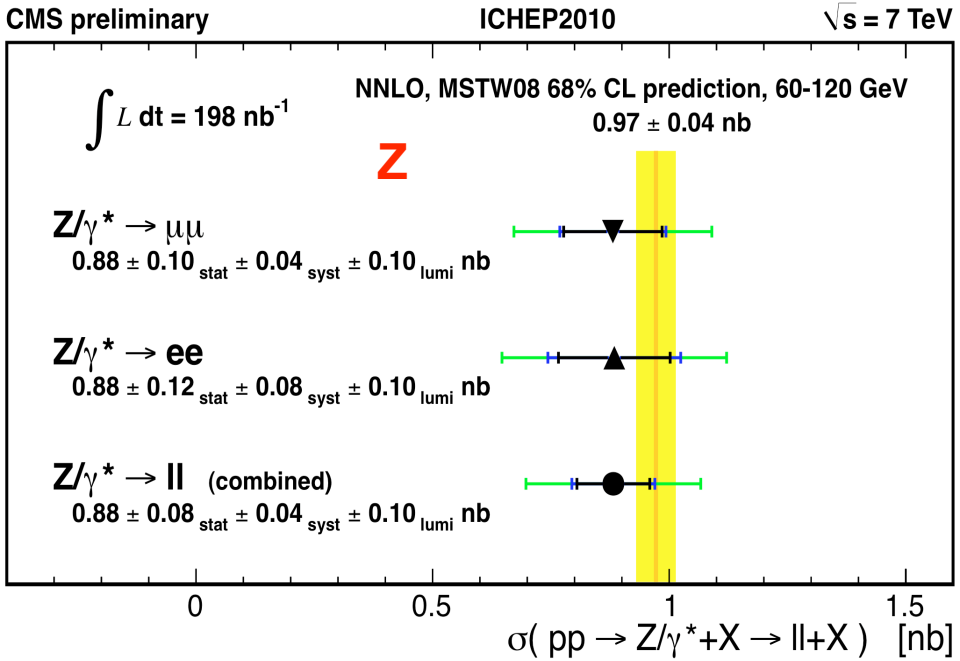




Cross sections results

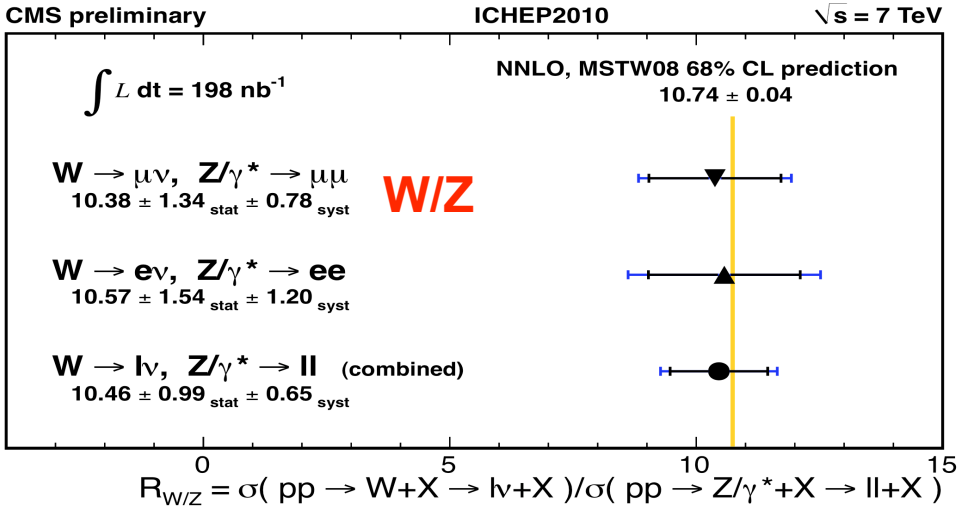
L=198 nb^{-1}





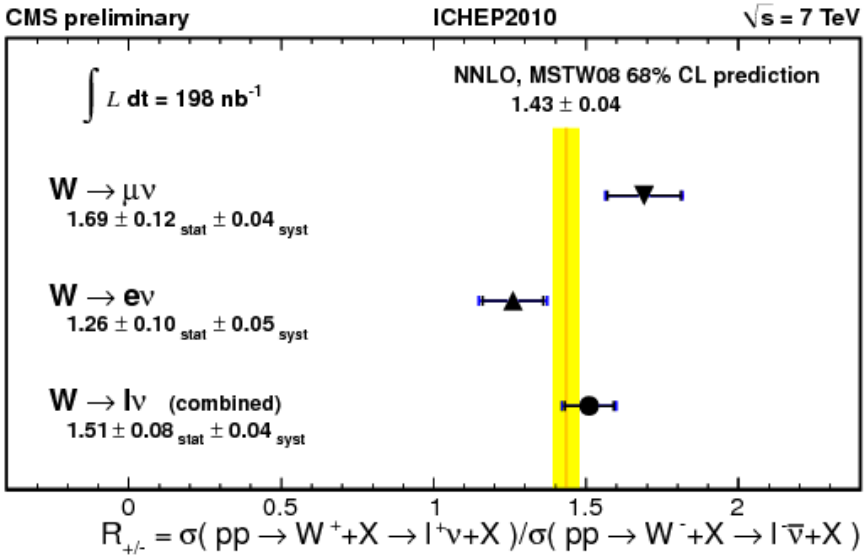
Notice: ~all major components of the measurements (efficiency, background, systematic errors etc) are carefully evaluated using data driven methods

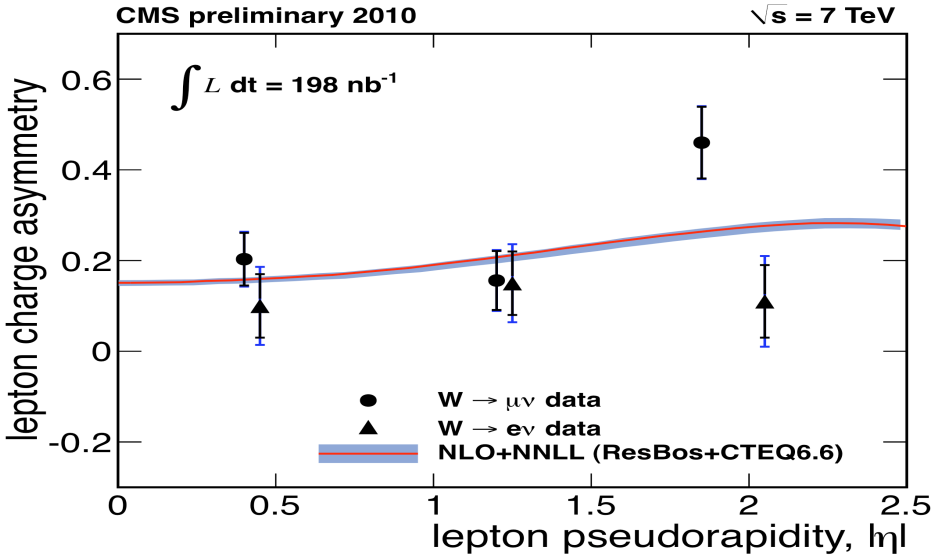
PDF uncertainties evaluated via CTEQ66,MSTW08NLO, NNPDF2.0 sets

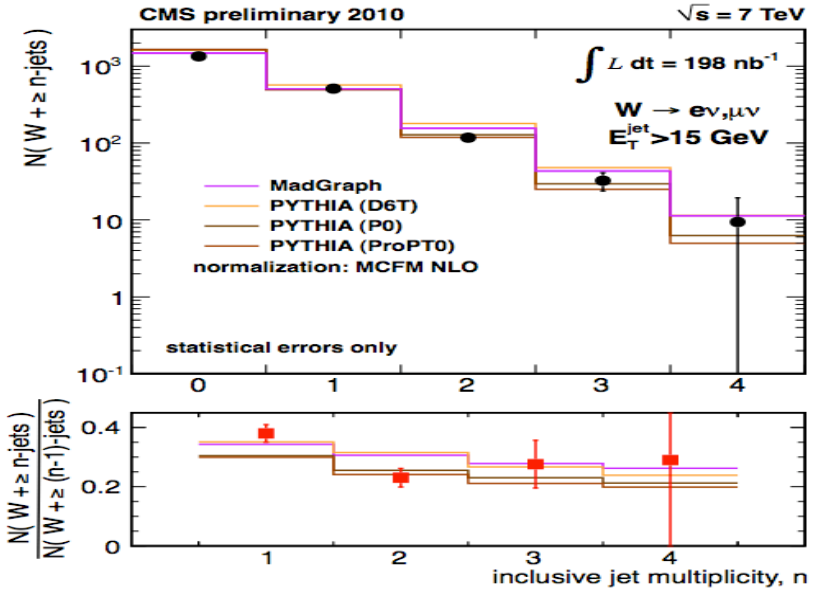


W^+,W^-, charge asymmetry and W+jets

L=198 nb^{-1}



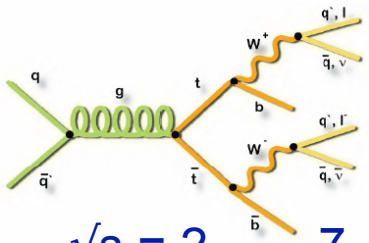




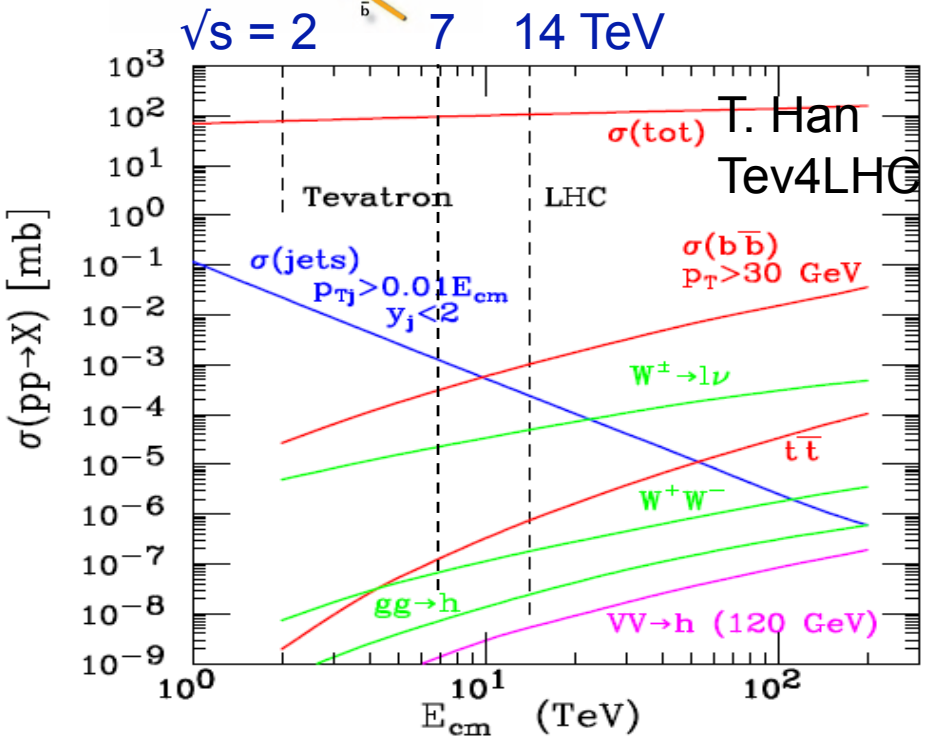
associated production of jets with threshold E_T>15 GeV

and then we deploy everything for hunting the top

Top



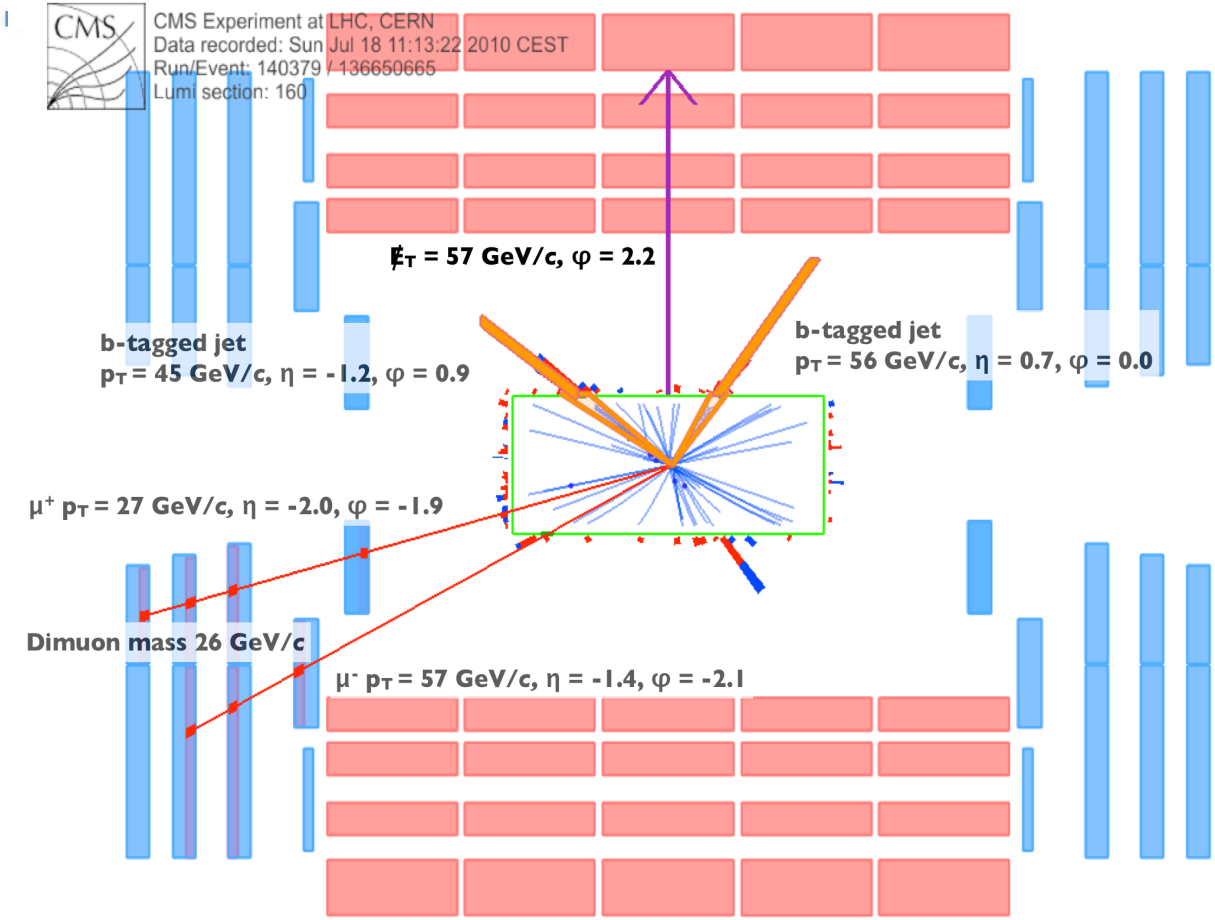
- Precise SM measurements
- A window to new physics
- In many new physics scenarios (e.g. SUSY) top is dominant BG
- Great tool to calibrate detector
  - Jet energy scale, b-jet eff.



- Monte Carlo samples
  - ttbar+jets, W/Z+jets: Madgraph, matching ME with parton showers
    - V+bb/c(c)+jets matrix elements included
  - Cross sections normalized to inclusive NLO cross sections
    - sigma(ttbar,NLO)=157pb (MCFM), mtop=172.5 GeV
    - sigma(W->lnu,NNLO)=31314pb (FEWZ)
  - QCD: PYTHIA (filtered at gen level)

See also posters by Thorsten Chwalek and Yvonne KüSSEL

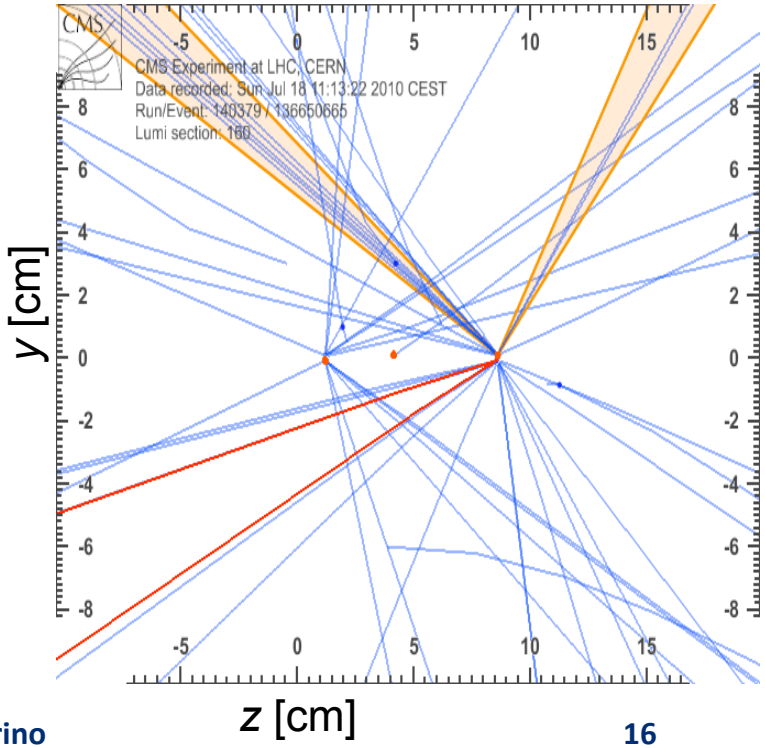
μμ +Jets Candidate



Multiple primary vertices → multiple *pp* collisions ("pile-up")

Jets & muons originate from same primary vertex

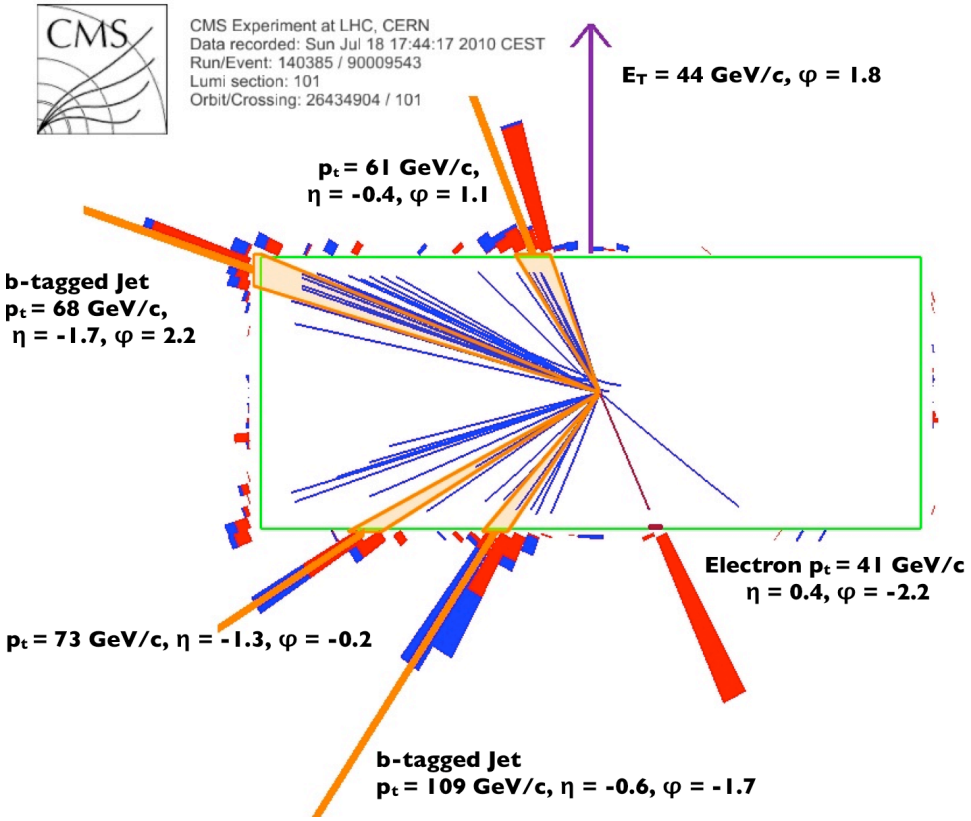
Preliminarily reconstr. Mass in the range 160–220 GeV/c^2 (consistent with m_{top})

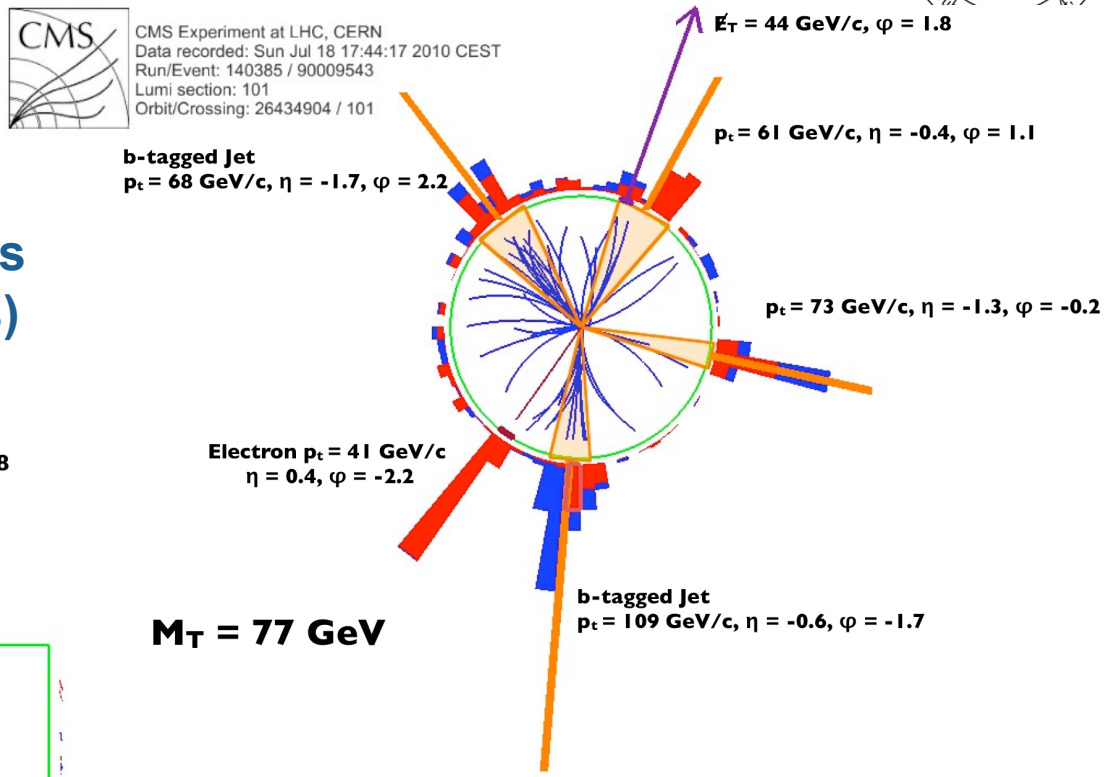


Very clean candidate sitting in a region where we expect very little background!

e+Jets candidate event

Event passes all cuts:
1 high-momentum electron
significant MET ≈ 44 GeV
4 high-p_T jets,
two of which with good/clear *b*-tags
(with reconstructed 2ndary vertices)





m_T(W) ≈ 77 GeV/c²

Mass of 2 untagged jets ≈ 102 GeV/c²

m(jjj) ≈ 208, 232 GeV/c²
(for the two 3-jet combinations)

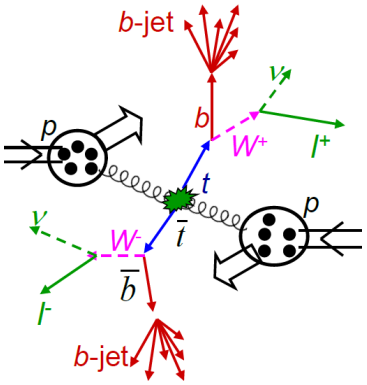
Dilepton and lepton+jets selection

DILEPTON

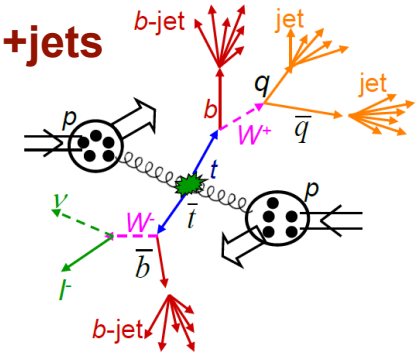
- Single lepton triggers
  - μ+X (Pt>9 GeV,) e+X (Pt>15 GeV)
- Two isolated, opposite charge leptons (ee,mumu,emu)
  - Pt>20 GeV, |eta|<2.5(mu),2.4(e)
  - Rel. isolation < 0.15

$$\text{Rel.isol.} = \frac{\sum_{R<0.3} p_T^{\text{track}} + \sum_{R<0.3} p_T^{\text{ECAL}} + \sum_{R<0.3} p_T^{\text{HCAL}}}{p_T(\text{lepton})}$$

- Z-boson veto
  - |M(ll)-M(Z)|>15 GeV
- Missing Et (MET)
  - Using calorimeter & tracking
  - MET>30(20) GeV in ee,mumu (emu)
- Jets
  - Anti-Kt (R=0.5)
  - Using calorimeter & tracking
  - Pt>30 GeV, |eta|<2.4
  - Expect >=2 jets for ttbar



LEPTON+jets

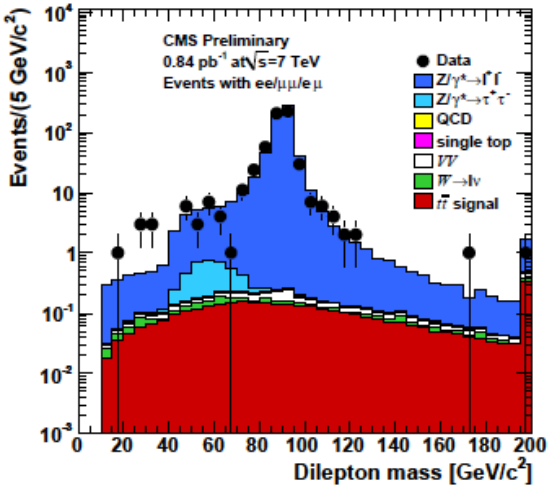


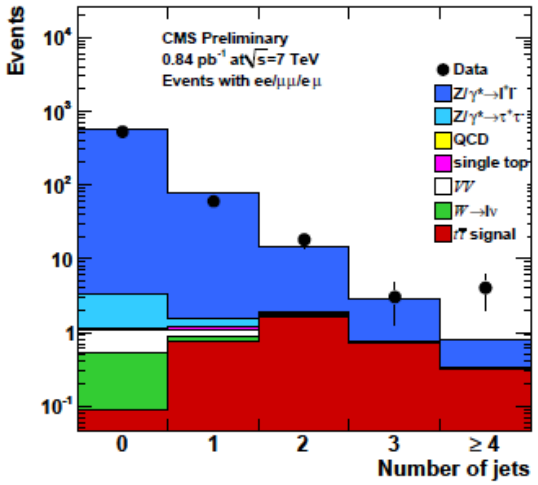
- Considered modes:
  - e+jets
  - mu+jets
- Single lepton triggers
- Exactly one isolated lepton
  - Muons: Pt>20 GeV,|eta|<2.1
  - Electrons: Pt>30 GeV, |eta|<2.4
- Missing Et (MET)
- Not used in event selection, but to reconstruct transverse Mass
- Jets
  - Anti-Kt (R=0.5)
  - Pt>30 GeV, |eta|<2.4
  - Expect >=4 jets for ttbar
  - No b-tagging in baseline selection

Data vs MC dileptons

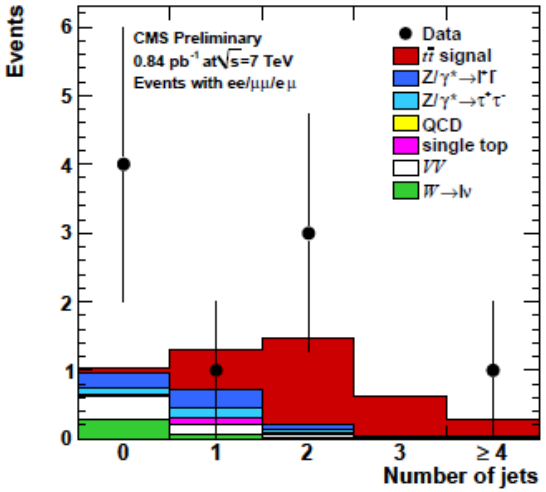
L=840 nb^{-1}

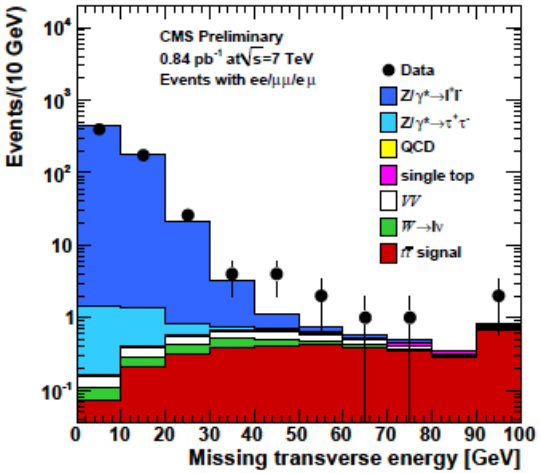
No cuts

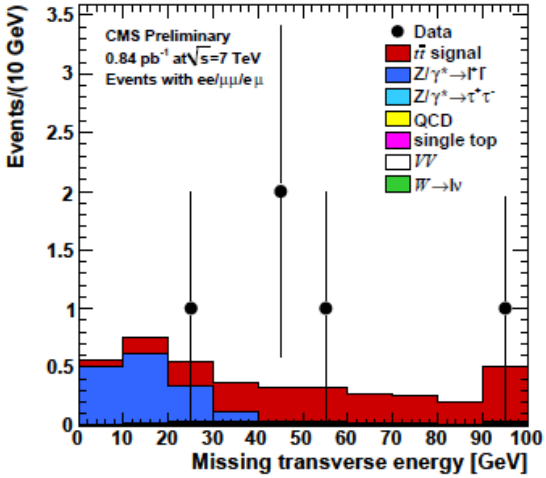




Z-Veto, MET cut



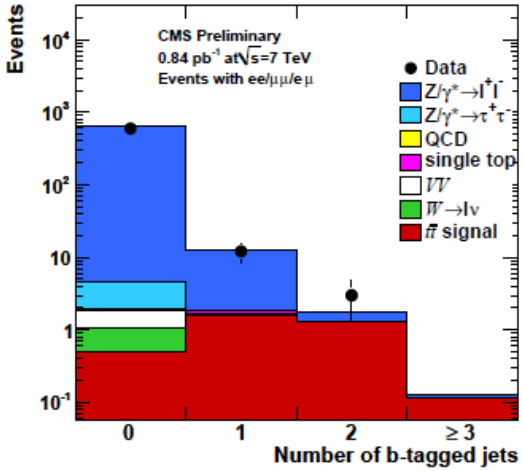




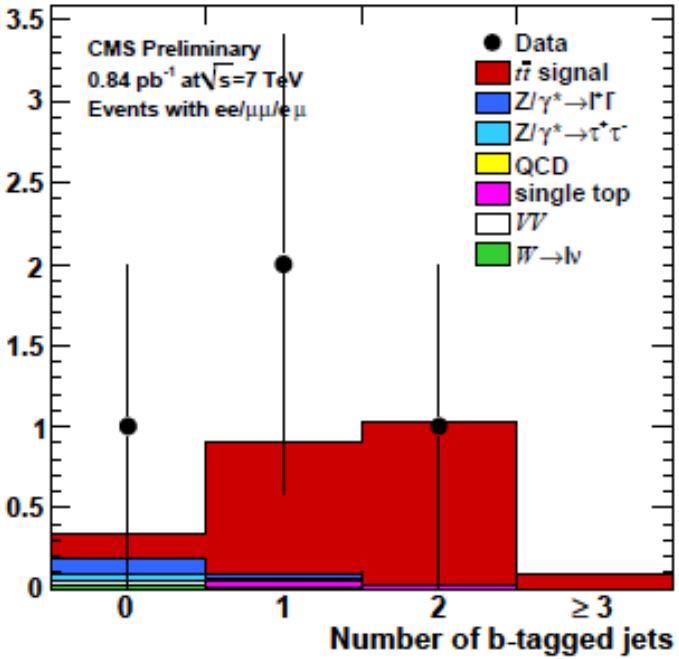
Z-veto, N(jets)>=2

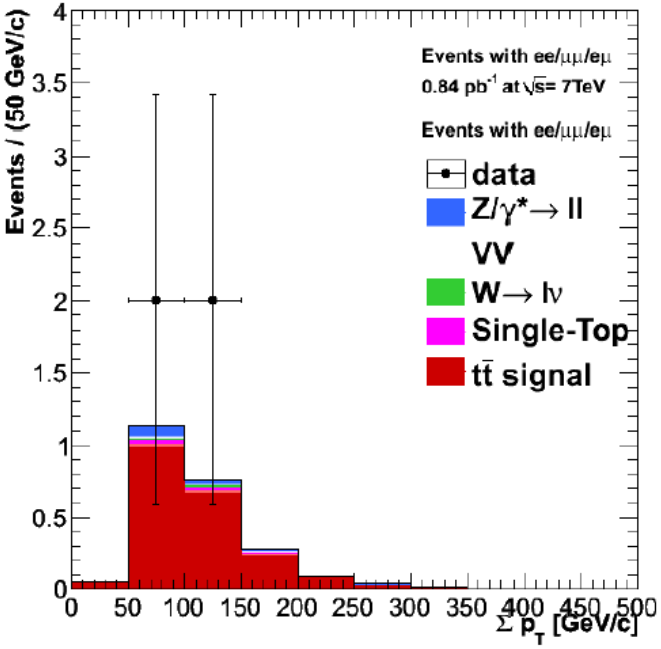
Dilepton: full selection ee/eμ/μμ

L=840 nb^{-1}



- Full selection applied: Z-bosonVeto, |M(ll)-M(Z)|>15 GeV
- MET >30 (20) GeV in ee,μμ, (eμ); N(jets)≥2



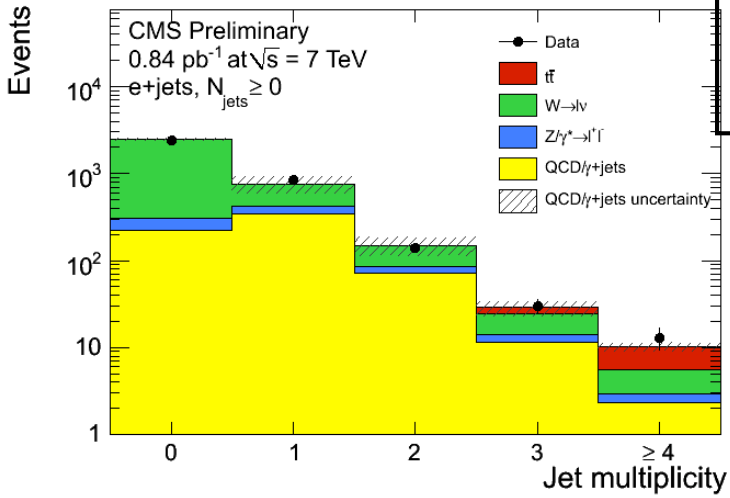


4 ttbar candidates (1eμ, 1ee, 2μμ) over a negligible background.

Electron, muon +Jets

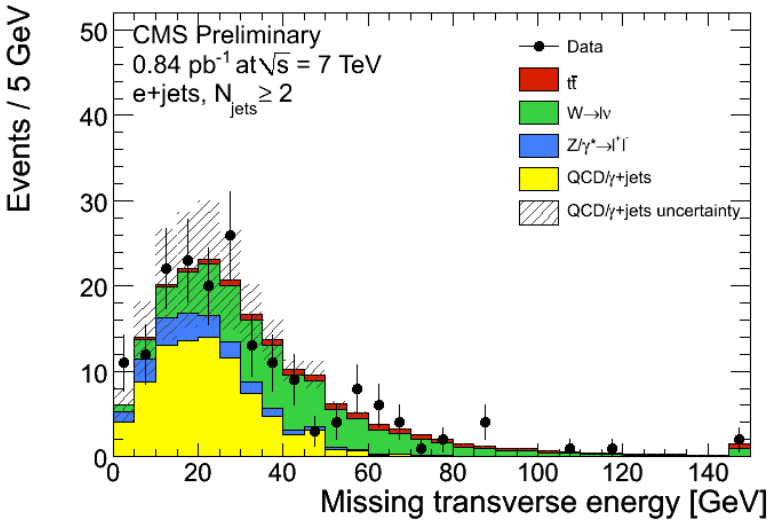
L=840 nb^{-1}

No b-tagging, no MET cut applied



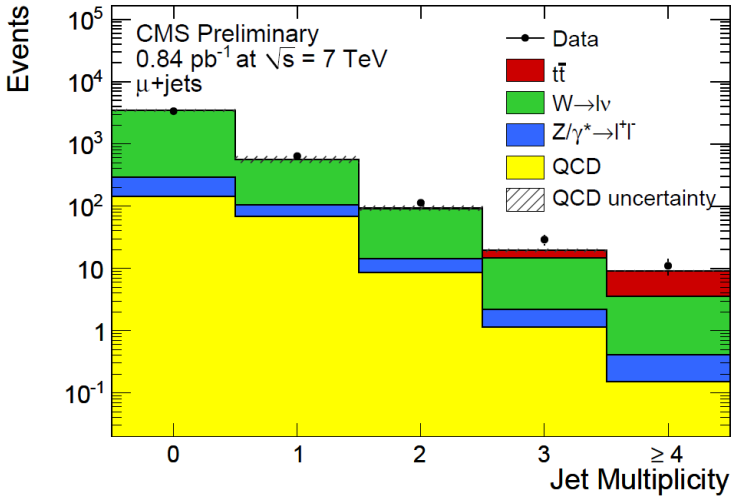
MC Uncertainties:

- Jet energy scale (known to 10%)
- Luminosity (known to 11%)
- Cross section unc. (scale,PDF)

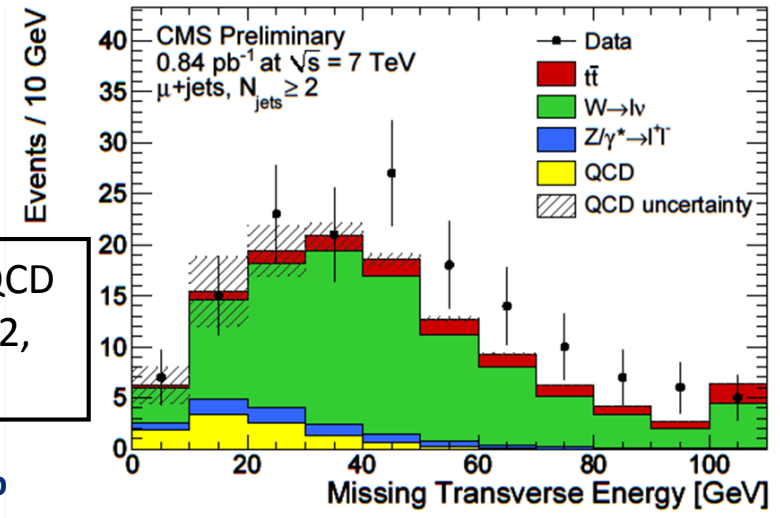


Njets>=2

Good agreement in all Jet bins!



- Consistent with QCD too low by factor ~2, indep. of N(jets)

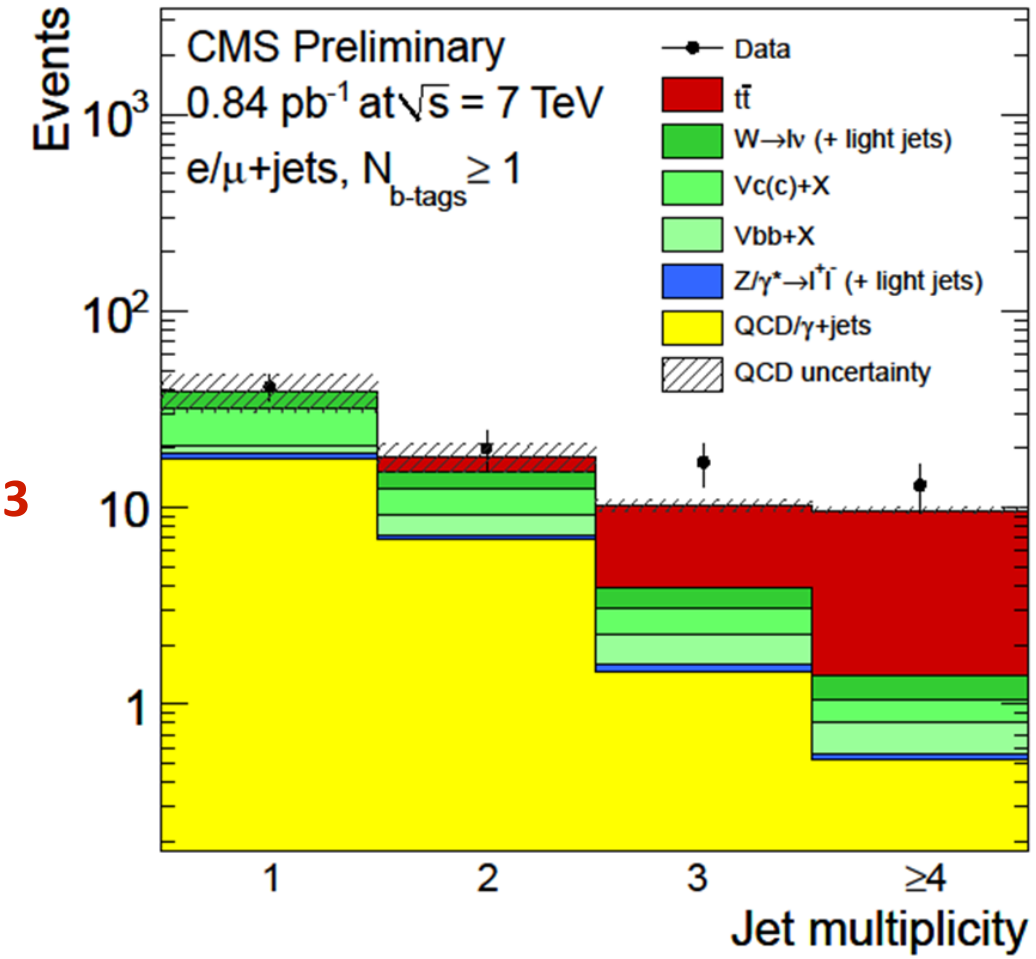


e/μ+jets with b-tagging

requiring at least 1 jet b-tagged
(secondary vertex tagger with ≥2 tracks; high efficiency with ~1% fake rate)

N(jets)>=3:

- **Observed: 30 candidates**
- **Prediced background: N(BG,MC)=5.3**
- **Predicted signal: N(ttbar,MC)=15**



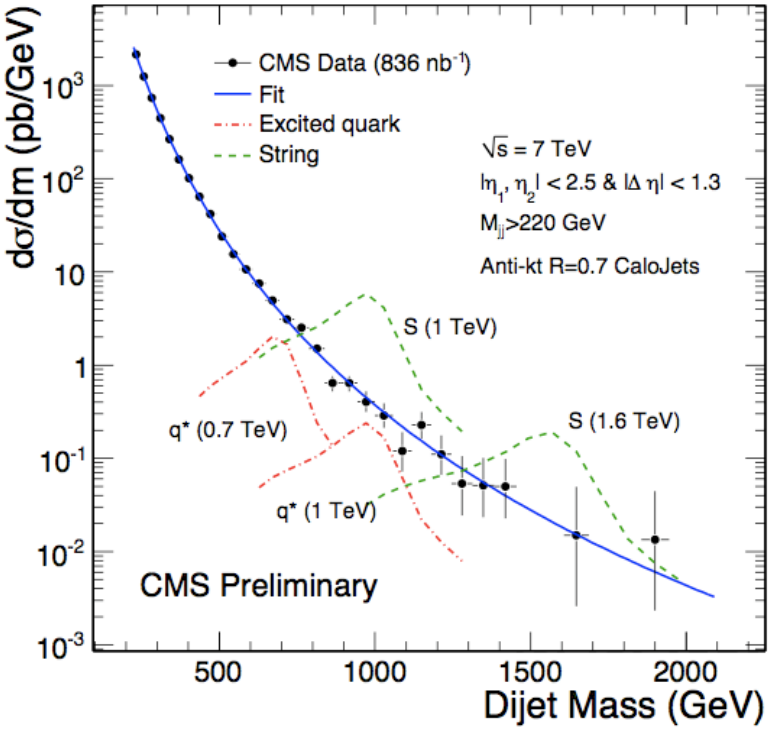
Seeing ttbar events at a rate roughly consistent with NLO cross section, considering experimental (JES,b-tagging) and theoretical (scale, PDF, HF modelling, …) uncertainties

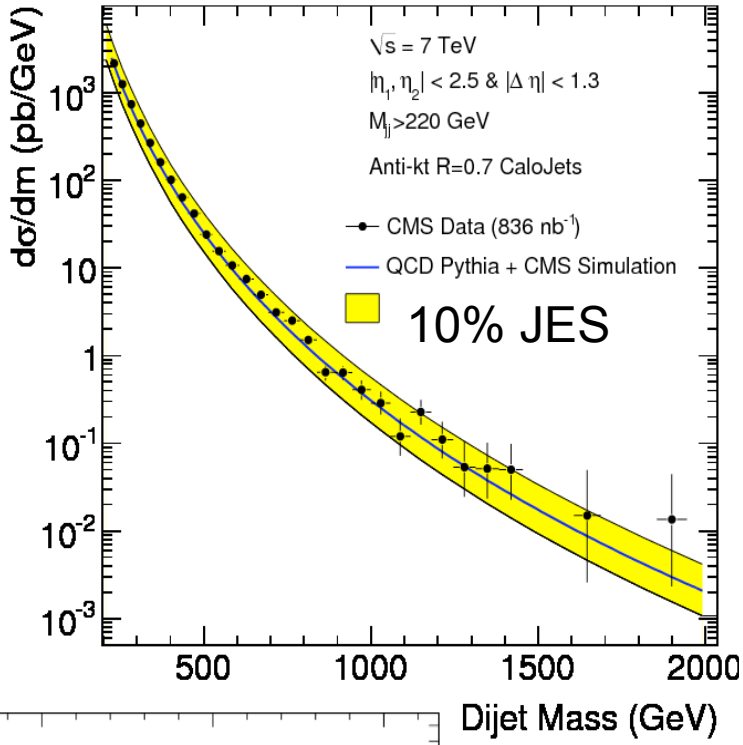
Search for narrow resonances in di-jet

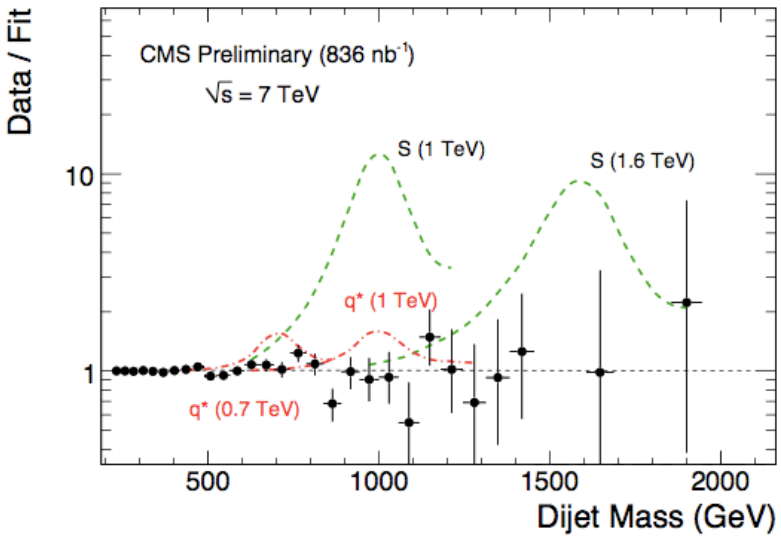
L=840 nb^{-1}

dijet mass differential cross section:

2 anti-k_t ($\Delta R<0.7$) calorimetric jets with
$|\eta_1,\eta_2|<2.5$ and $|\Delta\eta_{12}|<1.3$
Distribution sensitive to the coupling
of any new massive object to quarks and gluons





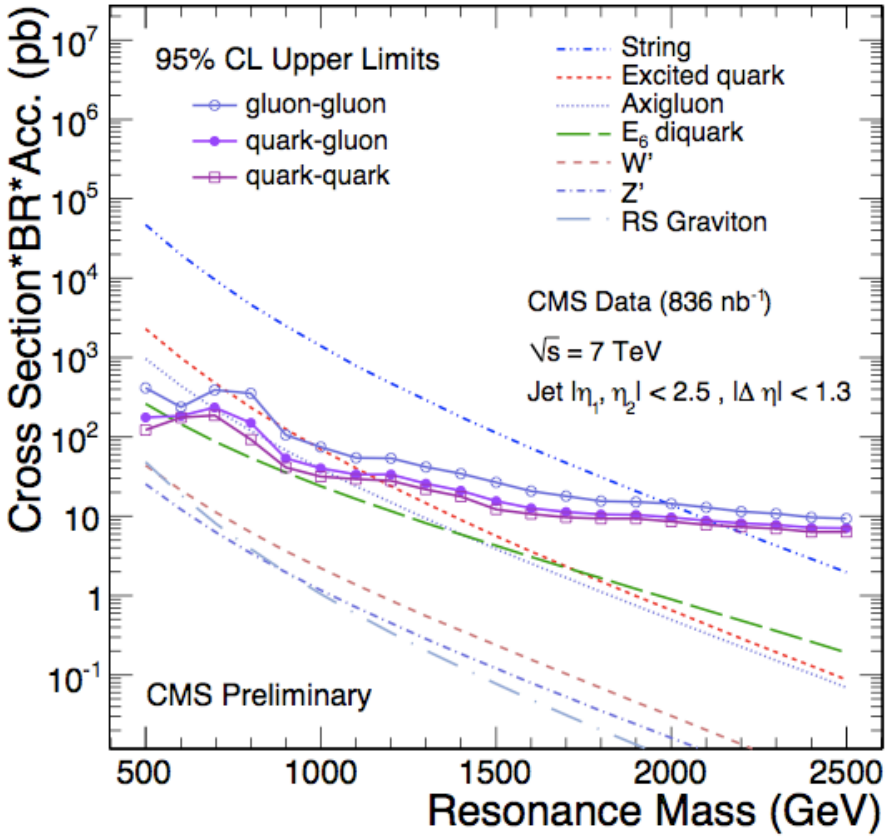


NO indication of New Physics

Di-jet resonances: cross section limits

Several models of parton resonances, massive qq, qg,gg decaying to di-jets, to be compared to cross section limits on qq, qg, gg obtained from data

Model Name	X	Color	J^P	$\Gamma/(2M)$	Final-state Partons
String	S	mixed	mixed	0.003-0.037	qq, qq, gg and qg
Axigluon	A	Octet	1^+	0.05	$q\bar{q}$
Coloron	C	Octet	1^-	0.05	$q\bar{q}$
Excited Quark	q*	Triplet	$1/2^+$	0.02	qg
E_6 Diquark	D	Triplet	0^+	0.004	qq
RS Graviton	G	Singlet	2^+	0.01	$q\bar{q}$, gg
Heavy W	W′	Singlet	1^-	0.01	$q\bar{q}$
Heavy Z	Z′	Singlet	1^-	0.01	$q\bar{q}$



L=840 nb^{-1}

95% C.L. Mass Limit [TeV] using CTEQ6L

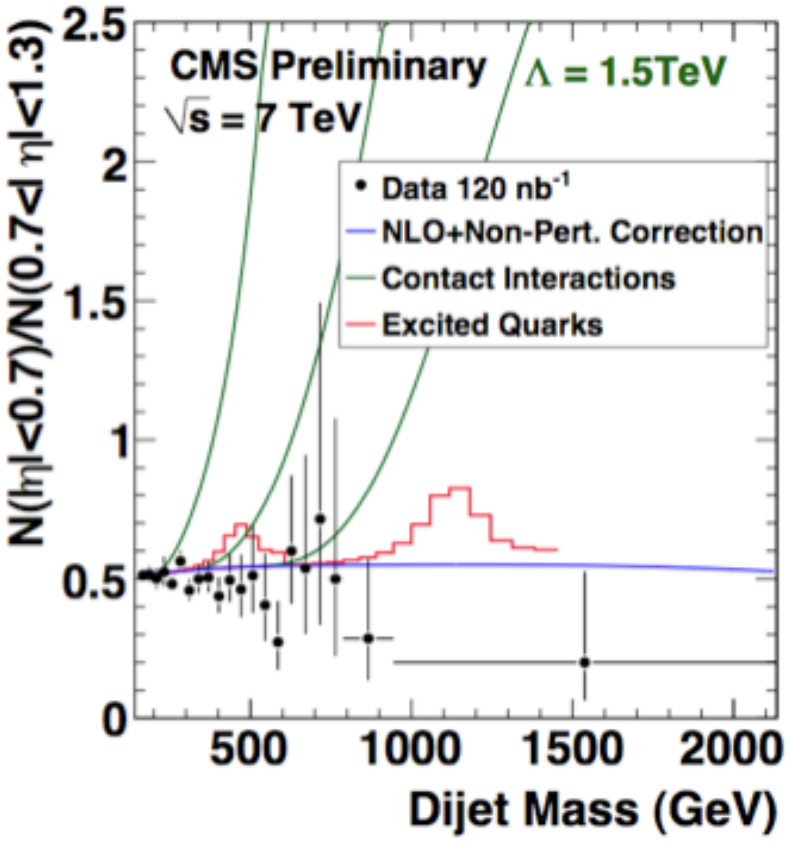
Model	CMS (836 nb^{-1})	CDF (1.13 fb^{-1})
String	2.10	1.4
q*	1.14	0.87
Axigluon/ Coloron	1.06	1.25
E_6 Diquark	0.58	0.63

Quark compositeness - di-jet centrality ratio

L=120 nb^{-1}

$$R = \frac{N(|\eta| < 0.7)}{N(0.7 < |\eta| < 1.3)}$$

quantifies the centrality of the dijet angular distribution at a given dijet mass (many uncertainties canceled)



- roughly flat for t-channel QCD

data agree well with NLO+non pert. Corrections

No sign for New Physics

- bumps for resonance

not seen

- rises for quark contact interaction

limit on the contact interaction scale Λ as a function of integrated luminosity

Λ< 1.9 TeV

excluded at 95% C.L.

(Tevatron excludes Λ<2.8 TeV)

Heavy stable charged particles

L=198 nb^{-1}

Long Lived Heavy Particles appear in many BSM scenarios:

✓**Leptons-like**: no strong interaction

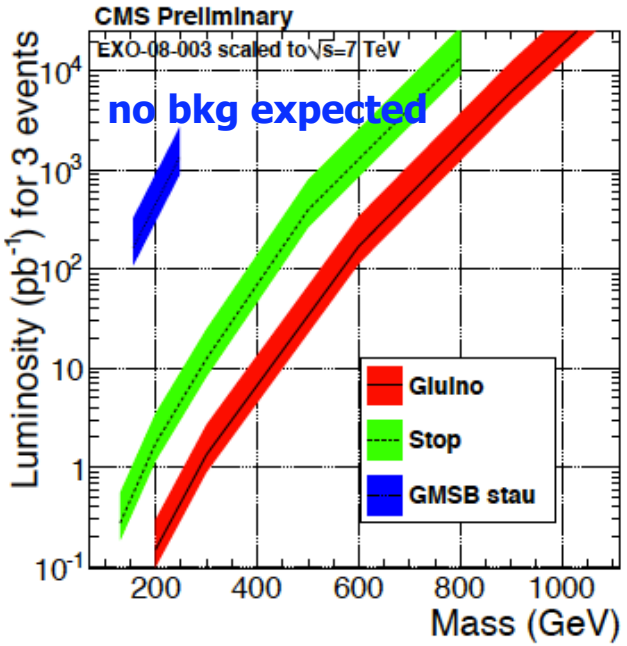
✓**Hadron-like:** hadronize to form **R-hadrons**

If charged, loose E in the detector and may even stop and decay out of time

- look for tracks with high p_T, high dE/dx in Silicon Tracker (sensitive to $\beta<0.3$)
- search for stopped particles (sensitive to $\beta>0.3$)

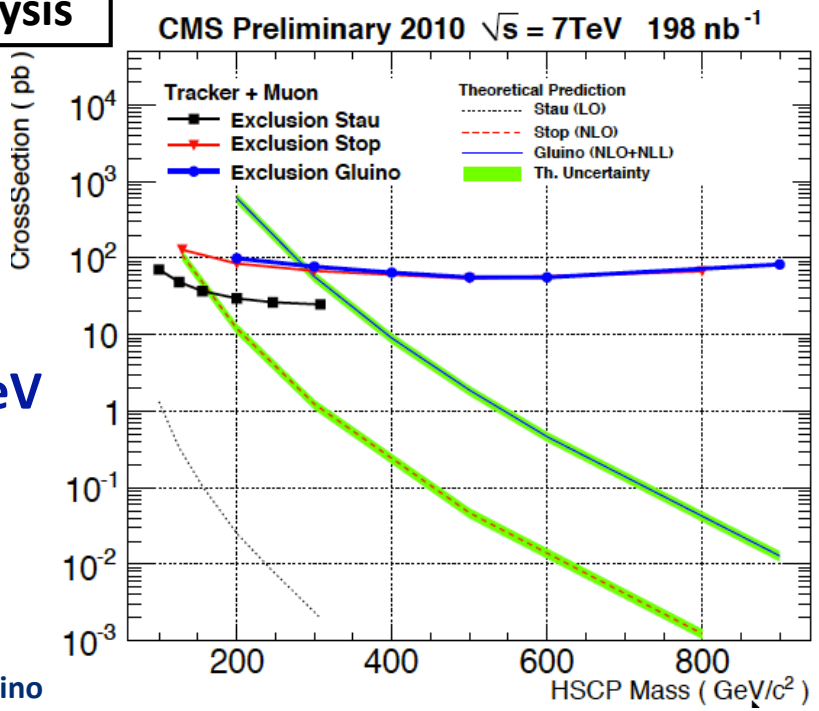
See also poster by Fedor Ratnikov

Discovery potential at 7 TeV



No event observed in track+muon analysis

Gluino mass < 284 GeV



Stopped gluinos

L=203-232 nb^{-1}

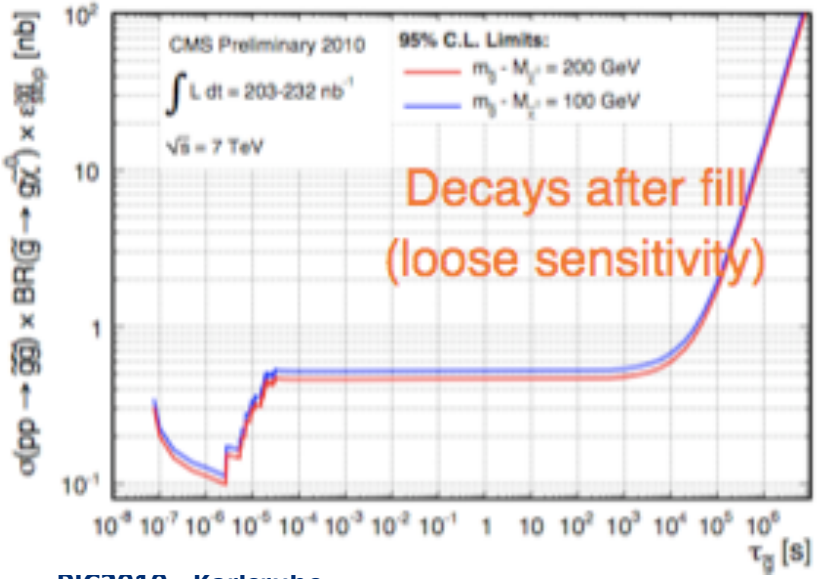
Search for particles stopping in the detector (~ 20%)

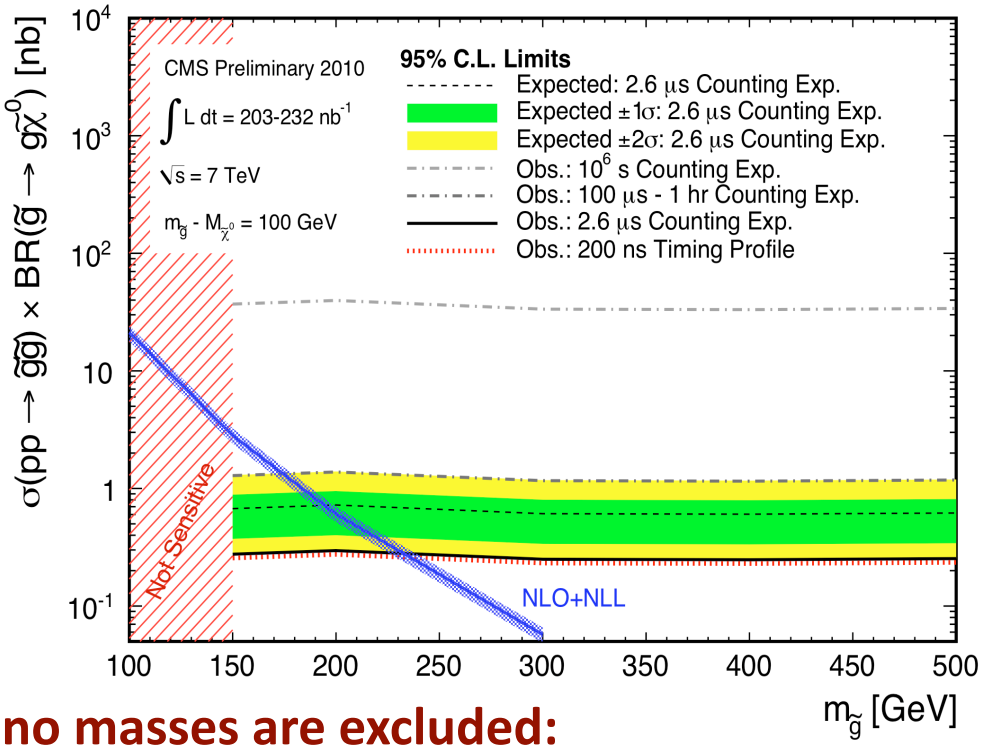
➔ **special calorimeter trigger for "no collisions"**

Counting experiment in lifetime bins

Lifetime [s]	Expected Background (± stat ± syst)	Observed
1e-07	$0.15 \pm 0.04 \pm 0.05$	0
1e-06	$1.8 \pm 0.5 \pm 0.5$	0
1e-05	$11.7 \pm 3.2 \pm 3.5$	8
1e-04	$28.3 \pm 7.8 \pm 8.5$	19
1e-03	$28.3 \pm 7.8 \pm 8.5$	19
1e+03	$28.3 \pm 7.8 \pm 8.5$	19
1e+04	$28.3 \pm 7.8 \pm 8.5$	19
1e+05	$28.3 \pm 7.8 \pm 8.5$	19
1e+06	$28.3 \pm 7.8 \pm 8.5$	19

Limit on cross section per stopping probability





Gluino masses are excluded:

< 200 GeV (120 ns < τ < 6 μs)

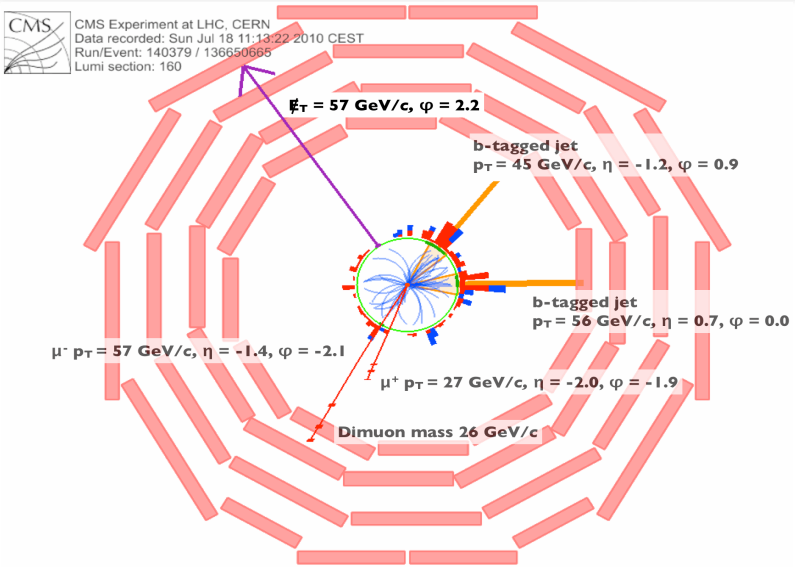
< 229GeV (τ=200ns)

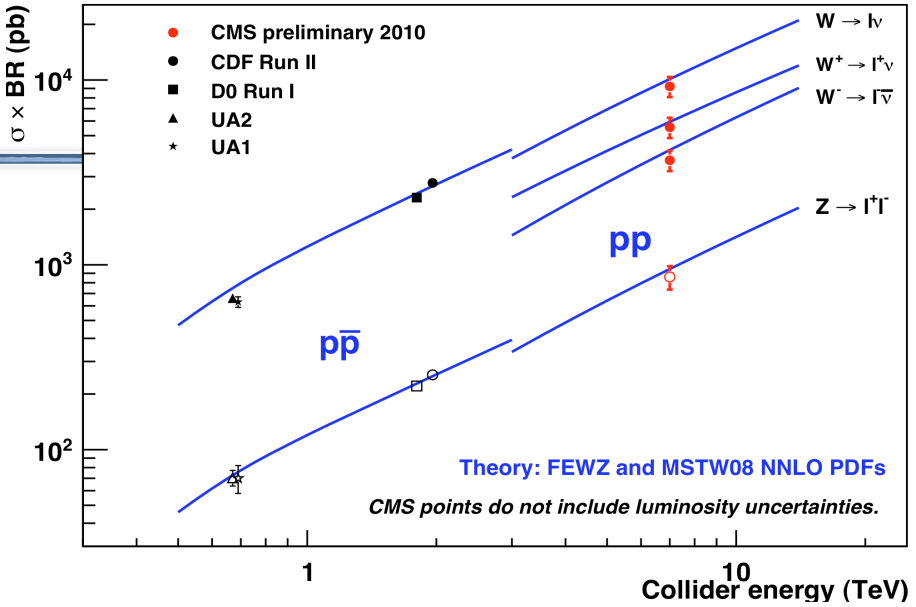
< 225GeV (τ=2.6μs)

Extend D0 results τ < 30 μs

See also poster by Fedor Ratnikov

Summary





- ✓ All measurements in fairly good agreement with theoretical predictions
- ✓ Measured, J/ψ, Y, W and Z cross section
- ✓ Established Top signal with ~1 pb^{-1}: cross sections soon!
- ✓ Exclusion limit on contact interaction $\Lambda < 1.9$ TeV (95% C.L.)
- ✓ First measurements BSM competitive with Tevatron:
- ✓ Exclusion limits on gluino mass
  - ✓ < 200 GeV (120 ns < τ < 6 μs)
  - ✓ < 284 GeV from HCSP searches

Model	CMS (836 nb^{-1})	CDF (1.13 fb^{-1})
String	2.10	1.4
q*	1.14	0.87
Axigluon/ Coloron	1.06	1.25
E_6 Diquark	0.58	0.63

Conclusions

- CMS is performing well and continues to produce physics results on SM
- Careful and systematic exploration of 7 TeV collisions is proceeding at full speed with integrated luminosity
- In the search for some of the new massive particles that could hint to new physics we have already reached Tevatron limits
- More needs to be understood: (open beauty in Daniel Troendle's poster), something new will come from approval: i.e. leptoquarks (Paolo Rumerio's poster) and all data collected so far must be digested
- More data are needed (1 fb^{-1}) for single top (Steffen Röcker's poster), di-bosons, Higgs…..

Stay tuned!