



Eredita` LHC Run1: QCD, Elettrodebole e Top

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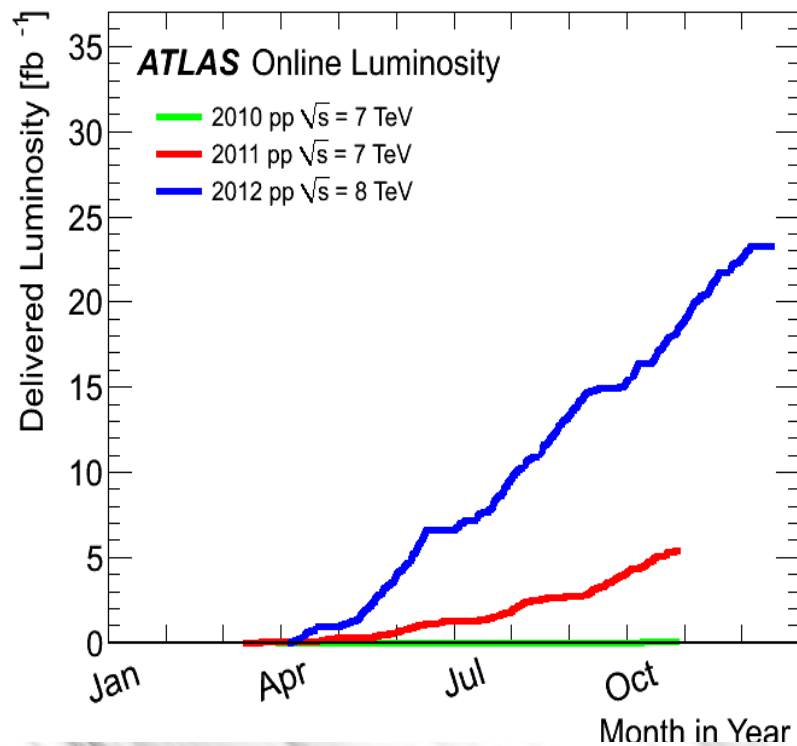
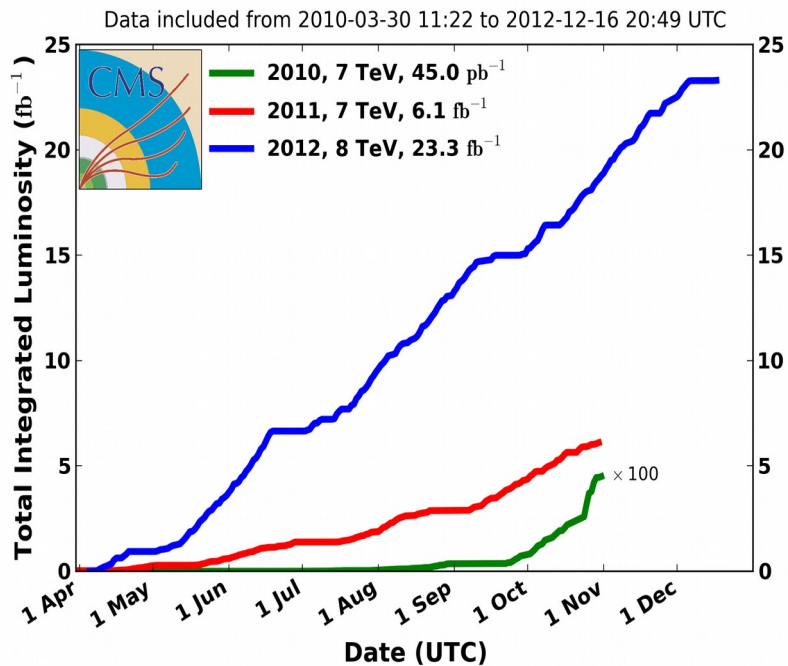
Per le collaborazioni ATLAS e CMS

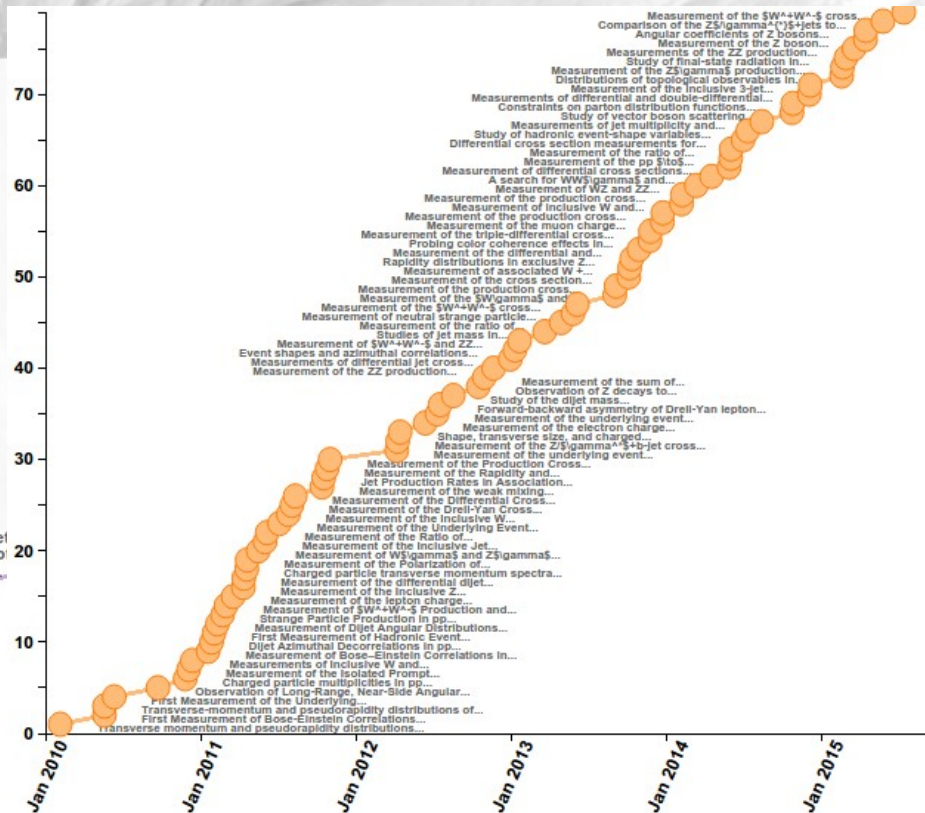
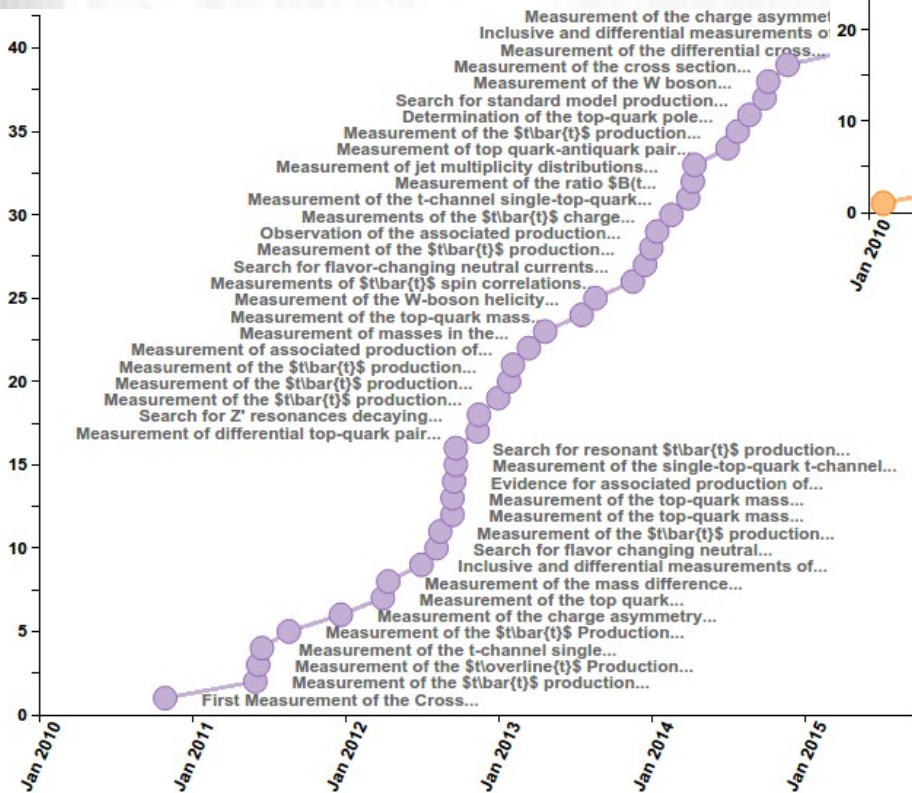
101-esimo Congresso Nazionale SIF
Roma, 24 Sett 2015





CMS Integrated Luminosity, pp

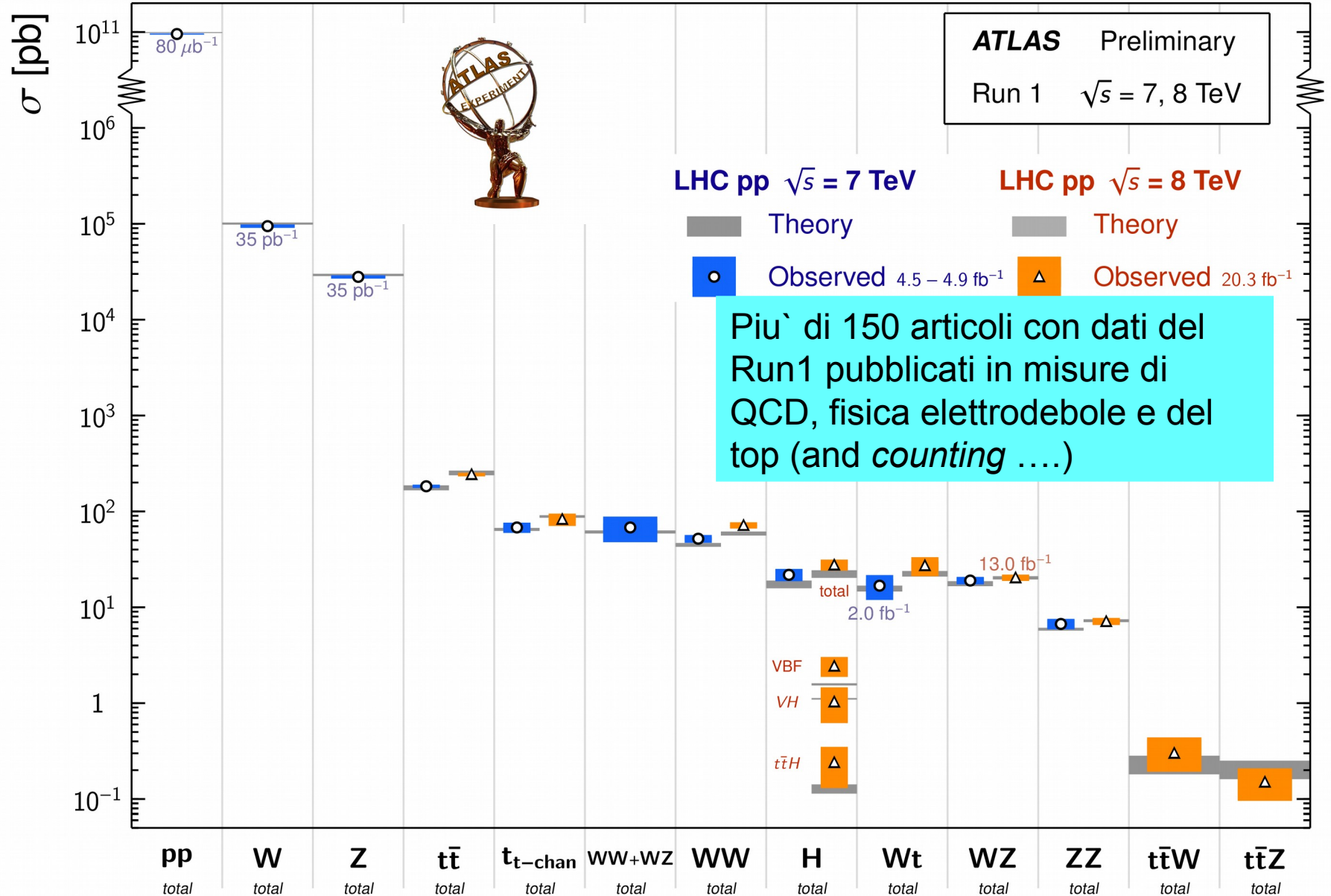




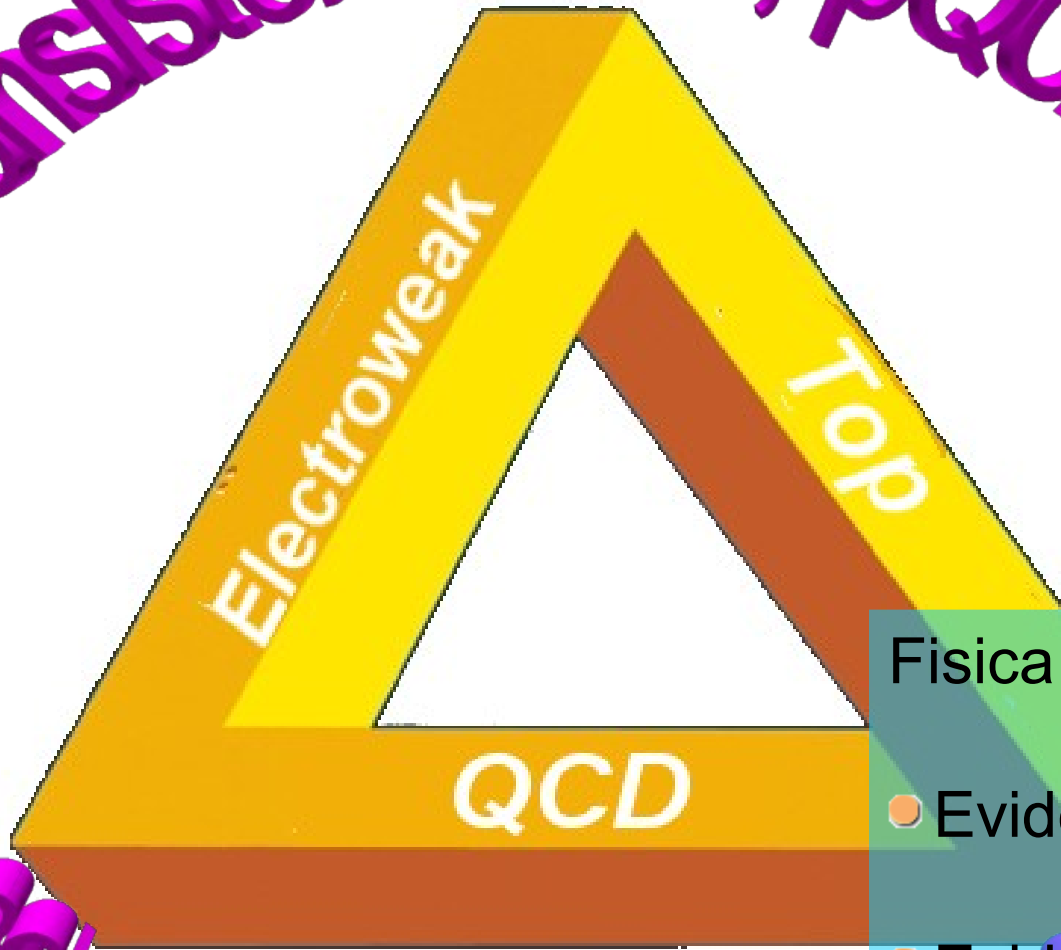
Piu di 130 articoli pubblicati da CMS nel Run1 (Top e SM)

Standard Model Total Production Cross Section Measurements

Status: March 2015

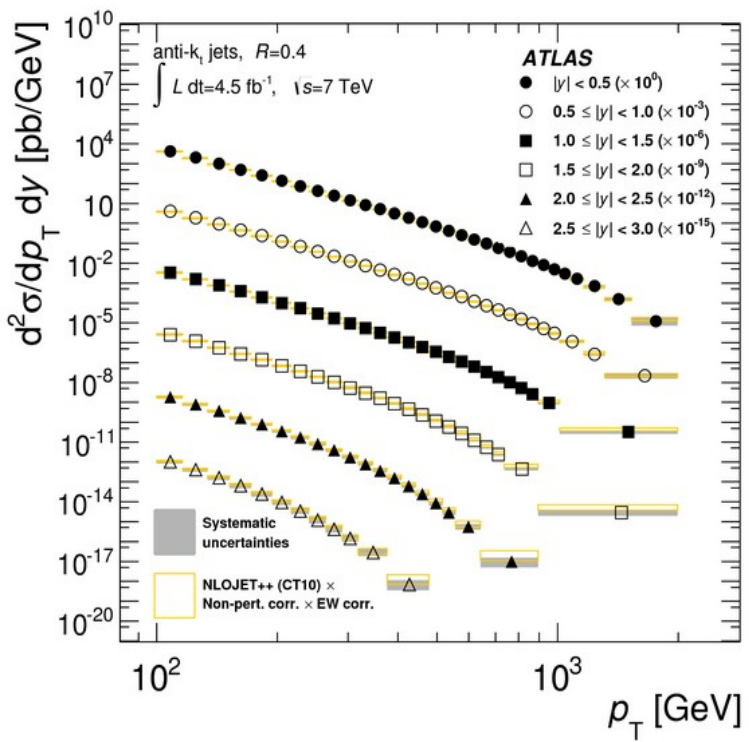


PDF, Consistenza SM, pQCD

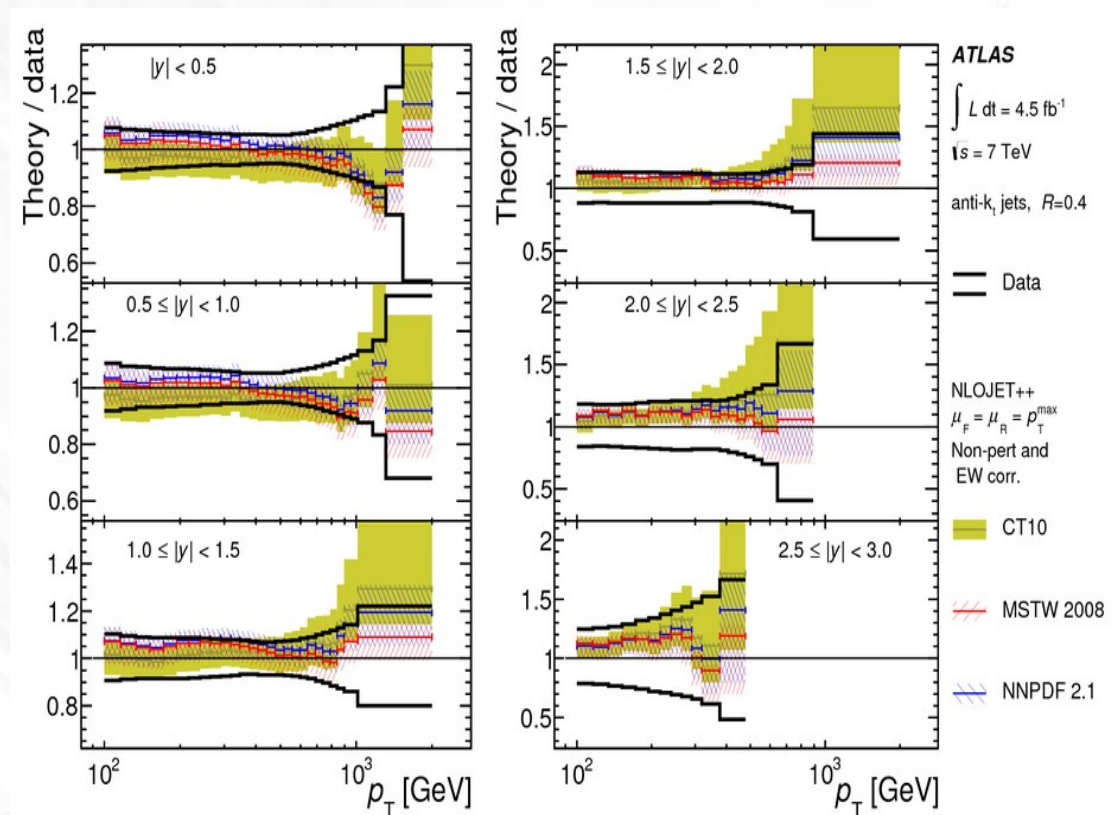


- Fisica BSM:
- Evidenze dirette
 - Evidenze indirette

Sezioni d'urto jet inclusive (7 TeV)



Sezione d'urto inclusiva di produzione di jet



Confronto con diverse previsioni teoriche (NLOJET e POWHEG) e diversi set di PDF

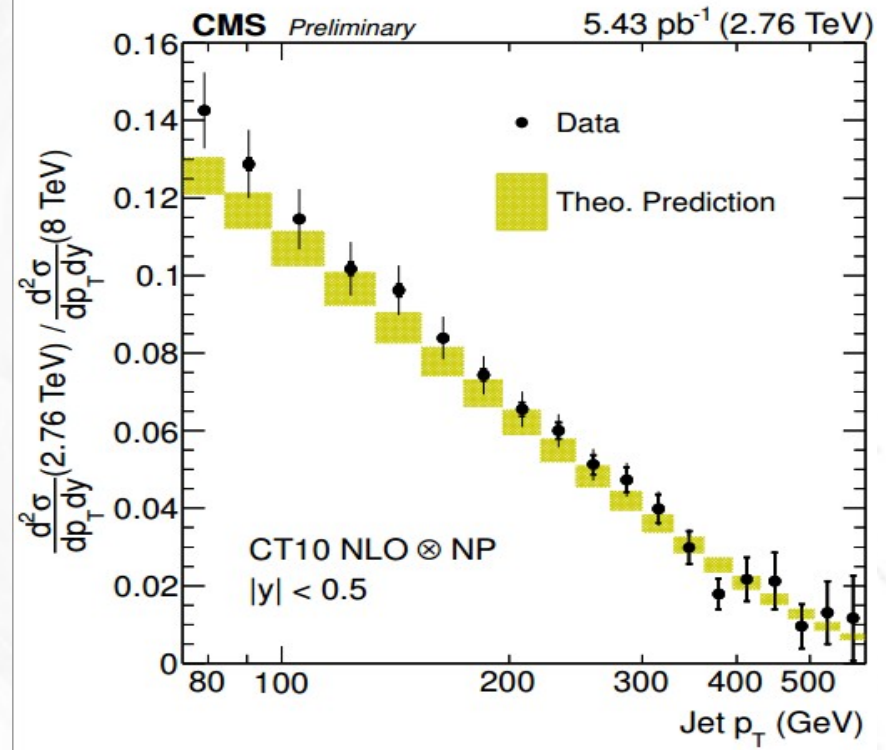
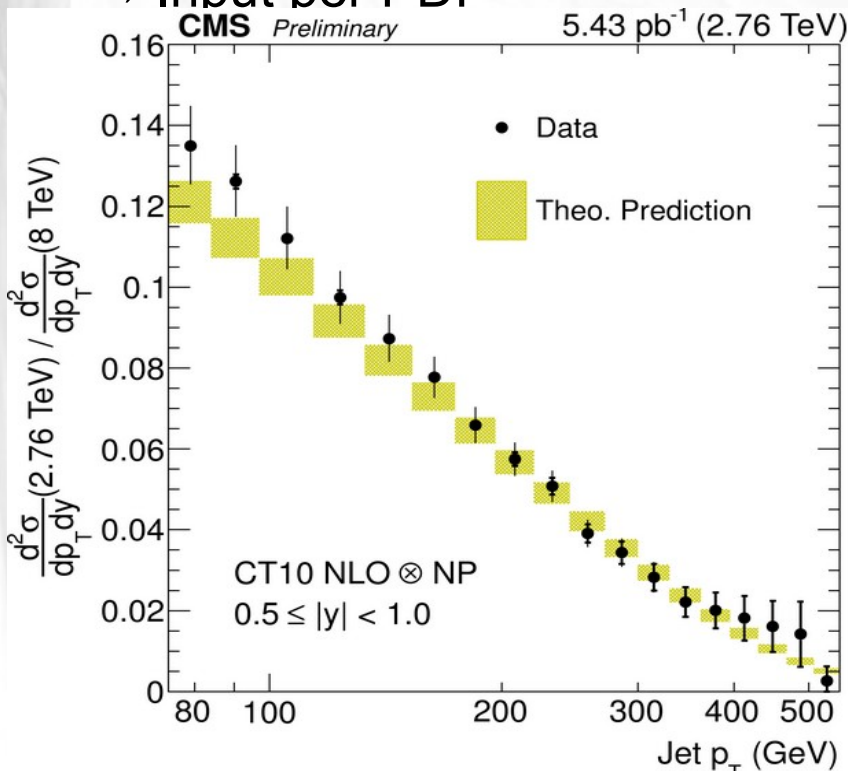
ATLAS :JHEP02(2015)153

Sezioni d'urto inclusive jet: 2.76 TeV vs 7 TeV

Rapporti di sezioni d'urto
2.76 TeV/7 TeV (in P_T e
rapidita`)

→ test stringente ad elevata
precisione per cancellazioni
incertezze sistematiche comuni

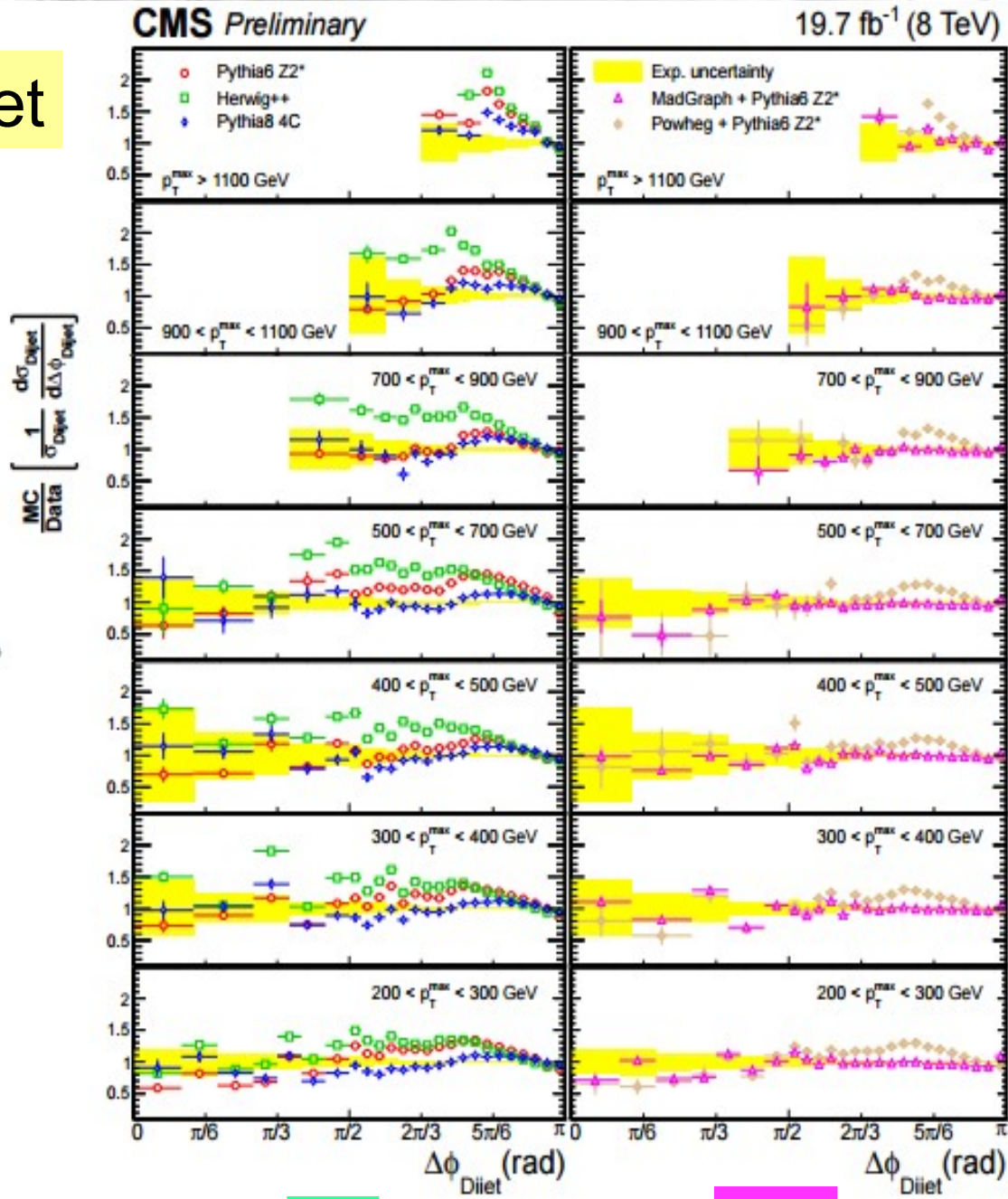
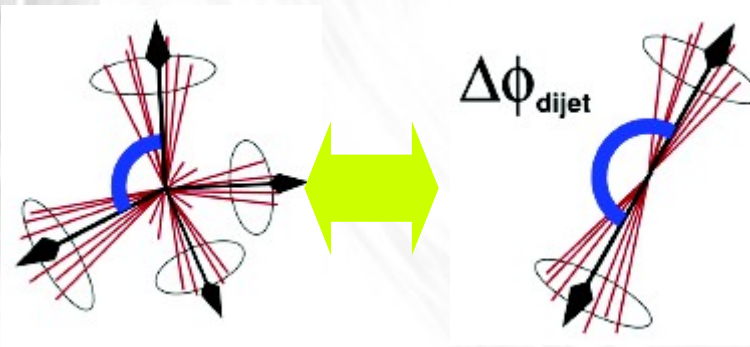
→ Input per PDF



Da ripetere a 13 TeV (cf risultati
preliminari relazione A. Di Ciaccio e
F. Cossutti) ed altre energie nel
centro di massa intermedie

Produzione multijet

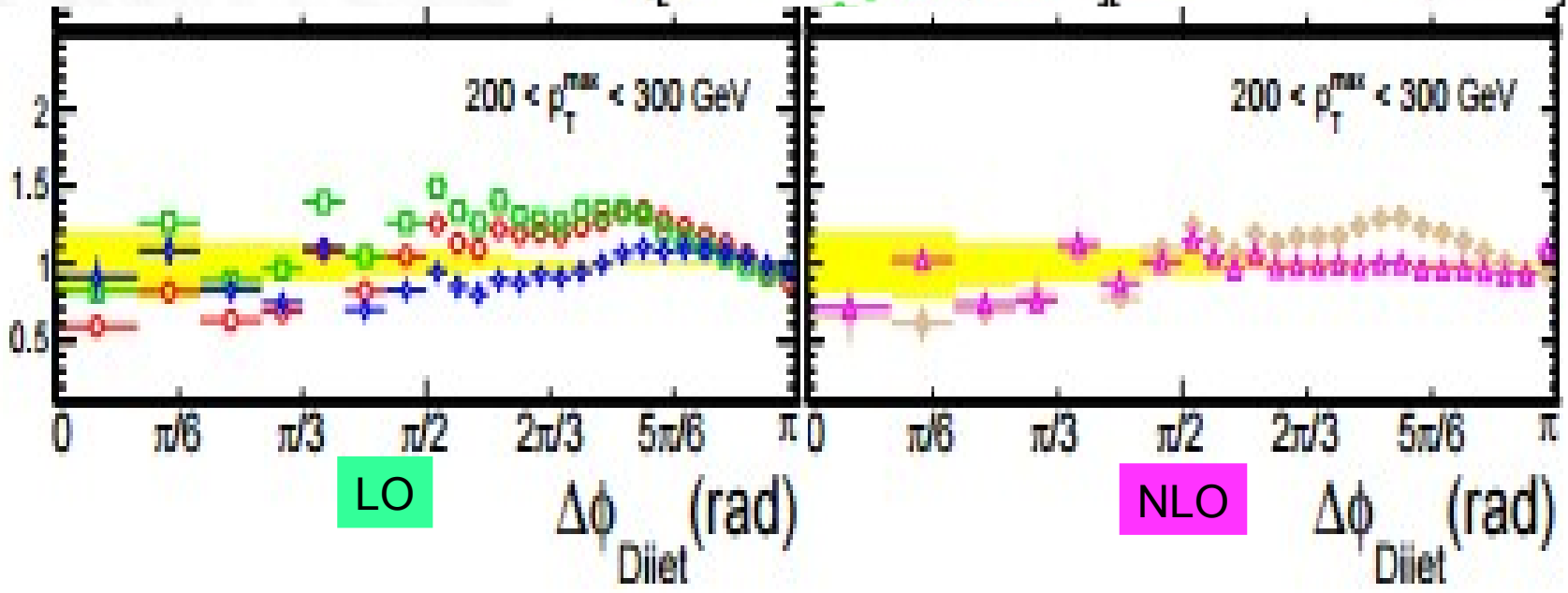
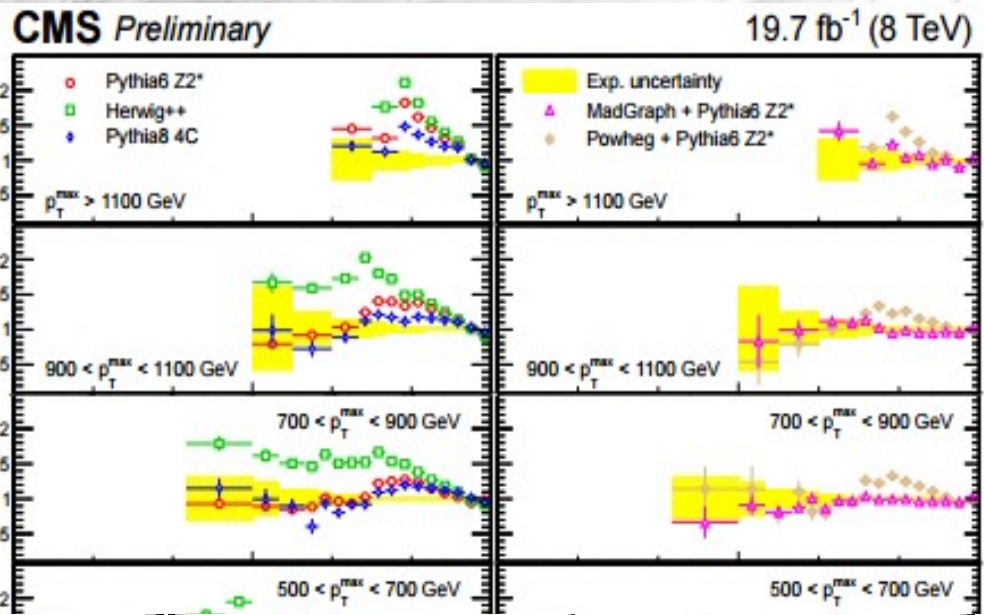
Misure della produzione multijet tramite decorrelazione azimutali
 → Misura dell' angolo $\Delta\phi$ tra due jet



CMS-PAS-SMP-14-015

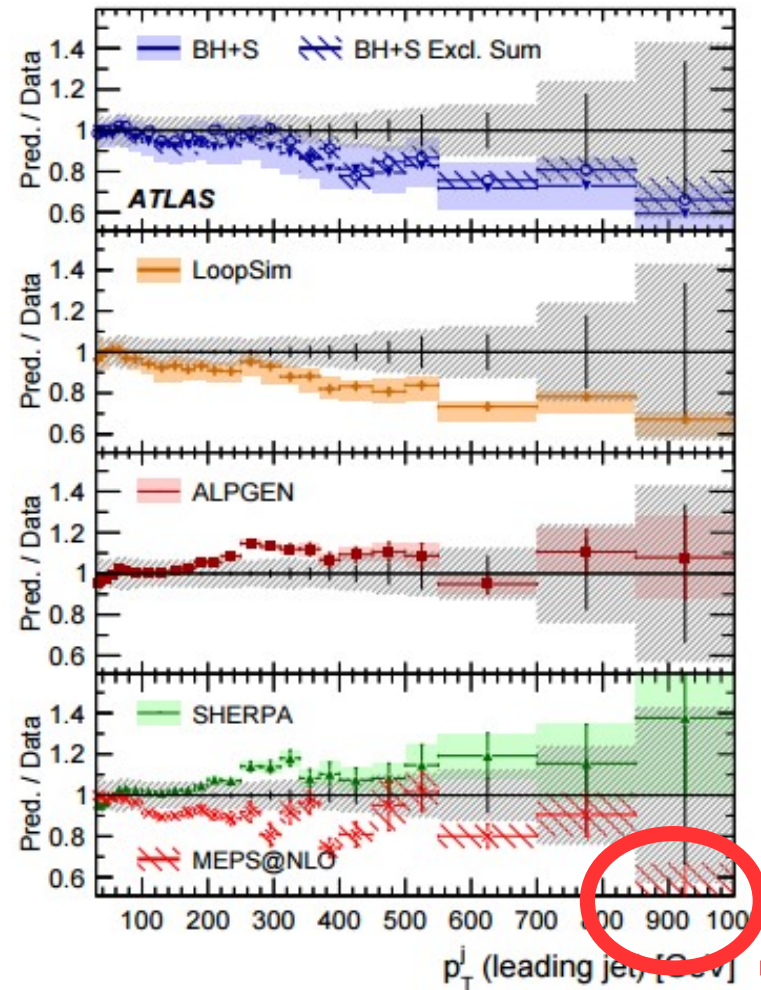
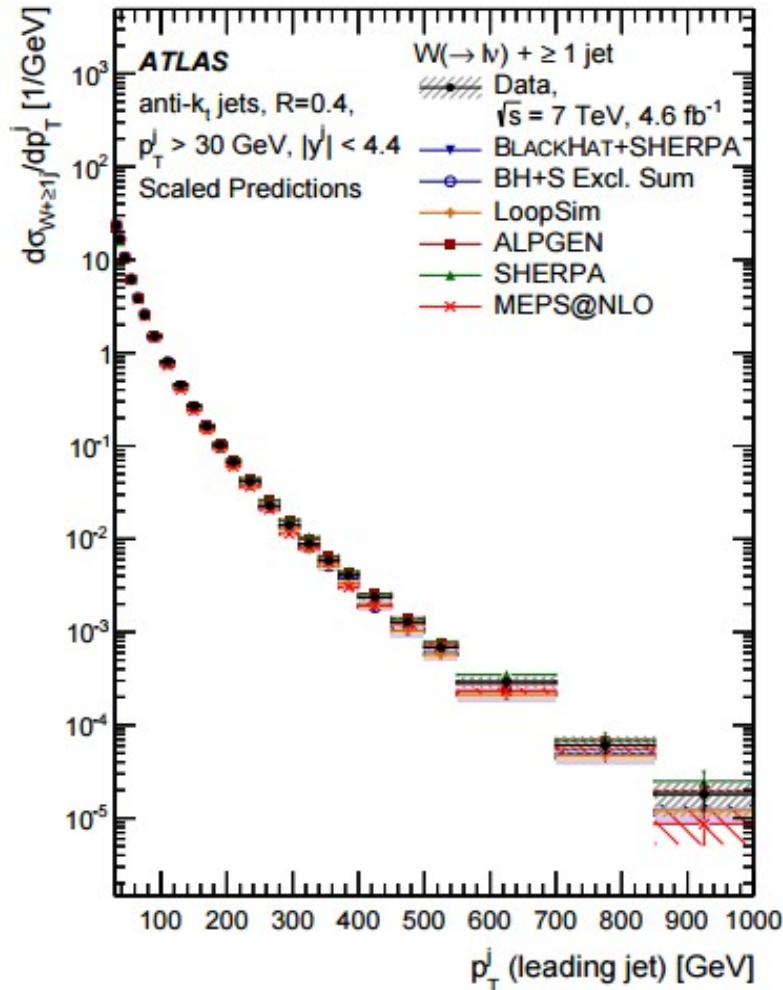
Produzione multijet

Misure della produzione multijet tramite decorrelazione azimutali
 → Misura dell' angolo $\Delta\phi$ tra due jet



W+Jet: Quark Leggeri

Misura della produzione W+Jet: Test stringente di QCD



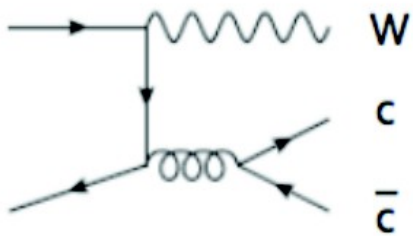
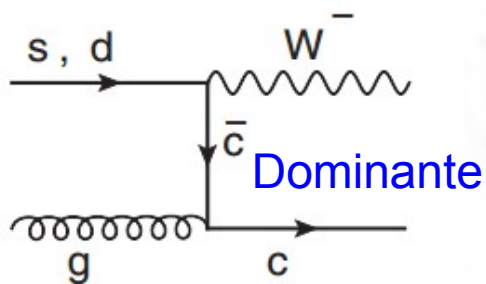
Eur. Phys. J. C (2015) 75 82

Correzioni elettrodeboli possono ulteriormente aumentare le discrepanze ad alto P_T

W+Jet: Quark Pesanti

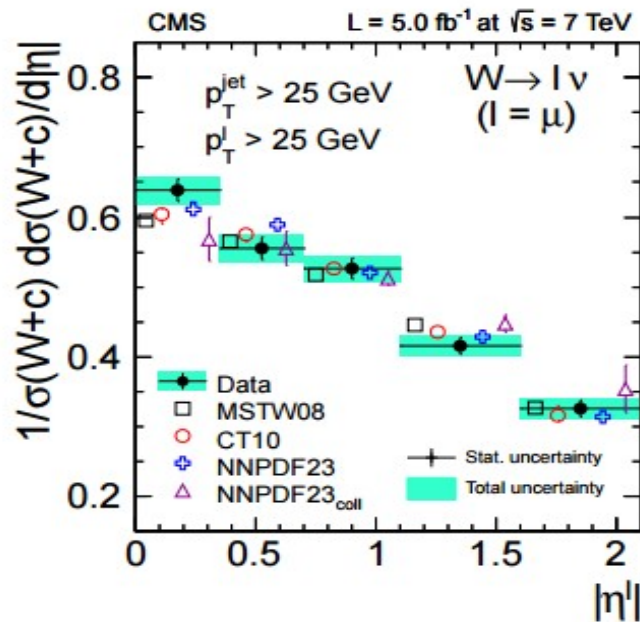
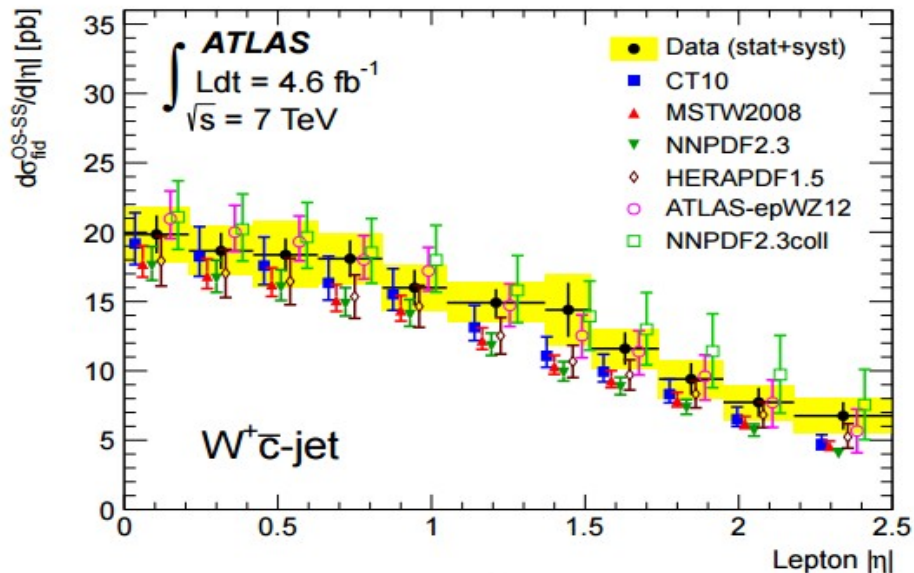
W+ Jet (HF):

- test diretto del contenuto di quark pesanti nel protone
- Gluon-splitting model
- Predizioni con b-quark: massless vs massive

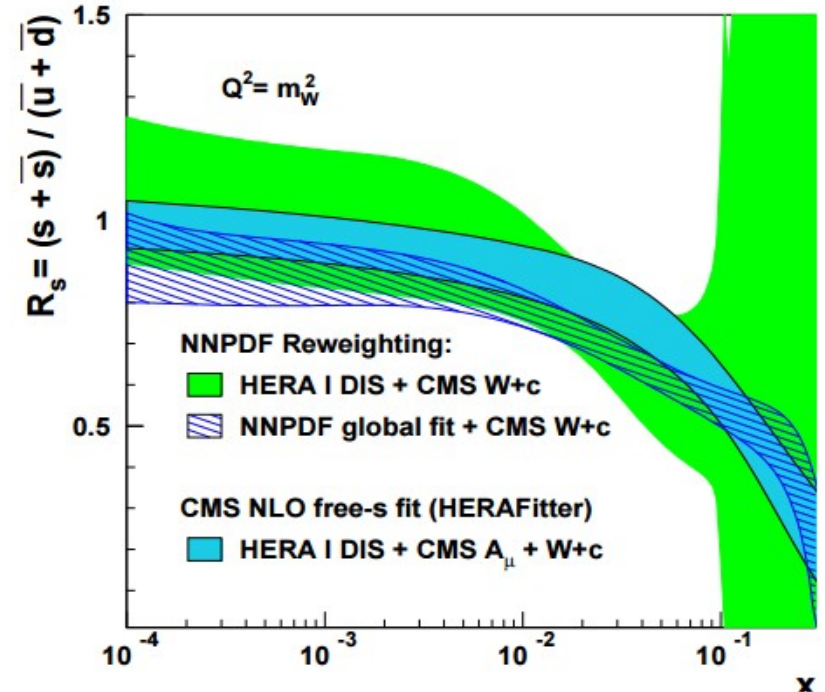
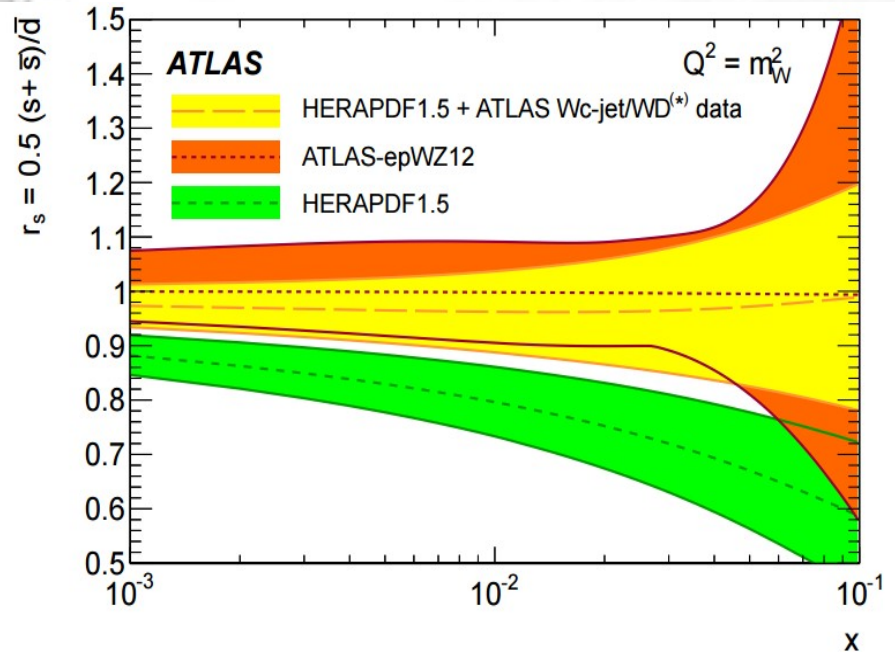


Contributo maggiore ad alto P_T

CMS: JHEP 02 (2014) 013
ATLAS: JHEP05(2014)068



W+Jet: Quark Pesanti



Qualche tensione tra ATLAS e CMS:
 ATLAS → No s-quark suppression
 CMS → s-quark suppression ad alto x

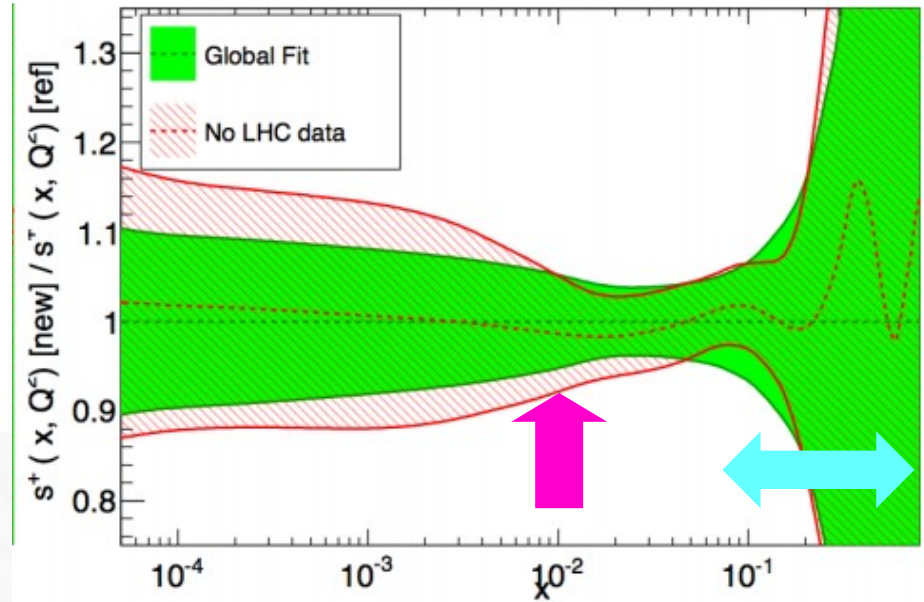
Futuro: PDF da fit combinati ATLAS + CMS

PDF per il Run2

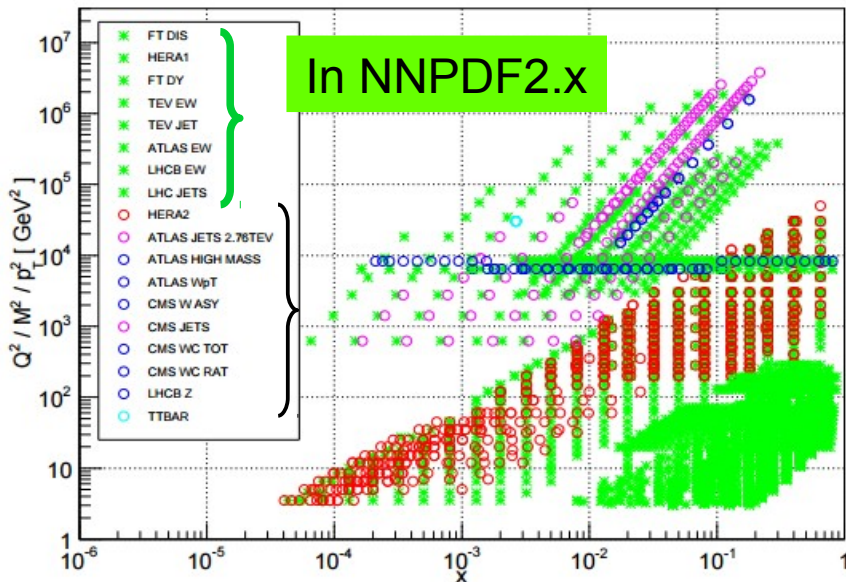
		σ (8 TeV)	uncertainty	
NNLL QCD +NLO EW	gg→H	19.5 pb	14.7%	
	VBF	1.56 pb	2.9%	
NNLO QCD +NLO EW	WH	0.70 pb	3.9%	
	ZH	0.39 pb	5.1%	
NLO QCD	ttH	0.13 pb	14.4%	

(J. Campbell, HCP2012)

NNLO, $\alpha_s = 0.118$, $Q^2 = 10^4 \text{ GeV}^2$

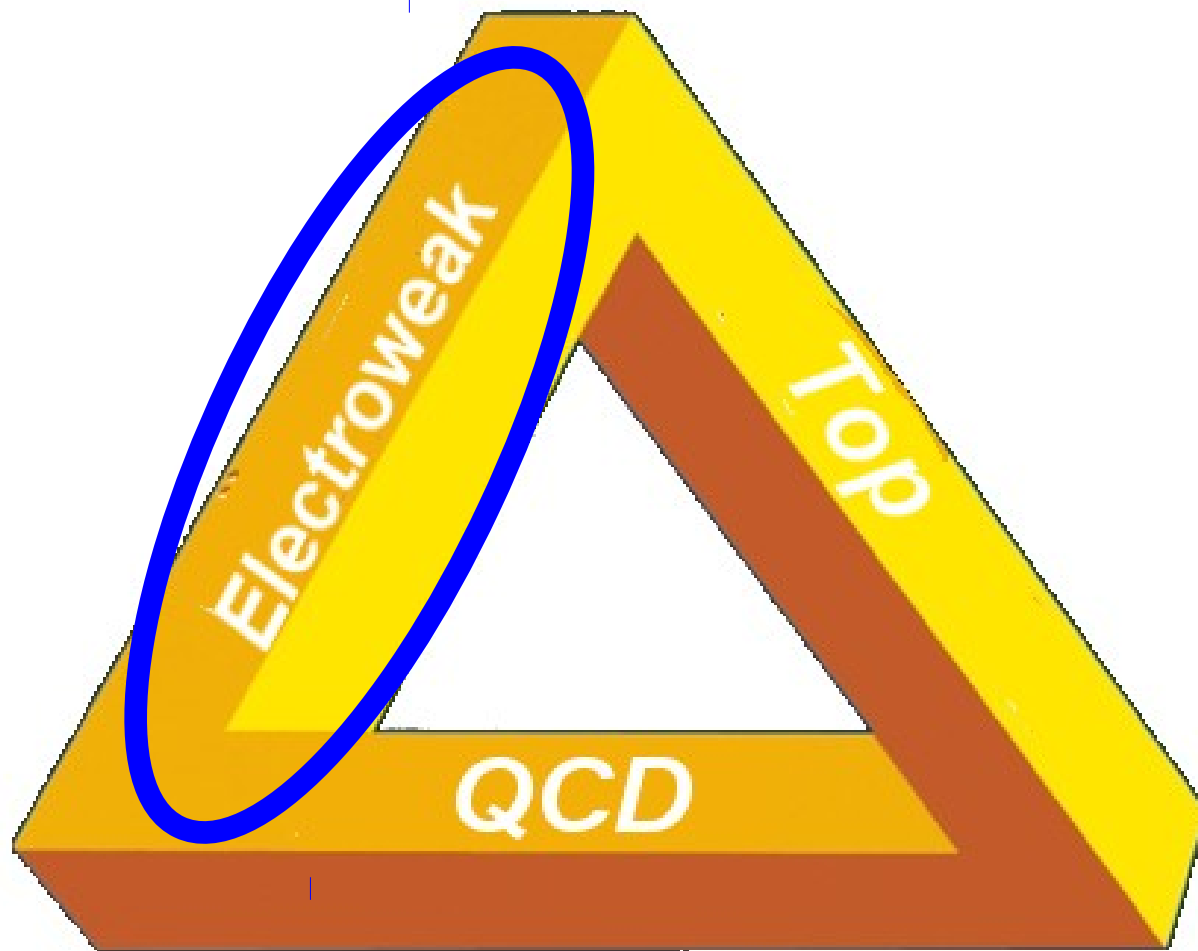


NNPDF3.0 NLO dataset



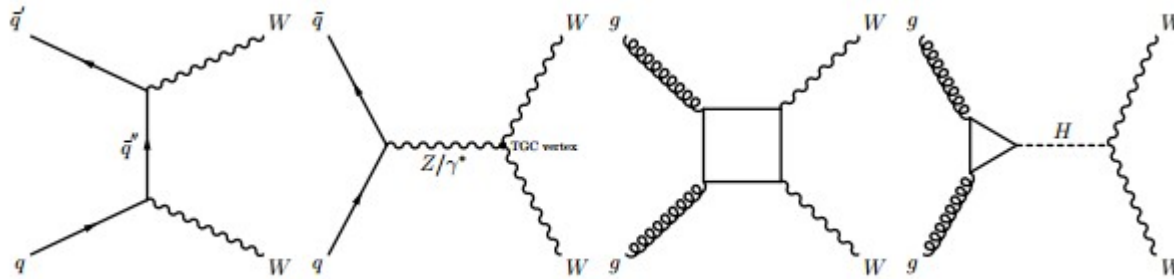
Higgs Production
(gg→H)

Ricerche di nuova
fisica (particelle BSM
ad alta massa)

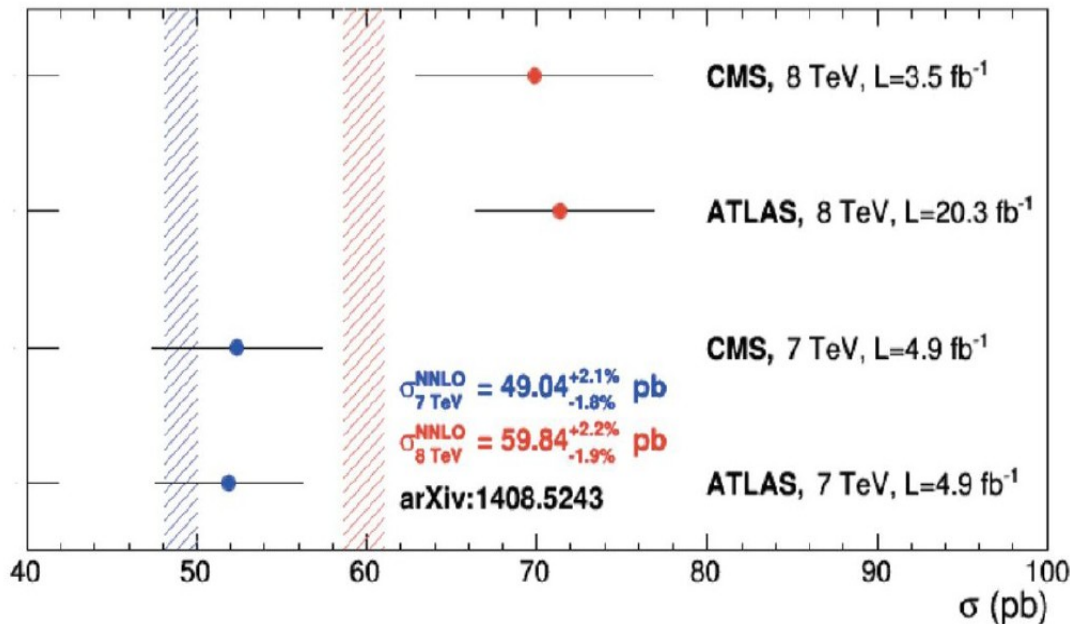


Sezione d'Urto di Produzione WW

Misura della sezione d'urto di produzione WW



Tensione con previsioni SM delle misure di ATLAS e CMS (7 TeV e 8 TeV)



7 TeV:
 ATLAS: Phys. Rev. D 87, 112001 (2013)
 CMS: Eur.Phys.J. C73 (2013) 2610
 8 TeV
 ATLAS: ATLAS-CONF-2014-033
 CMS: Phys. Lett. B 721 (2013) 190–211
 Teoria: (Gehrmann, Grazzini et al.) arXiv: 1408.5243

Miglioramenti in analisi

recente da CMS:

Calcolo NNLO di efficienze
di jet veto (aumento ~7%
previsione teorica)

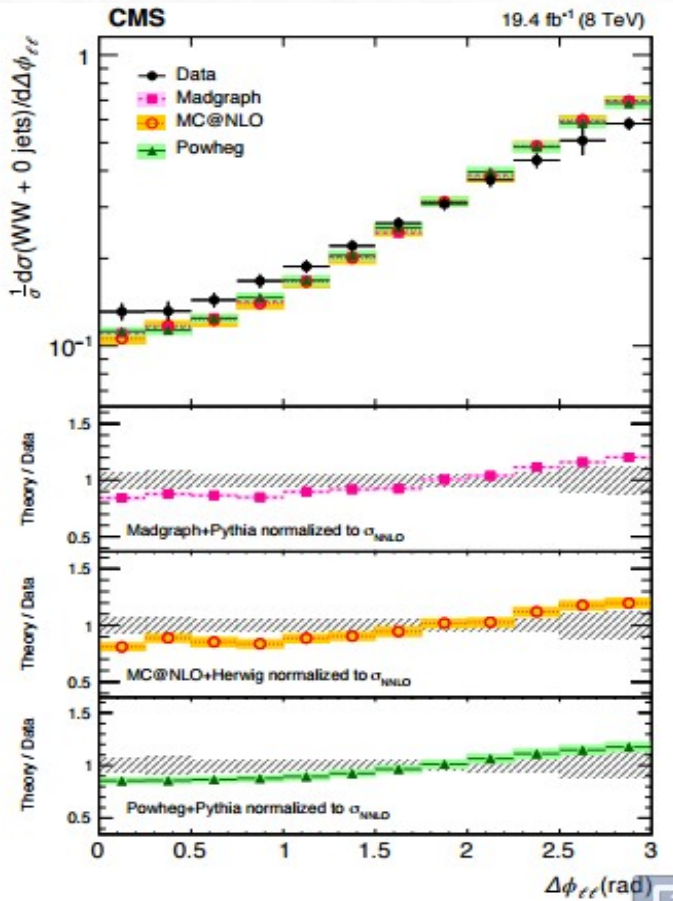
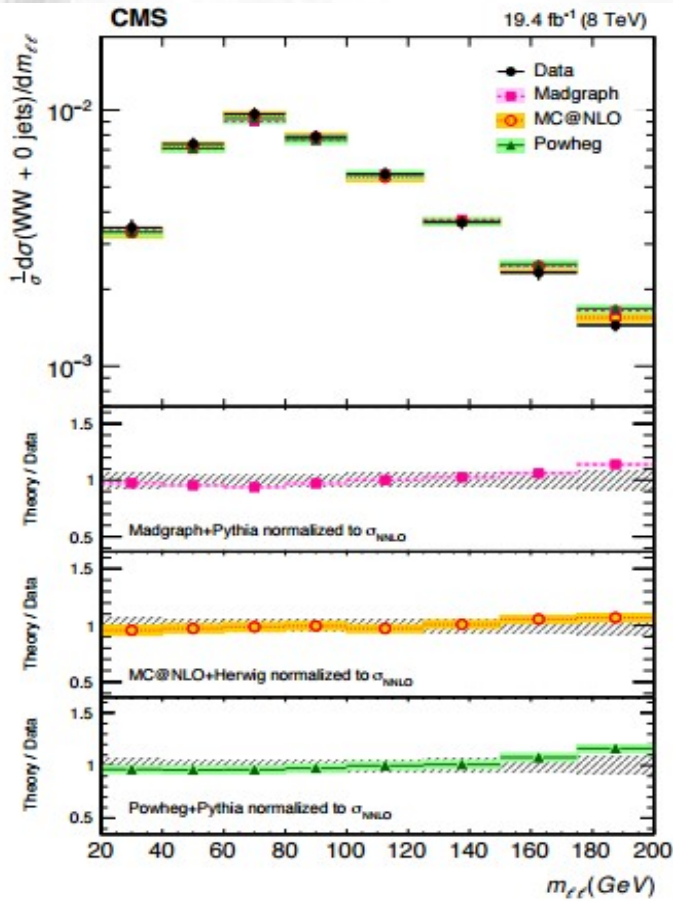
Madgraph → Powheg

0-jet

	0-jet	1-jet
σ	59.7 ± 1.1 (stat) ± 3.3 (exp) ± 3.5 (theo) ± 1.6 (lumi)	59.1 ± 2.8 (stat) ± 6.0 (exp) ± 6.2 (theo) ± 1.6 (lumi)
σ	64.3 ± 2.1 (stat) ± 4.6 (exp) ± 4.3 (theo) ± 1.7 (lumi)	65.1 ± 5.5 (stat) ± 8.3 (exp) ± 8.0 (theo) ± 1.7 (lumi)

DF

SF

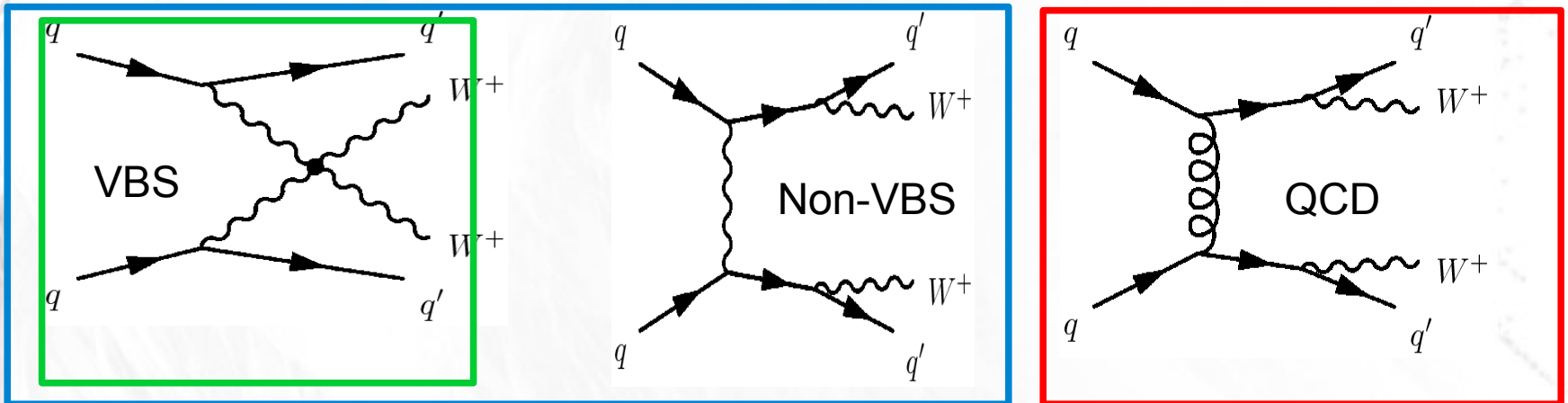


$\sigma_{Data} = 60.1 \pm 4.8$ pb

$\sigma_{Theo} = 59.8^{+1.3}_{-1.1}$ pb

Tuttavia qualche discrepanza nelle sezioni d'urto differenziali

Scattering WW (VBS)



Scattering $V_L V_L \rightarrow V_L V_L$ intimamente legato a struttura EWSB (violazione dell'unitarieta` in assenza di Higgs)

Signature sperimentali:

Dileptoni (SS), MET, 2 jet, $M_{JJ} > 500$ GeV e $|\Delta\eta_{JJ}| > 2.5$

Contributo QCD depresso da richiesta leptoni SS

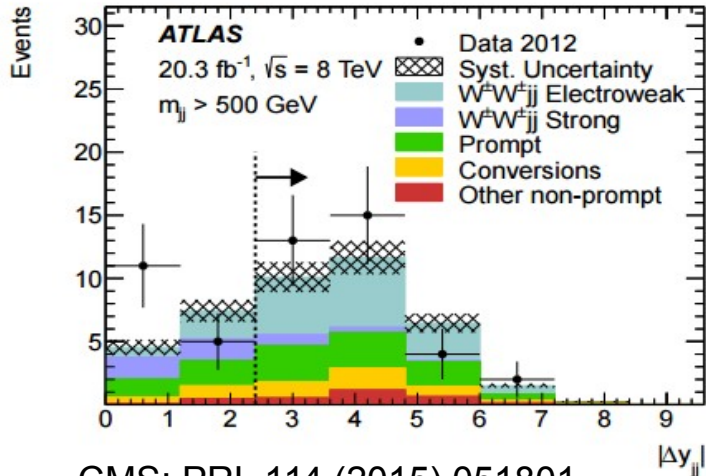
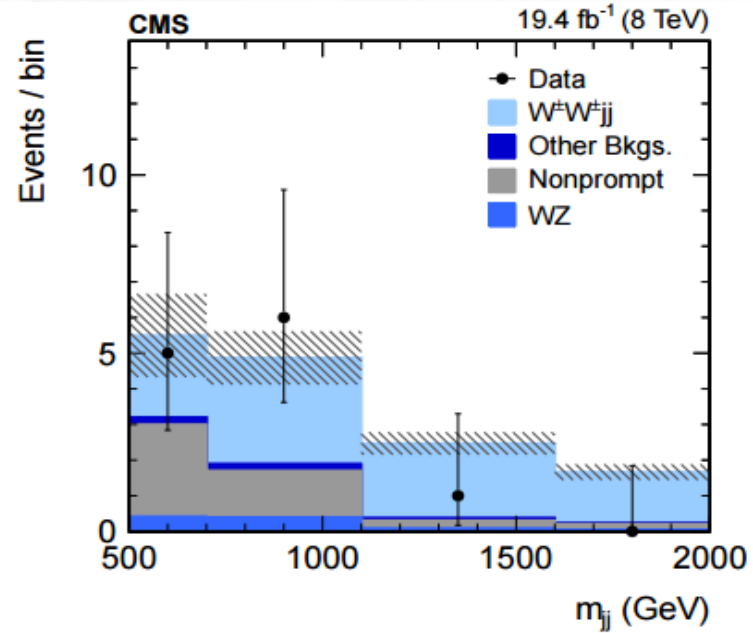
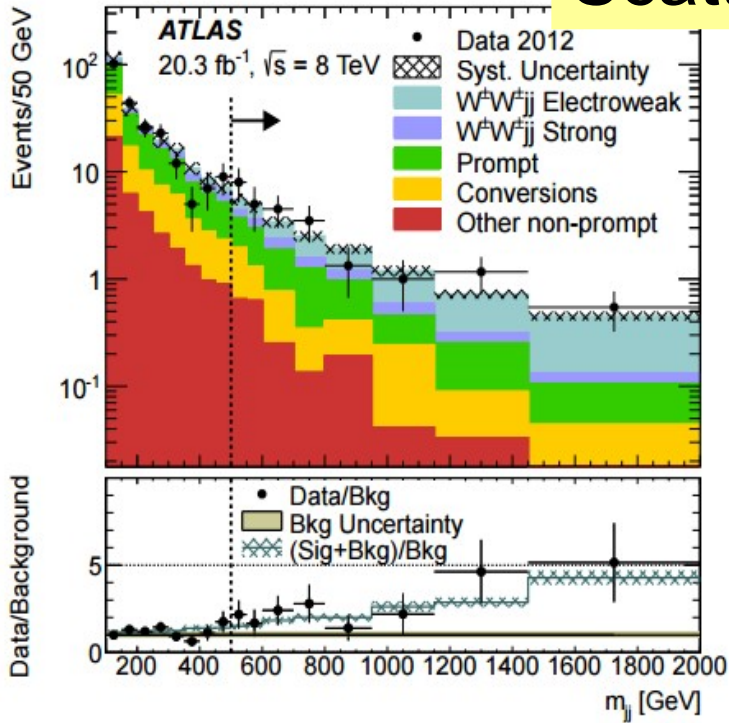
Contributo EWK non-VBS depresso da richiesta veto jet centrali

Significanze Osservate (Attese): ATLAS 3.6σ (2.8σ), CMS 1.9σ (2.9σ)

CMS: PRL 114 (2015) 051801

ATLAS: PRL 113 (2014) 0141803

Scattering WW (VBS)



ATLAS:

$$\sigma_{\text{Fid}} (\text{Meas}) = 1.3 \pm 0.4 (\text{stat}) \pm 0.2 (\text{syst}) \text{ fb}$$

$$\sigma_{\text{Fid}} (\text{Theo}) = 0.95 \pm 0.06 \text{ fb}$$

CMS:

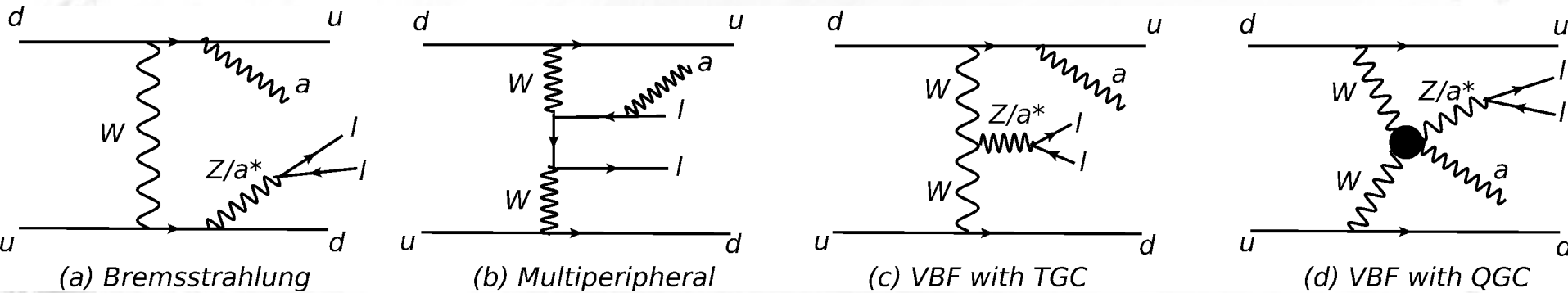
$$\sigma_{\text{Fid}} (\text{Meas}) = 4.0^{+2.4}_{-2.0} (\text{stat})^{+1.1}_{-1.0} (\text{syst}) \text{ fb}$$

$$\sigma_{\text{Fid}} (\text{Theo}) = 5.8 \pm 1.2 \text{ fb}$$

CMS: PRL 114 (2015) 051801

ATLAS: PRL 113 (2014) 0141803
Roma, Sett. 2015

Z γ Produzione Elettrodebole



Evidenza del processo $qq \rightarrow qq Z\gamma \rightarrow (l^+l^-\gamma jj)$

Stato finale ricostruito $\rightarrow m(Z\gamma)$ sensibile a aQGC

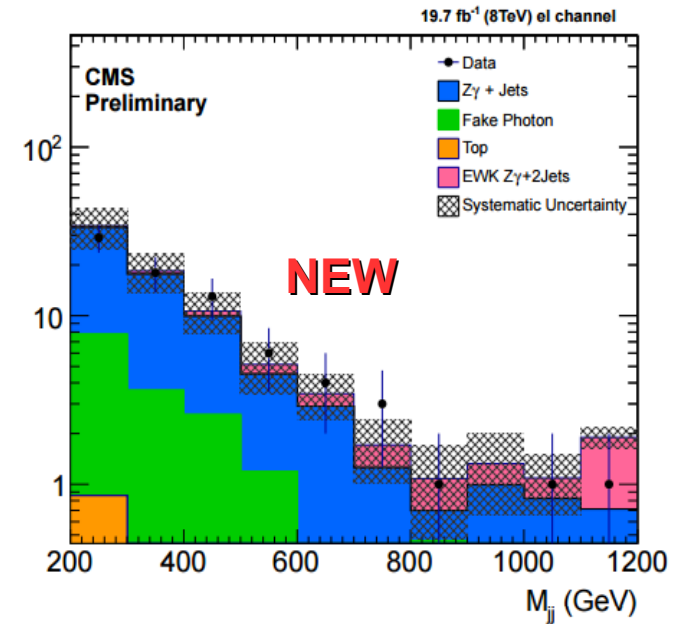
Selezione per misura sezione d'urto:

2 lepton + γ ($P_T(\gamma) > 20$ GeV), $|\eta(\gamma)| < 1.4$

$70 < m(l\bar{l}) < 110$ GeV

$M(jj) > 400$ GeV, $|\Delta\eta(JJ)| > 2.5$

Selezione piu` stringente per limiti su aQGC



Anomalous Gauge Coupling (aGC)

Accoppiamenti tripli (TGC) e quartici (QGC) → struttura non-Abeliana dello SM

Fisica BSM puo` modificare TGC e QGC → aGC

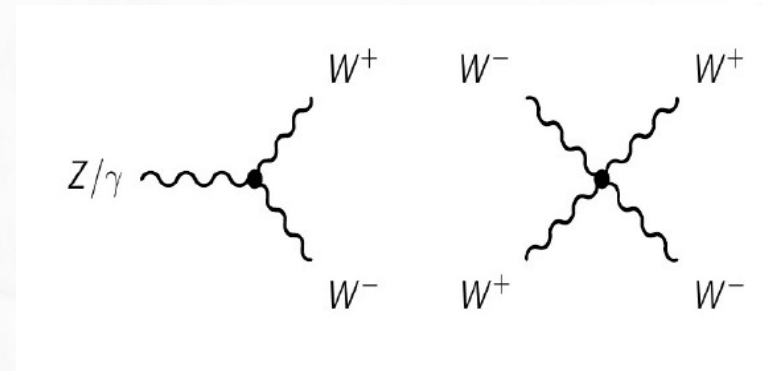
Due possibilita` per quantificare effetti:

• Lagrangiana Effettiva (esempio per aTGC):

$$\mathcal{L}_{WWW} = ig_{WWW} \left(g_1^V (W_{\mu\nu}^+ W^{-\mu} - W^{+\mu} W_{\mu\nu}^-) V^\nu + \kappa_V W_\mu^+ W_\nu^- V^{\mu\nu} + \frac{\lambda_V}{M_W^2} V^{\mu\nu} W_\nu^{+\rho} W_{\rho\mu}^- \right)$$

• Teoria di Campo Effettiva (EFT) (Λ scala per la nuova fisica. Con operatori di dimensione superiore (d=6, 8)) (→ cf relazione F. Maltoni)

$$\mathcal{L}_{eff} = \mathcal{L}_{SM} + \sum_d \sum_i \frac{c_i^{(d)}}{\Lambda^{d-4}} \mathcal{O}_i^{(d)}$$



Modifiche a:

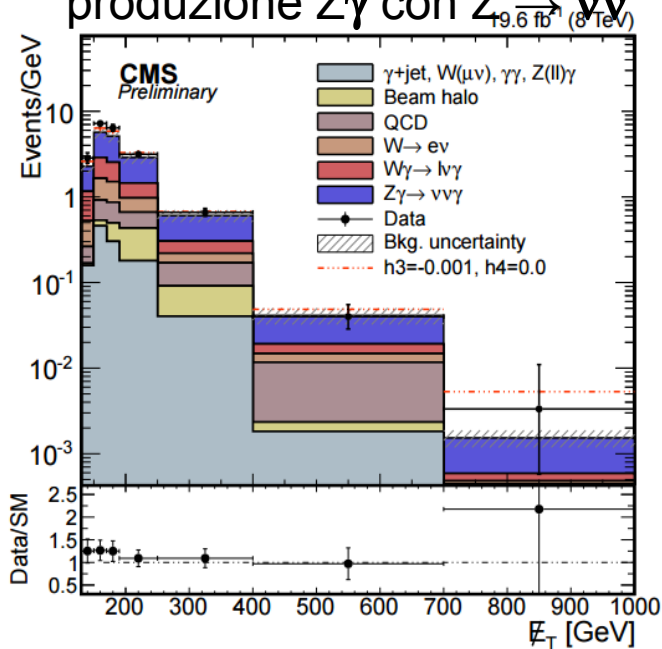
- Sezioni d'urto totali
- Distribuzioni cinematiche

Simile a teoria di Fermi

Anomalous Gauge Coupling (aGC)

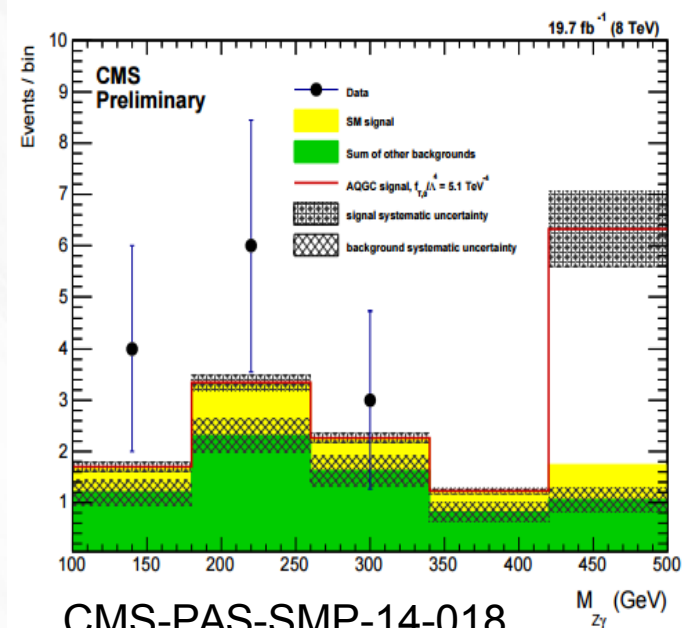
In generale effetti di aGC sono amplificati ad alto \hat{s}
 → effetto su code di $m(\ell\ell)$, $m(jj)$, $m(Z\gamma)$, $m(VV)$, $PT(VV)$, etc...

Esempio (aTGC):
 produzione $Z\gamma$ con $Z \rightarrow \nu\nu$



CMS-PAS-SMP-14-019

Esempio (aQGC):
 Produzione elettrodebole $Z\gamma$

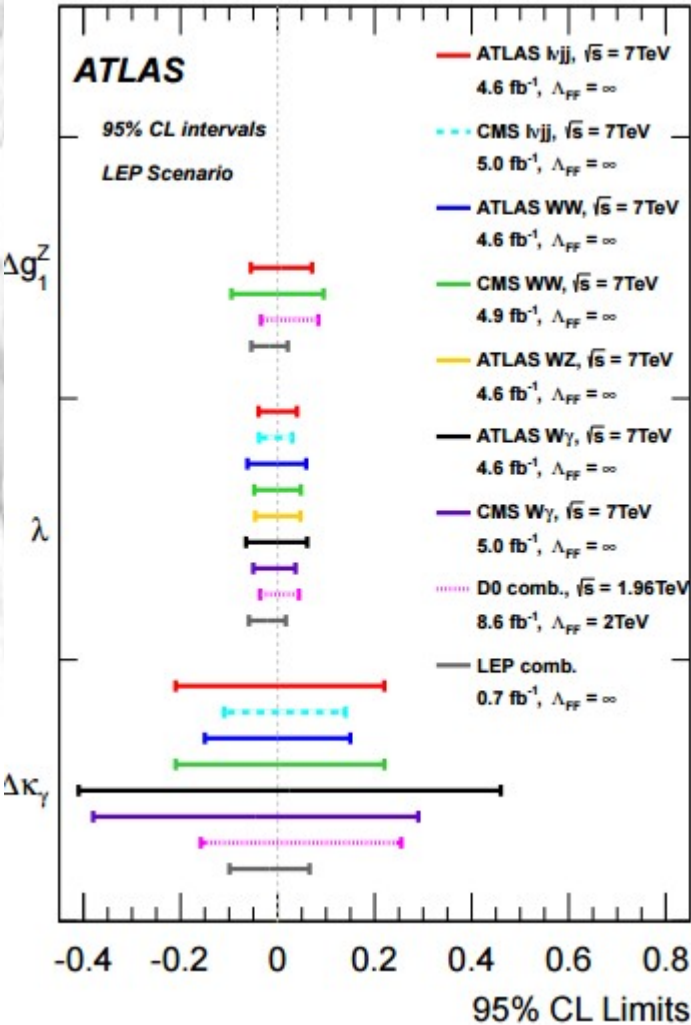


CMS-PAS-SMP-14-018

Produzione di diboson: WW , WZ , γW
 Produzione elettrodebole di bosoni ($Z\gamma$,...)

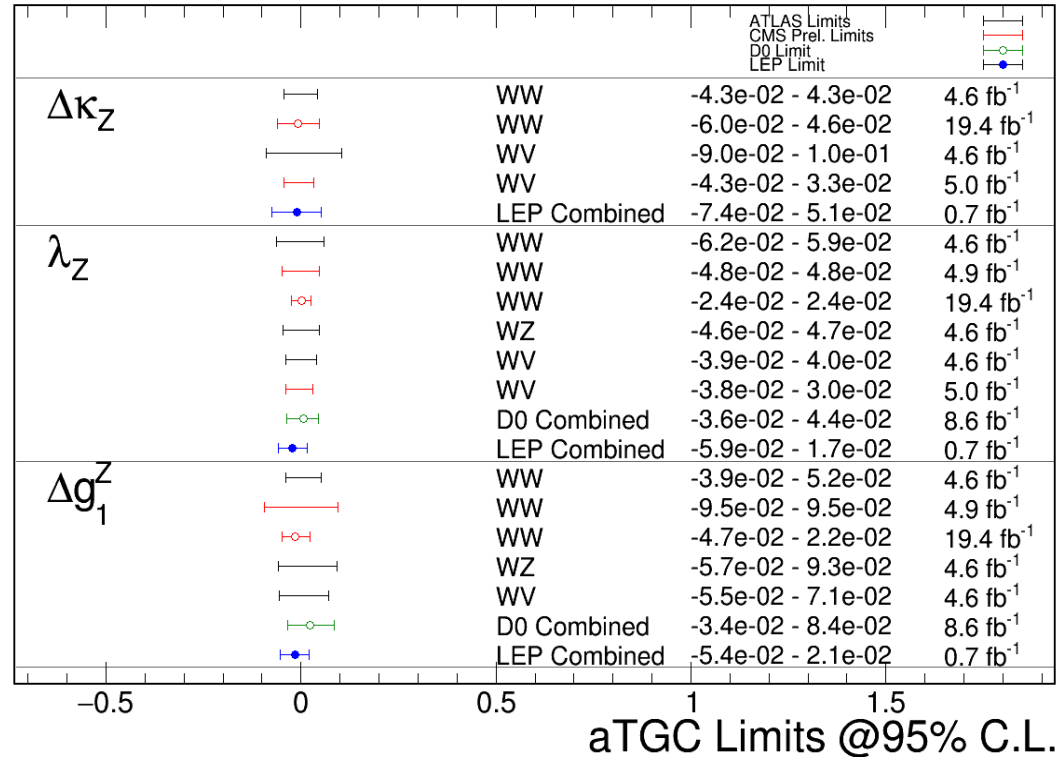
Produzione di triboson: WWW , ...
 Produzione elettrodebole di diboson (VBS)

aTGC: Sommario



JHEP01(2015)049

July 2015

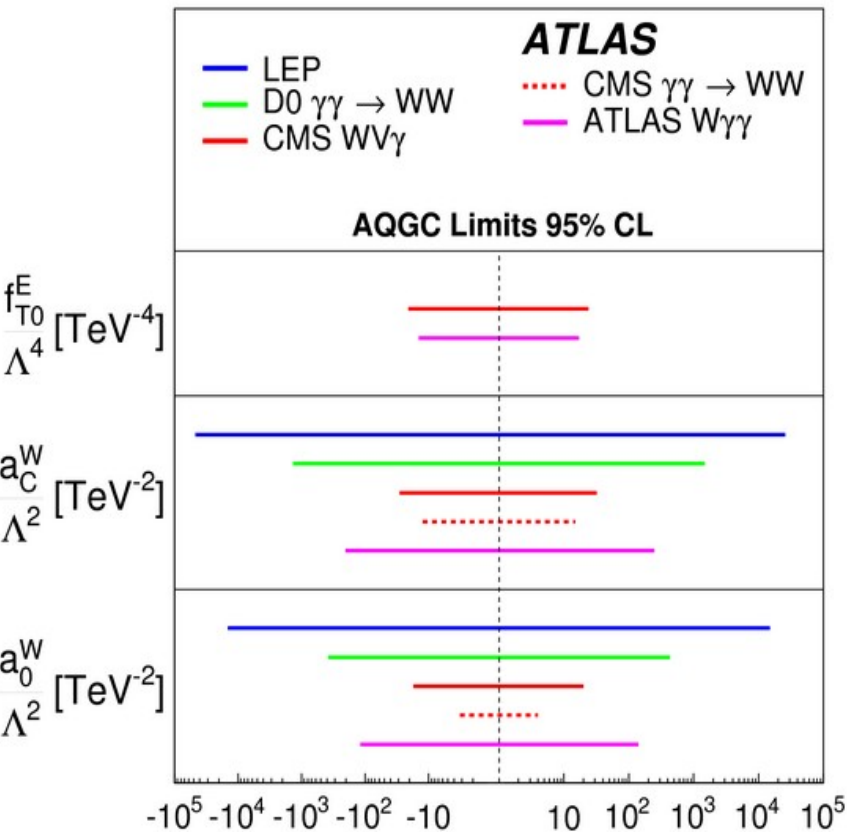


From:

<https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMPaTGC>

(espressione in termini di Lagrangiana Effettiva)

aQGC: Sommario



August 2015		CMS	ATLAS	Channel	Limits	$\int Ldt$	\sqrt{s}
f_{T0} / Λ^4	-----	-----	-----	$W\gamma\gamma$	-9.0e+01 - 9.0e+01	20.3 fb ⁻¹	8 TeV
				$WW\gamma$	-2.5e+01 - 2.4e+01	19.3 fb ⁻¹	8 TeV
				EWK $Z\gamma+2Jets$	-3.8e+00 - 3.4e+00	19.7 fb ⁻¹	8 TeV
				ss WW	-4.2e+00 - 4.6e+00	19.4 fb ⁻¹	8 TeV
f_{T1} / Λ^4	-----	-----	-----	EWK $Z\gamma+2Jets$	-4.4e+00 - 4.4e+00	19.7 fb ⁻¹	8 TeV
				ss WW	-2.1e+00 - 2.4e+00	19.4 fb ⁻¹	8 TeV
f_{T2} / Λ^4	-----	-----	-----	EWK $Z\gamma+2Jets$	-9.9e+00 - 9.0e+00	19.7 fb ⁻¹	8 TeV
				ss WW	-5.9e+00 - 7.1e+00	19.4 fb ⁻¹	8 TeV
f_{T8} / Λ^4	-----	-----	-----	EWK $Z\gamma+2Jets$	-1.8e+00 - 1.8e+00	19.7 fb ⁻¹	8 TeV
f_{T9} / Λ^4	-----	-----	-----	EWK $Z\gamma+2Jets$	-4.0e+00 - 4.0e+00	19.7 fb ⁻¹	8 TeV

aQGC Limits at 95% CL (TeV⁻⁴)

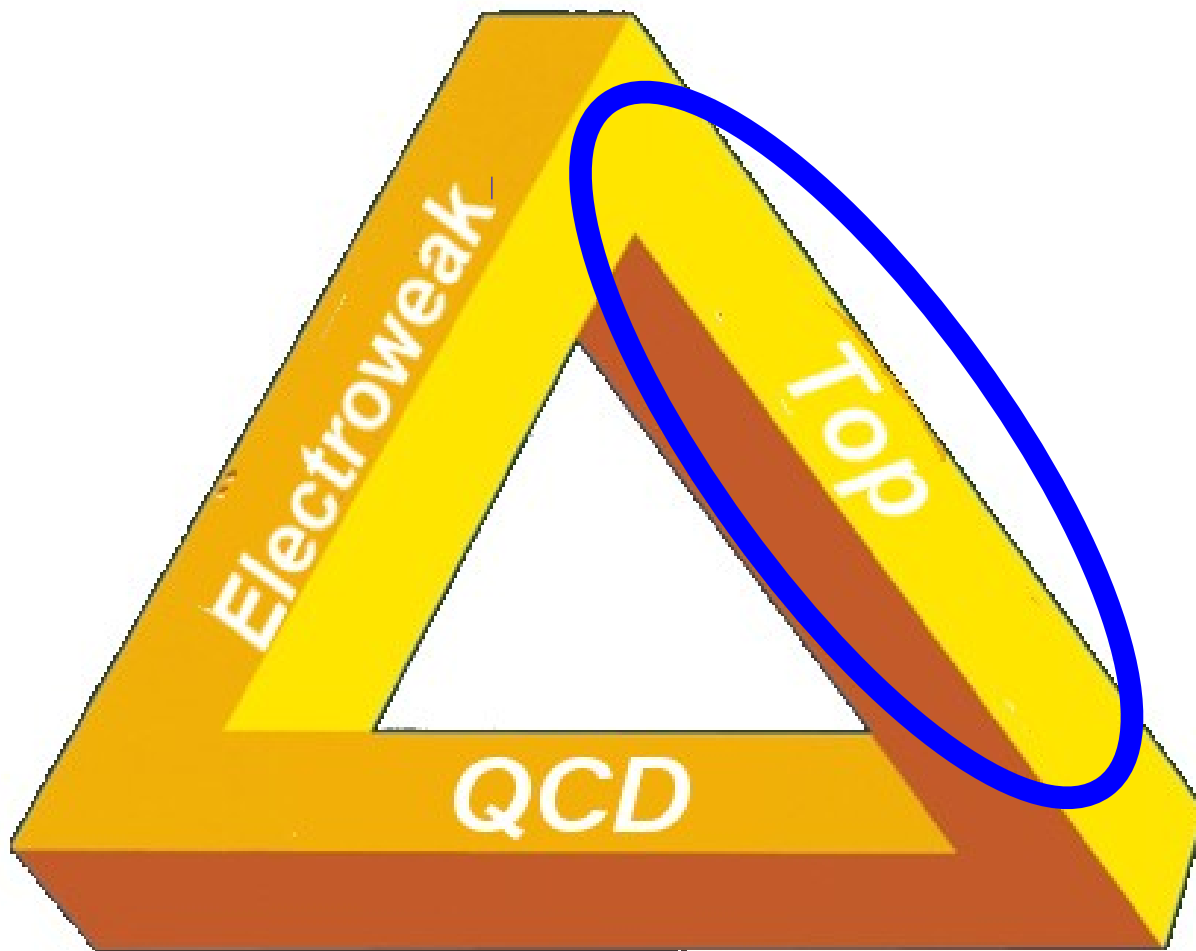
CMS-SMP-14-018

Phys. Rev. Lett. 115, 031802 (2015)

Limiti sempre piu` stringenti.

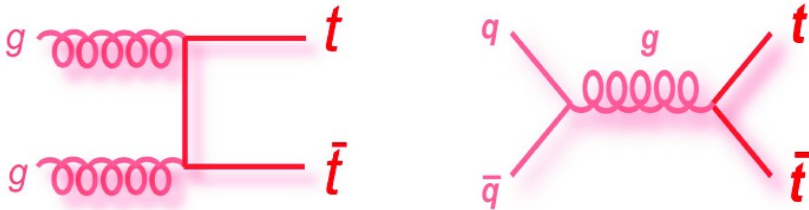
Stati triboson \rightarrow statistica adeguata

Accesso a produzione elettrodebole di diboson con VBS



Fisica del Top

Produzione coppie $t\bar{t}$



	$\sigma(t\bar{t})$	$\sigma(gg)/\sigma(t\bar{t})$	
Tevatron (Run2)	~ 7 pb	15%	1 all'ora
LHC (7 TeV)	~ 170 pb	85%	10 al minuto
LHC (13 TeV)	~ 800 pb	90%	~ 1 Hz !

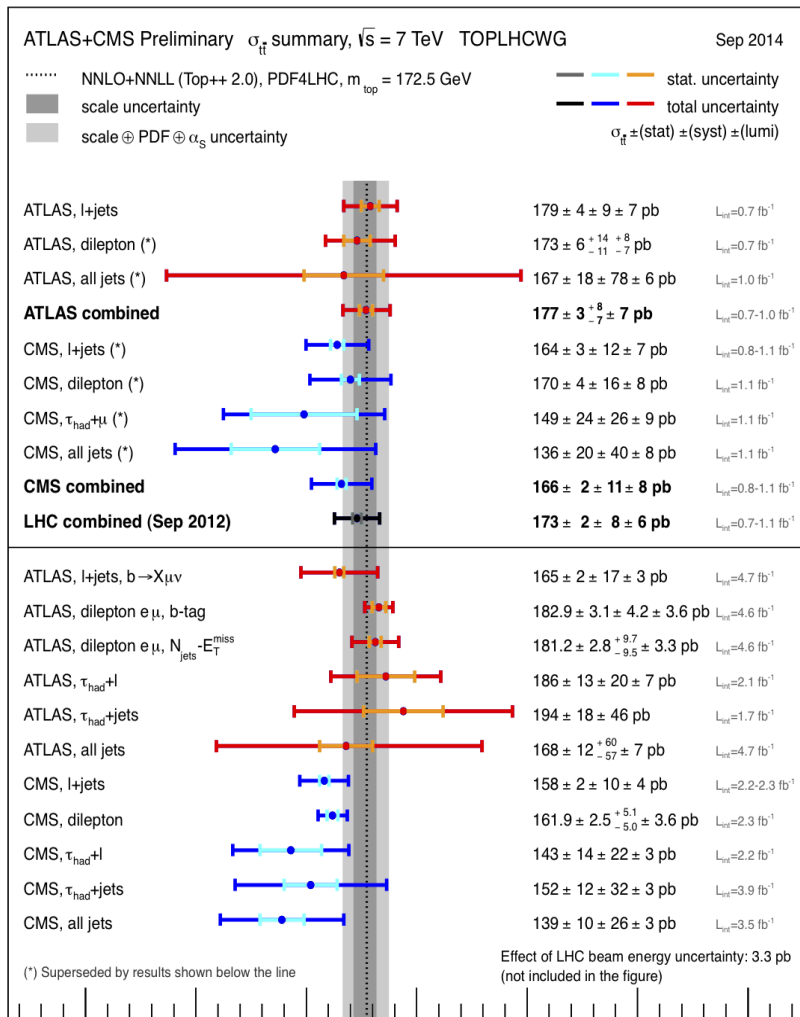
$W^- \rightarrow$	hadrons	τ	μ	e
hadrons	All Hadronic	Tau + Jets	Lepton + Jets	
τ	Tau + Jets			
μ	Lepton + Jets			Dilepton

Il top quark è la particella elementare più pesante finora scoperta
 → ruolo "speciale" in EWSB?

Misura sezione d'urto di produzione

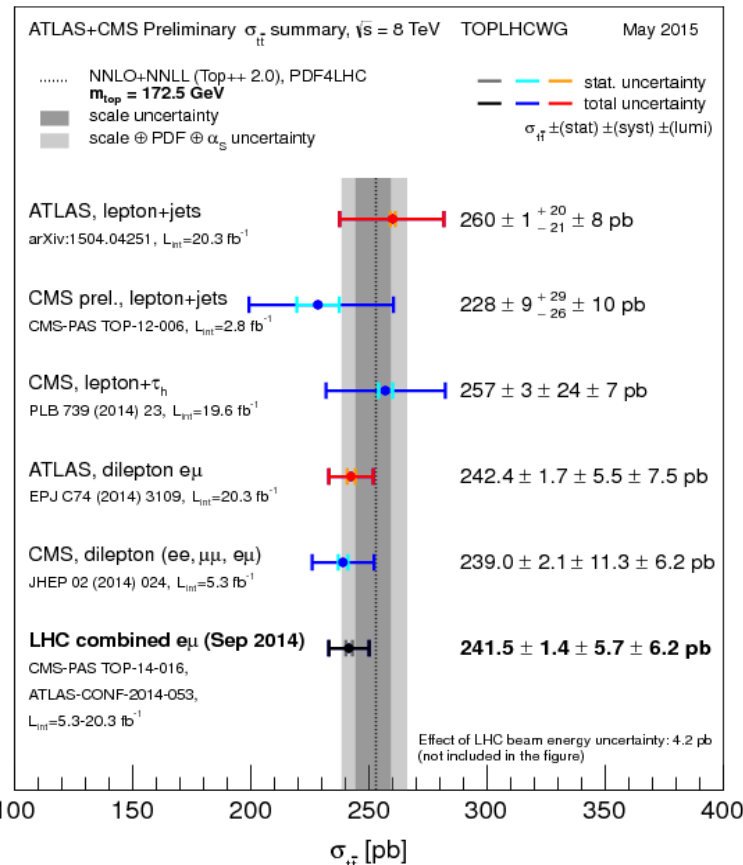
TOPLHCWG

8 TeV



7 TeV

σ_{tt} [pb]



Incertezze misure combinate

~ incertezze teoria

→ Incertezza sull'energia dei fasci

Statistica raccolta permette misura di sezioni d'urto differenziali

A. Sidoti – SIF 2015

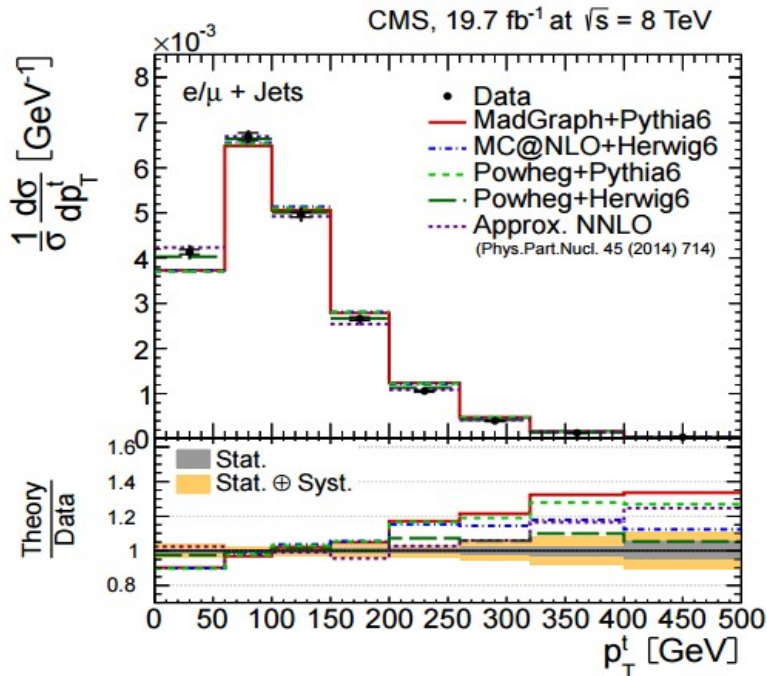
Sezioni d'urto differenziali

Misure di sezioni d'urto differenziali (canale $l+jet$): funzione $P_T(Top)$, $y(Top)$, $M_{t\bar{t}}$

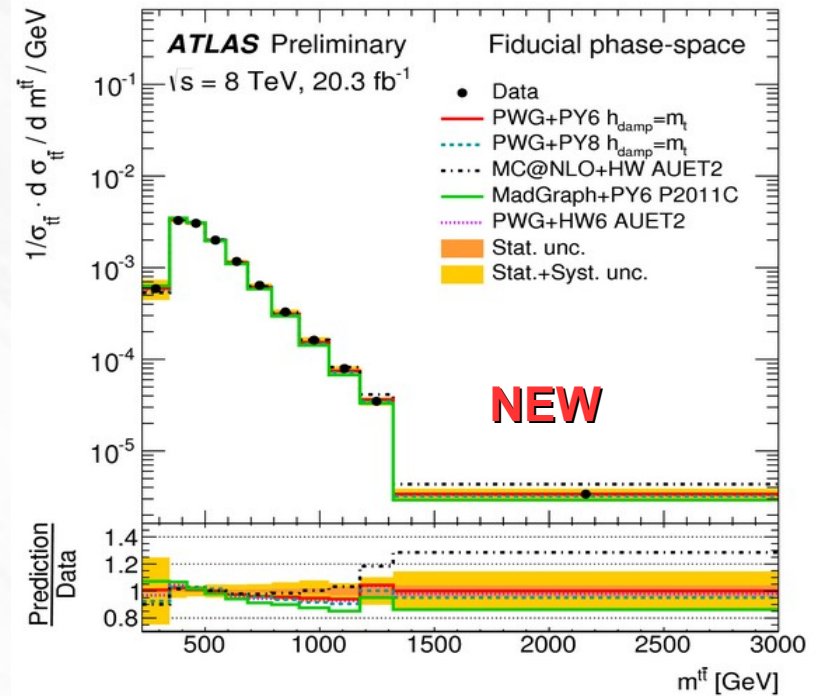
→ test di pQCD

Input per PDF (alto P_T)

$d\sigma/dM_{t\bar{t}}$ sensibile a nuova fisica (risonanze pesanti,...)



CMS-TOP-12-028

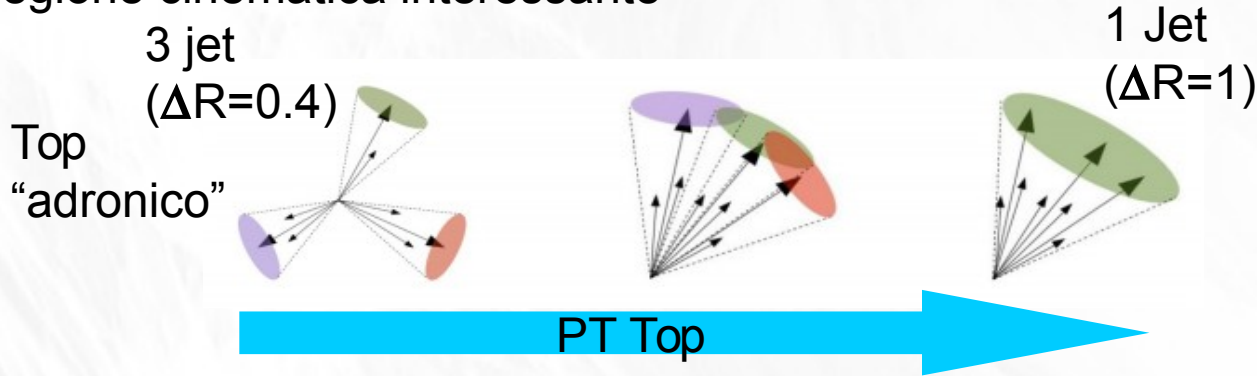


ATLAS-TOPQ-2015-06

cf comunicazione V. Scarfone

Sezioni d'urto differenziali: Boosted

Ricostruzione del top poco efficiente se quark top prodotti ad alto PT
 → regione cinematica interessante

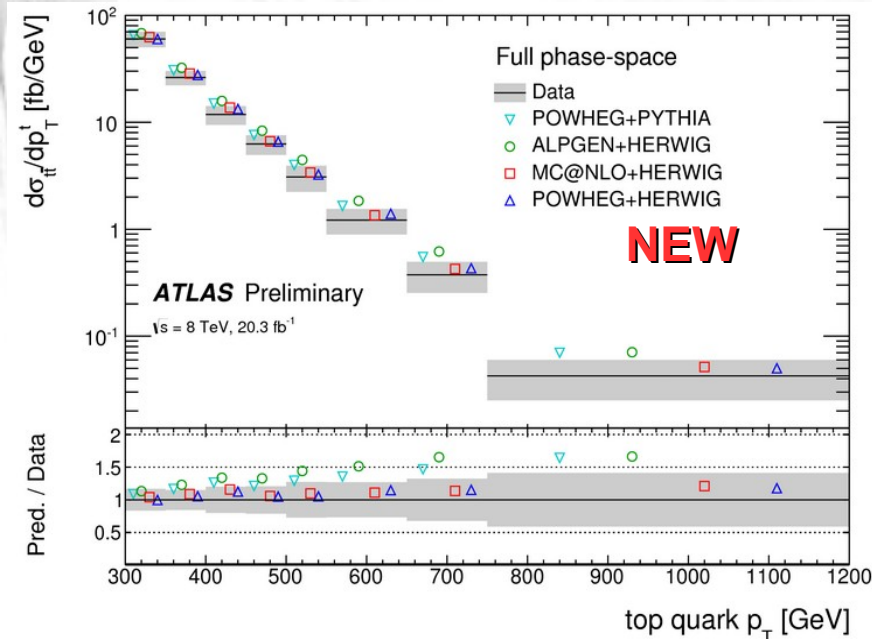


Procedura di unfolding per sezioni d'urto differenziali:

- Particle level
- Parton level

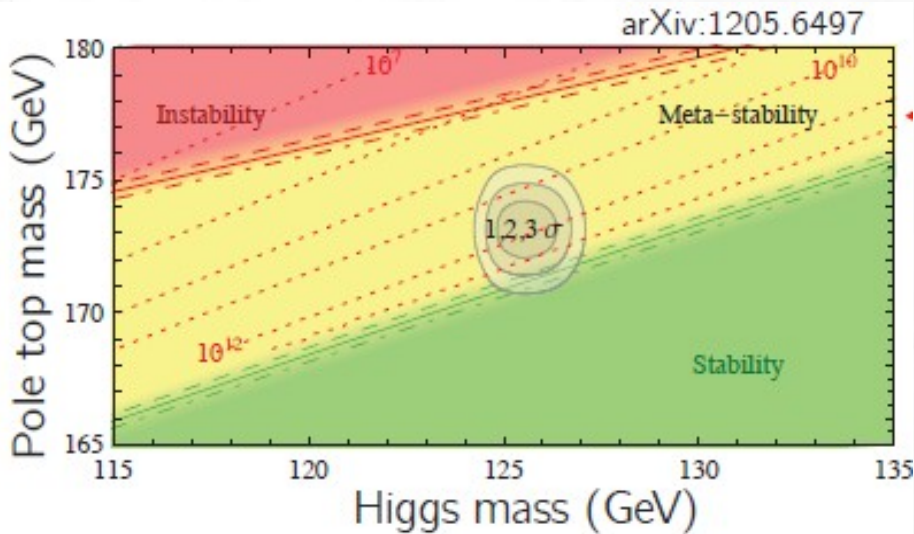
Piu` semplice il confronto con previsioni teoriche

In Run2 regione cinematica "boosted" ancora piu` importante (non solo top, anche bosoni elettrodeboli, Higgs)



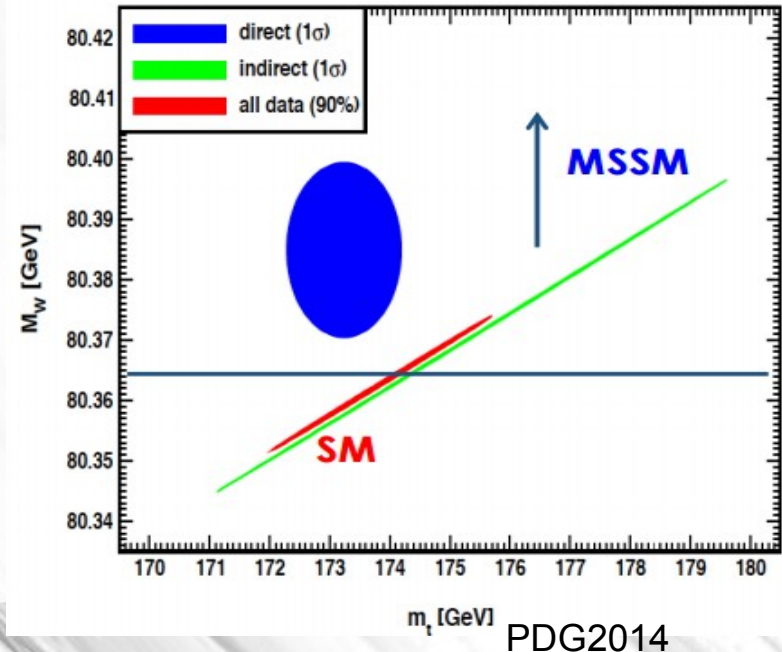
cf comunicazioni F. Fabbrì e S. Biondi

Massa top

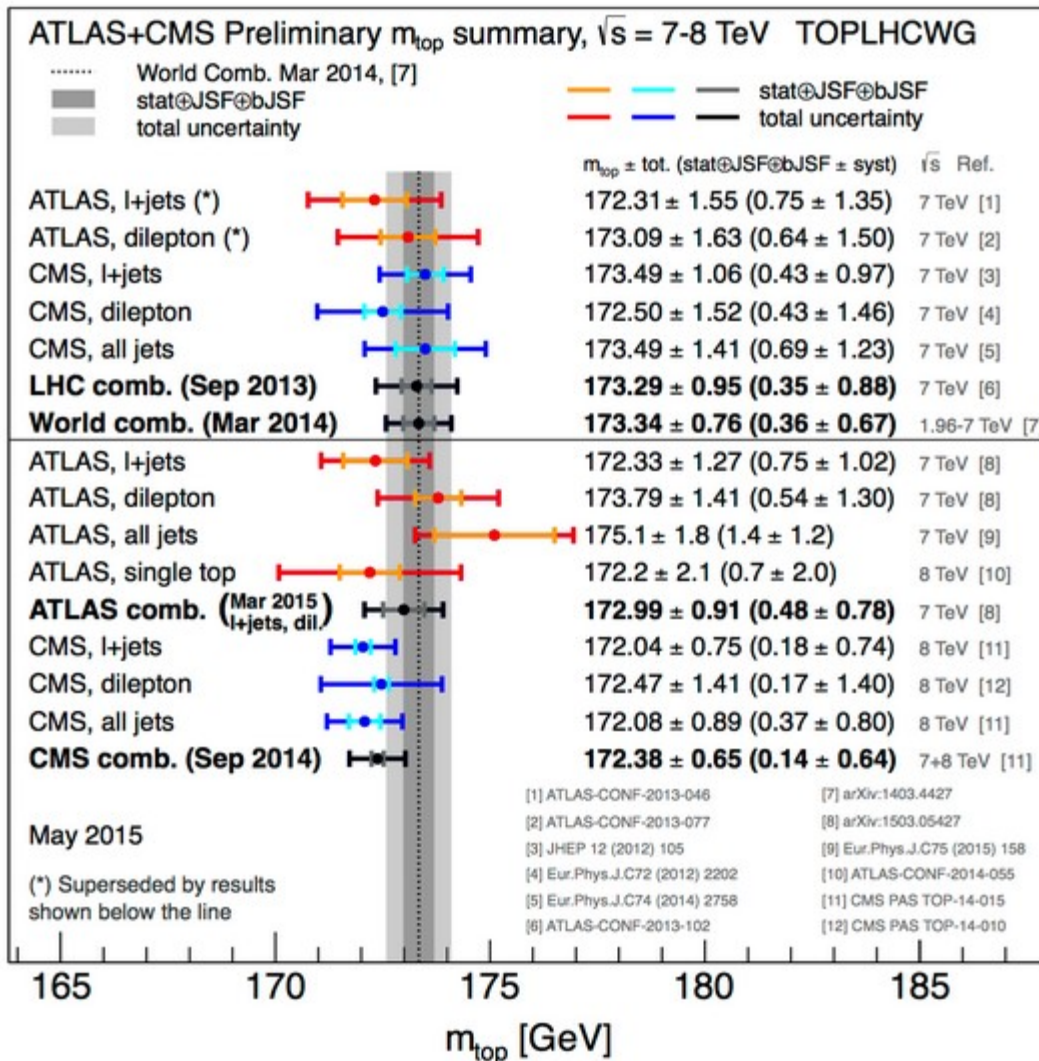


Massa del quark top e
bosone di Higgs →
stabilita` del vuoto

Massa top e massa bosone W
→ Modello Standard sistema
“sovravincolato”
→ test importante per
consistenza del MS



Massa top



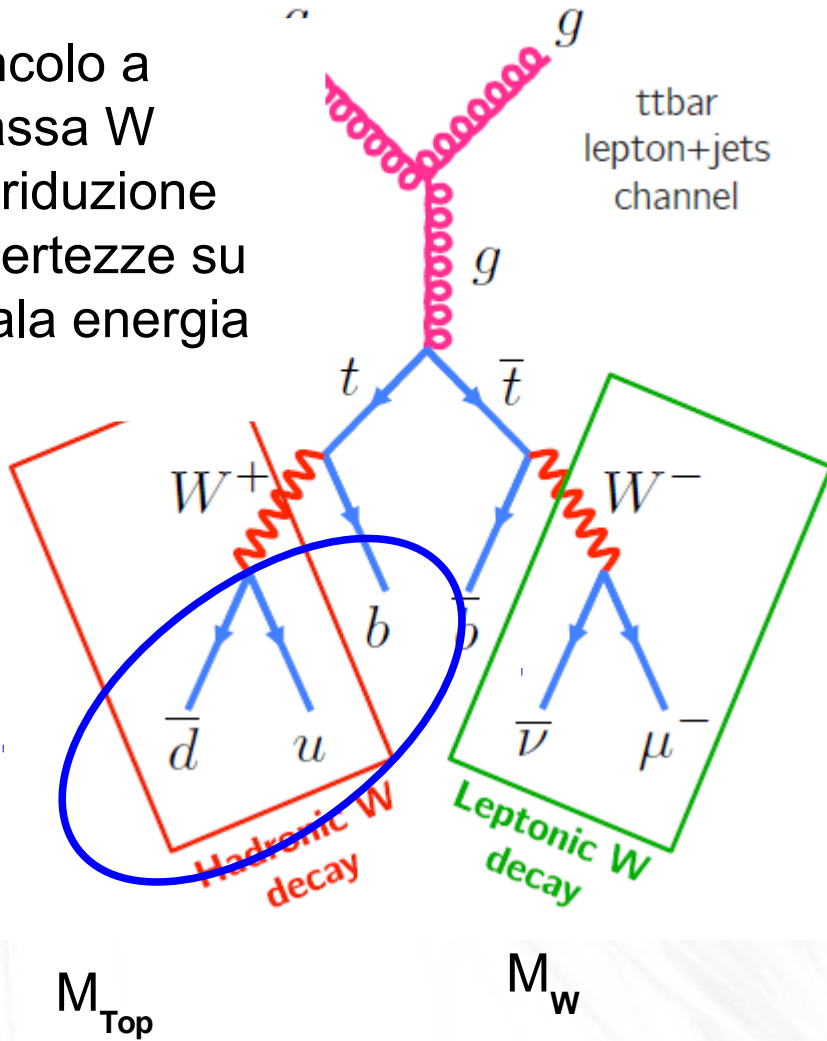
Combinazione Tevatron:
 $M_{top} = 174.34 \pm 0.64 (0.37 \pm 0.52)$ GeV

Precisione LHC molto vicina a
 precisione Tevatron
 → paragonabile con Λ_{QCD}
 → Cruciale una corretta
 interpretazione

Incertezze maggiori:
 Calibrazioni jet in-situ
 Modellizzazione segnale
 (adronizzazione, ISR, FSR,...)

Massa top: lepton + jet

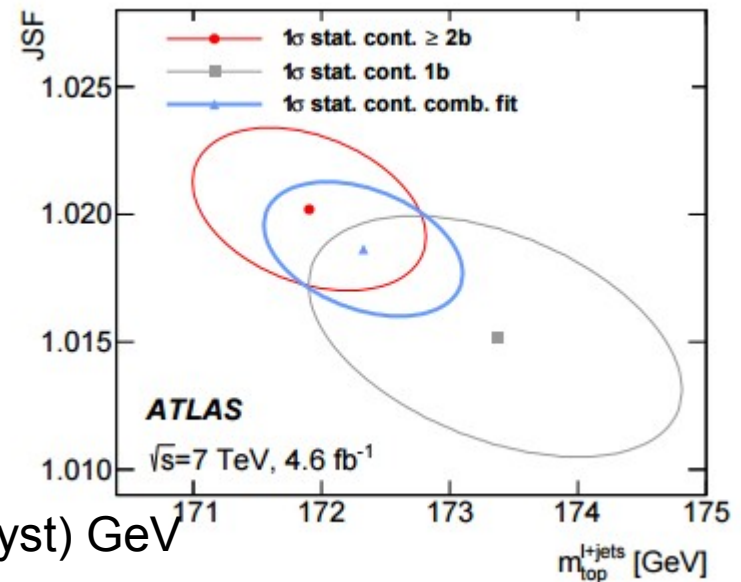
Vincolo a massa W
 → riduzione incertezze su scala energia jet



Nel canale lepton + jet
 3D fit:
 M_{top} , M_W e R_b

$$R_{bq}^{reco,2b} = \frac{p_T^{b_{had}} + p_T^{b_{lep}}}{p_T^{W_{jet1}} + p_T^{W_{jet2}}}$$

Fit simultaneo di M_{top} , JES (light-jet), bJES (b-jet)



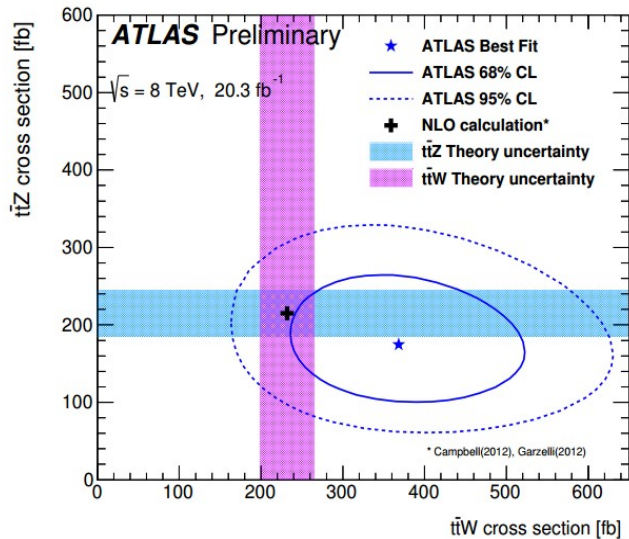
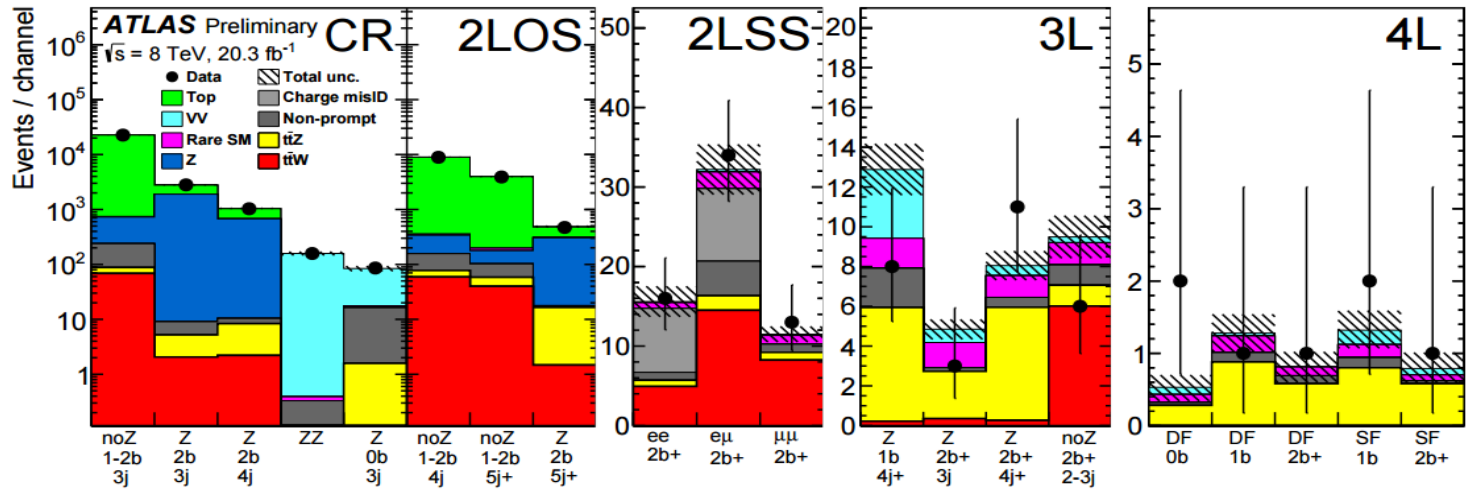
$$M_{Top} = 172.33 \pm 0.75 \text{ (stat+JSF+bJSF)} \pm 1.02 \text{ (syst) GeV}$$

Eur. Phys. J. C (2015) 75:330

Roma, Sett. 2015

A. Sidoti – SIF 2015

Produzione ttV

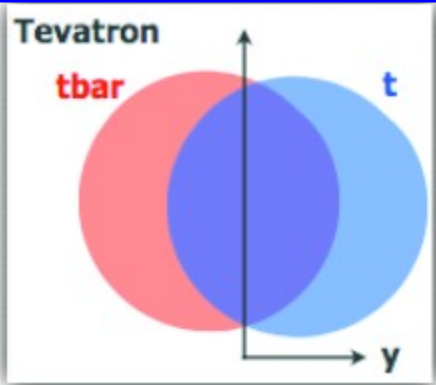


Fondo irriducibile per produzione associata di Higgs con coppie tbar (e tH)
 Analisi con molteplici stati finali
 Incertezze su predizioni teoriche ~10%

ATLAS-CONF-2015-032

Asimmetria di carica $t\bar{t}$

Tevatron



$$A_{FB} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$$

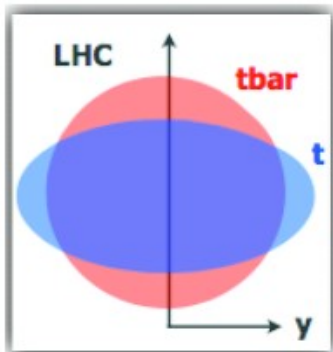
$$\Delta y = y_t - y_{\bar{t}}$$

CDF Note 11161
FERMILAB-PUB-15-312-E

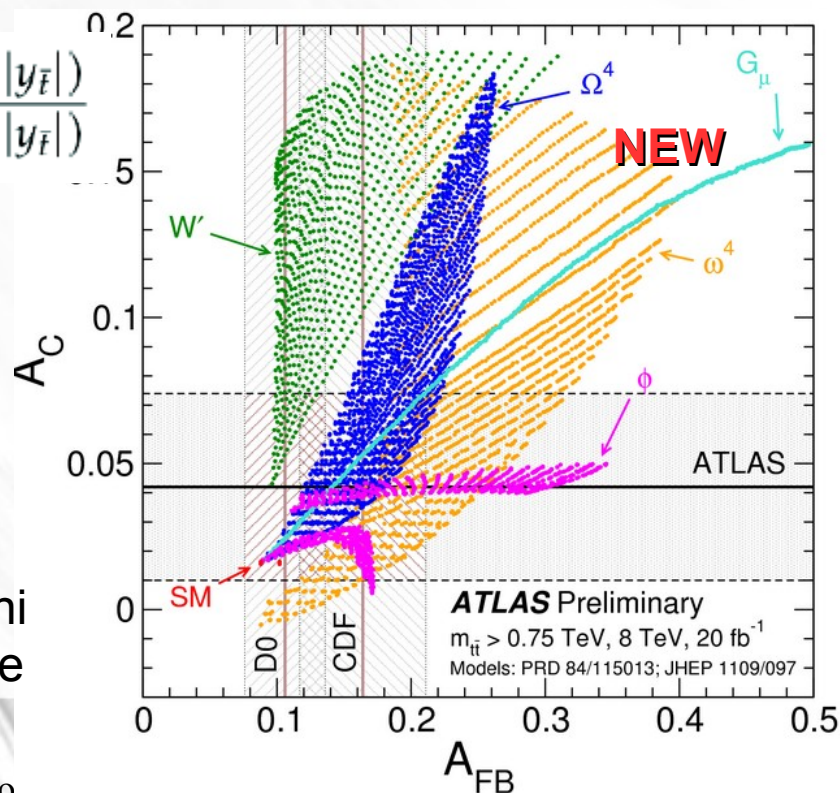
Asimmetria Forward Backward misurata al Tevatron
→ Tensione con previsioni teoriche

LHC

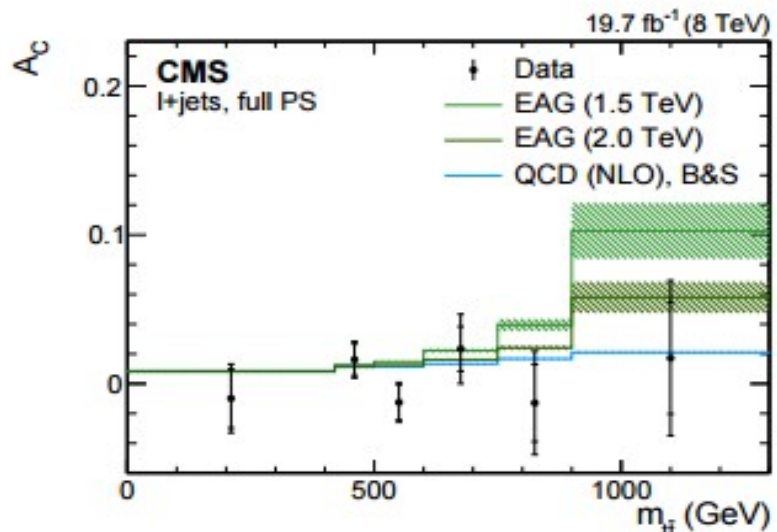
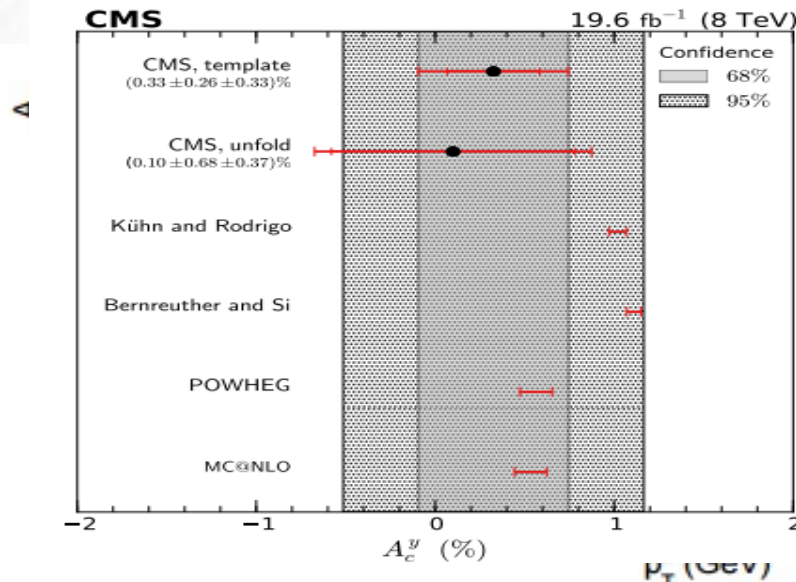
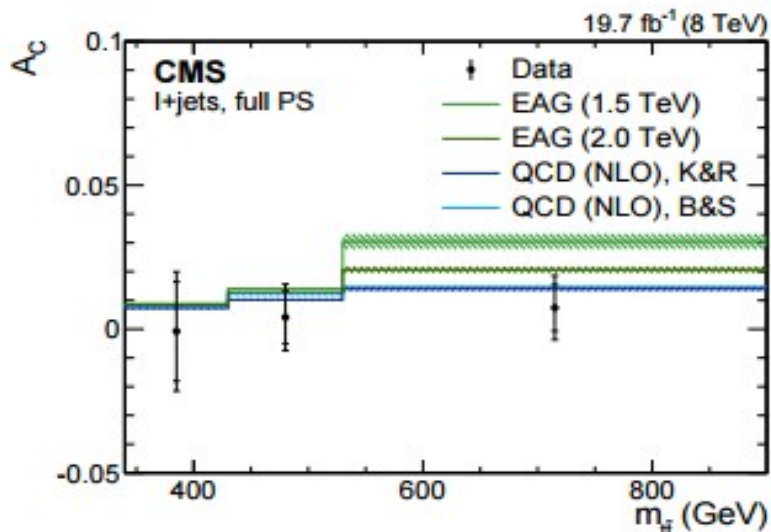
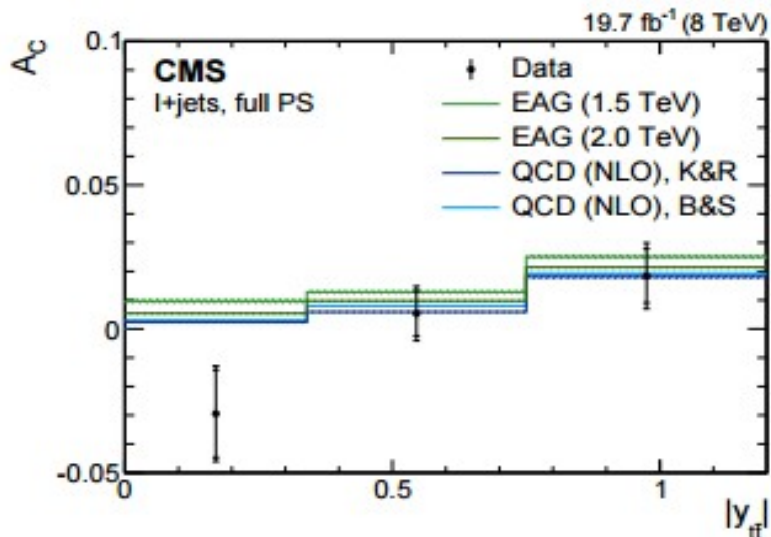
$$A_C = \frac{N(|y_t| > |y_{\bar{t}}|) - N(|y_t| < |y_{\bar{t}}|)}{N(|y_t| > |y_{\bar{t}}|) + N(|y_t| < |y_{\bar{t}}|)}$$



Maggiore sensibilita` a deviazioni con misure differenziali e regione cinematica boosted



Asimmetria di carica $t\bar{t}$



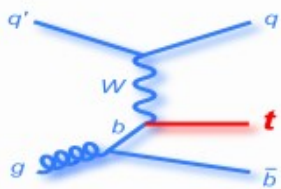
NEW

maggiore sensibilità a deviazioni
con misure differenziali e regione
cinematica boosted

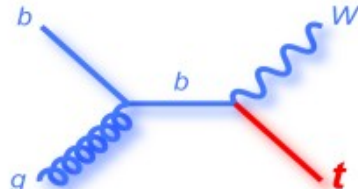
ArXiv:1508.03862 (Template)
arXiv:1507.03119 (Differential)

Top singolo

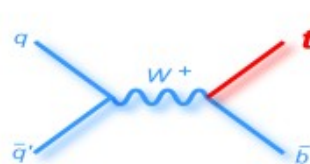
t-channel



Wt channel



s-channel



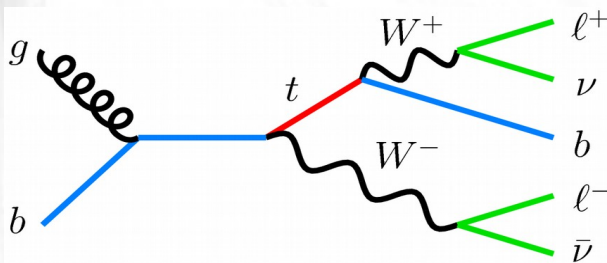
\sqrt{s} (pb)	σ (t-channel)	σ (Wt)	σ (s-channel)
8 TeV	87.8 ± 3.4 Phys. Rev. D 83, 091503(R) (2011)	22.4 ± 1.5 Phys. Rev. D 82, 054018 (2010)	5.6 ± 0.2 Phys. Rev. D 81, 054028 (2010)

Produzione elettrodebole top singolo importante:

- Test unitarieta' CKM (Vtb diretto)
- PDF per b-quark
- Sonda per BSM (W', H+ etc)
- Fondo per Higgs e ricerche BSM

Prima osservazione top-singolo a LHC in canale s-channel!

NEW

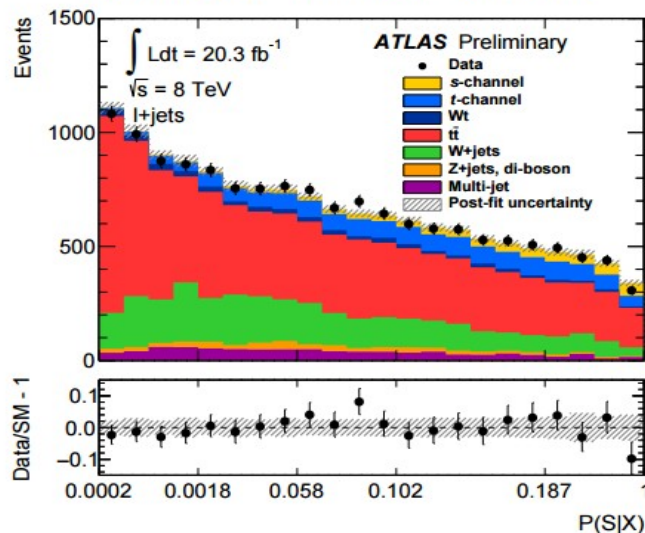


$$\sigma_s(\text{Exp}) = 4.8 \pm 1.1 \text{ (stat)} + 2.2 - 2.0 \text{ (syst)} \text{ pb}$$

$$3.2 \sigma \text{ (exp } 3.9 \sigma)$$

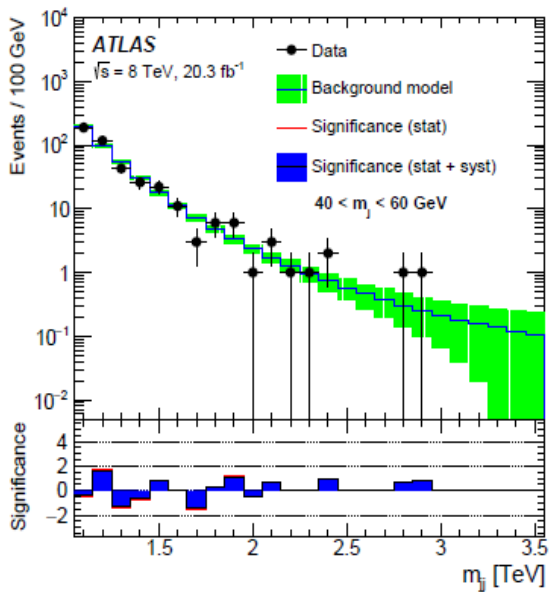
$$\sigma_s(\text{Theo}) = 5.61 \pm 0.22 \text{ pb}$$

2-jet 2-tag ($\sim 4.3\%$ of s-channel)

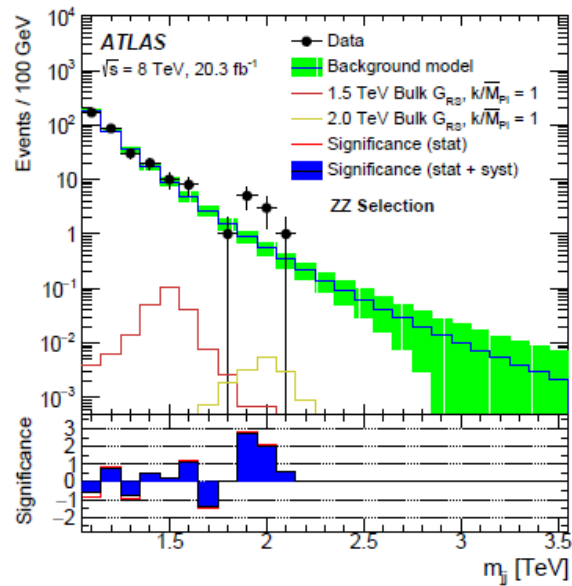


Risonanze VV

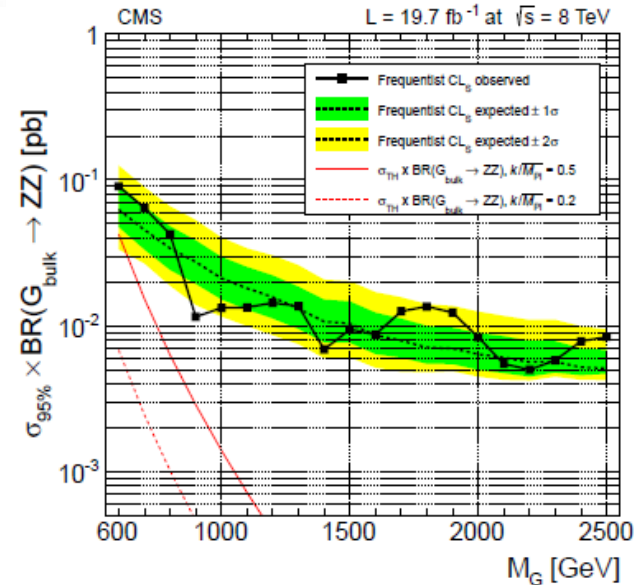
Esempio di applicazione di tecniche per ricostruzione stati finali boosted
 ATLAS: Per ricerca di risonanze BSM VV ($WW/WZ/ZZ$) \rightarrow $qqqq$
 Segnale: Due jet ($\Delta R=1.2$) e richiesta selezione boson tagging
 CMS: canale semileptonico $VV \rightarrow$ $l\nu qq$ oppure $ll qq$ con boson tagging



Regione di Controllo



Segnale



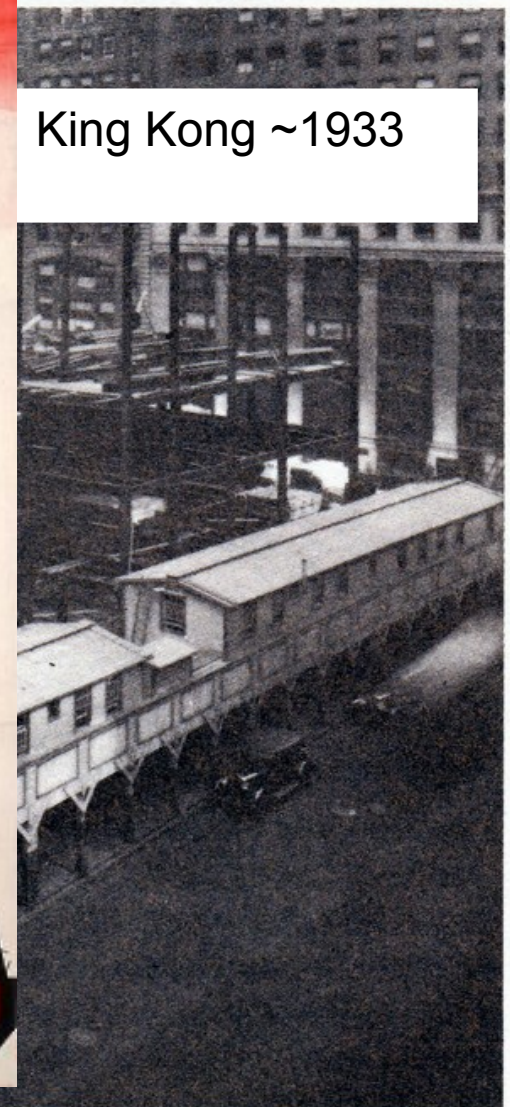
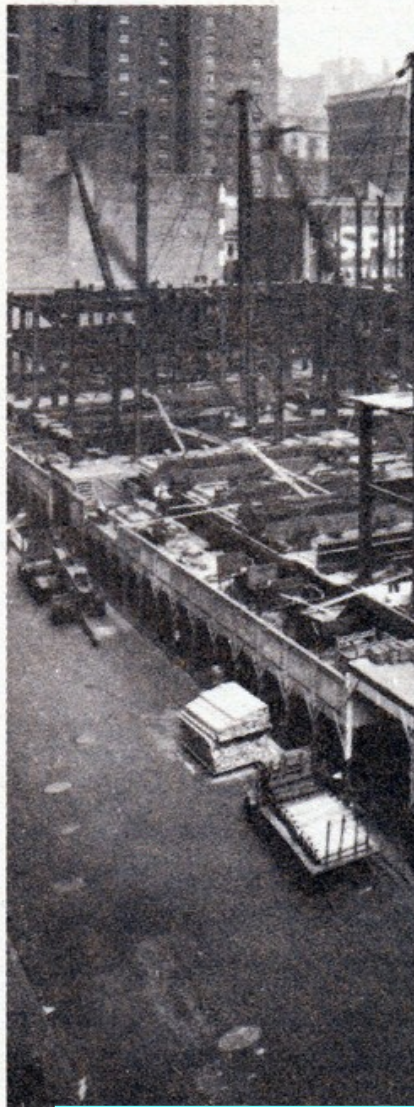
Exclusion plot

Sicuramente una regione cinematica particolare da tenere d'occhio nel Run2

Fondamenta Empire State Building,
New York ~1930



QCD, fisica elettrodebole e top
fondamenta per:
comprensione Modello Standard



King Kong ~1933

...e ricerche di Fisica oltre il Modello Standard

Conclusioni

- La scoperta del bosone di Higgs e` stata l'eredita` principale del Run1 di LHC
- Luminosita` integrata senza precedenti raccolta alle energie piu` alte hanno permesso di testare le fondamenta del Modello Standard in dettagli ed in tutti gli angoli dello spazio delle fasi possibili
- Per il Run2 di LHC partiamo con fondamenta piu` solide:

Comprensione teoriche

→ modello dei fondi

→ ricerche di deviazioni da previsioni teoriche

PDF

Tecniche sperimentali

Consistenza del Modello

Standard



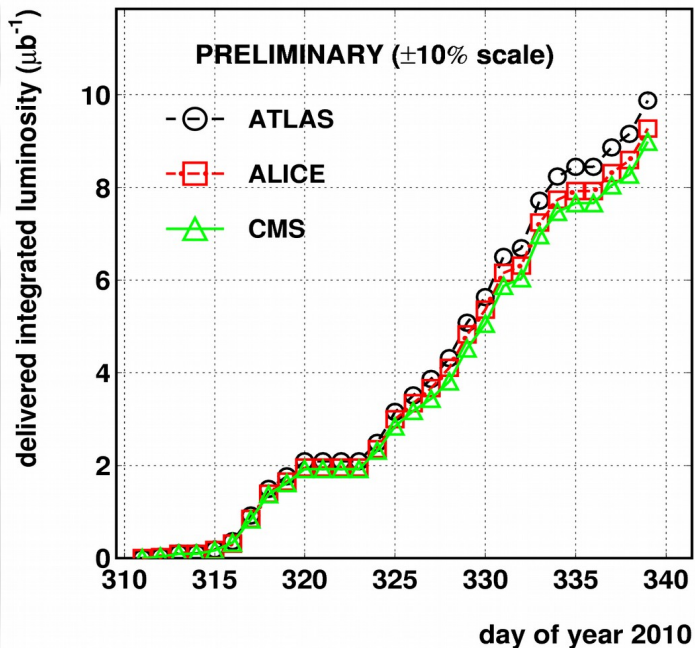
BackUp

2010/12/06 21.35

LHC 2010 HI RUN (3.5 Z TeV/beam)

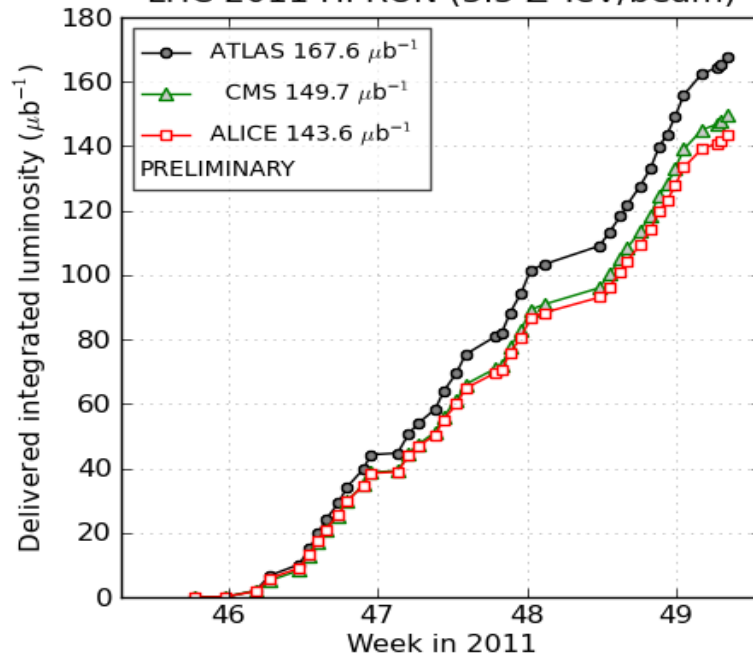
PRELIMINARY ($\pm 10\%$ scale)

- ATLAS
- ALICE
- △- CMS



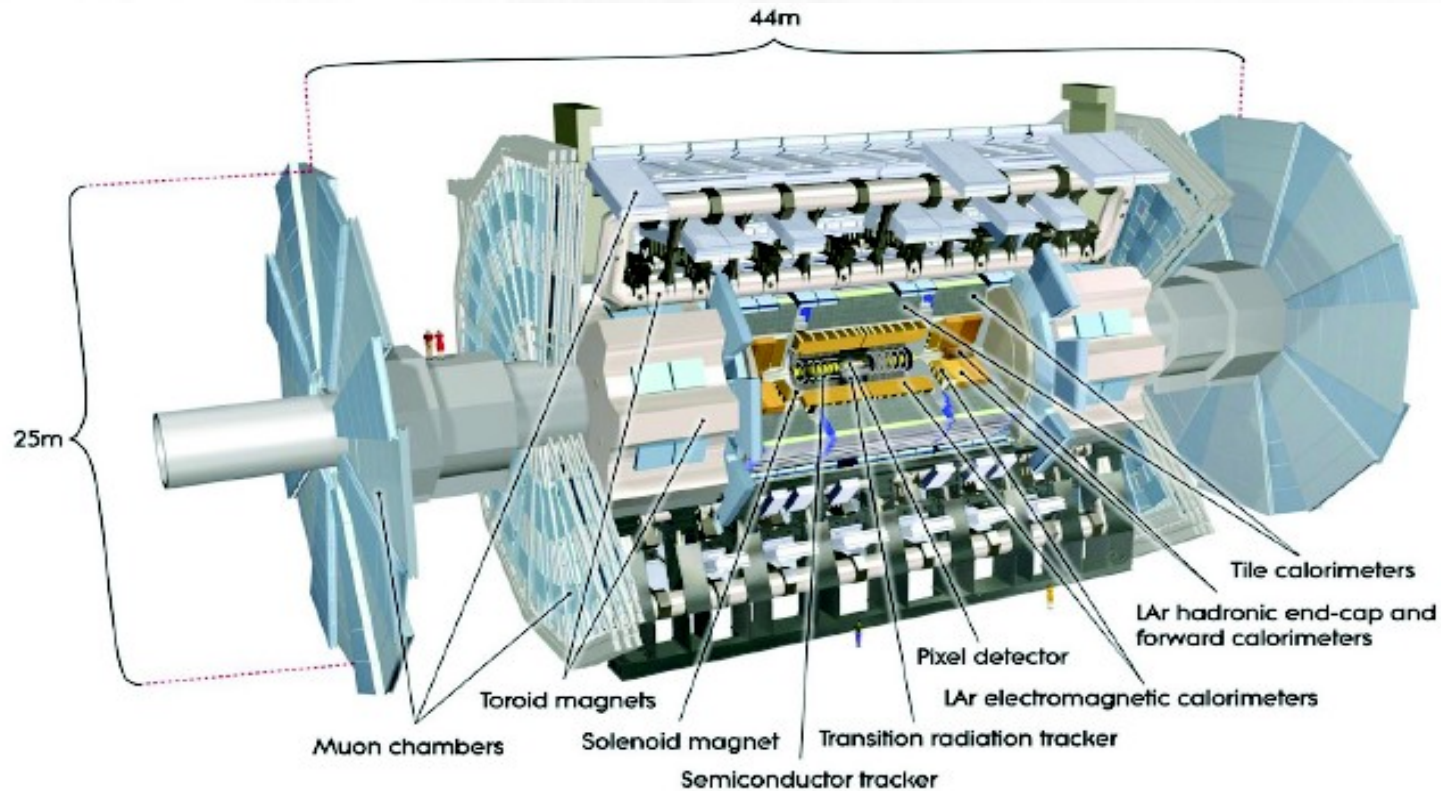
LHC 2011 HI RUN (3.5 Z TeV/beam)

- ATLAS 167.6 μb^{-1}
 - △ CMS 149.7 μb^{-1}
 - ALICE 143.6 μb^{-1}
- PRELIMINARY



(generated 2011-12-20 08:08 including fill 2351)

ATLAS Detector



Inner Detector

$|\eta| < 2.5$

vertex and track reconstruction

Calorimeter

$|\eta| < 3.2$

jet / electron / photo reconstruction

Muon Spectrometer

$|\eta| < 2.7$

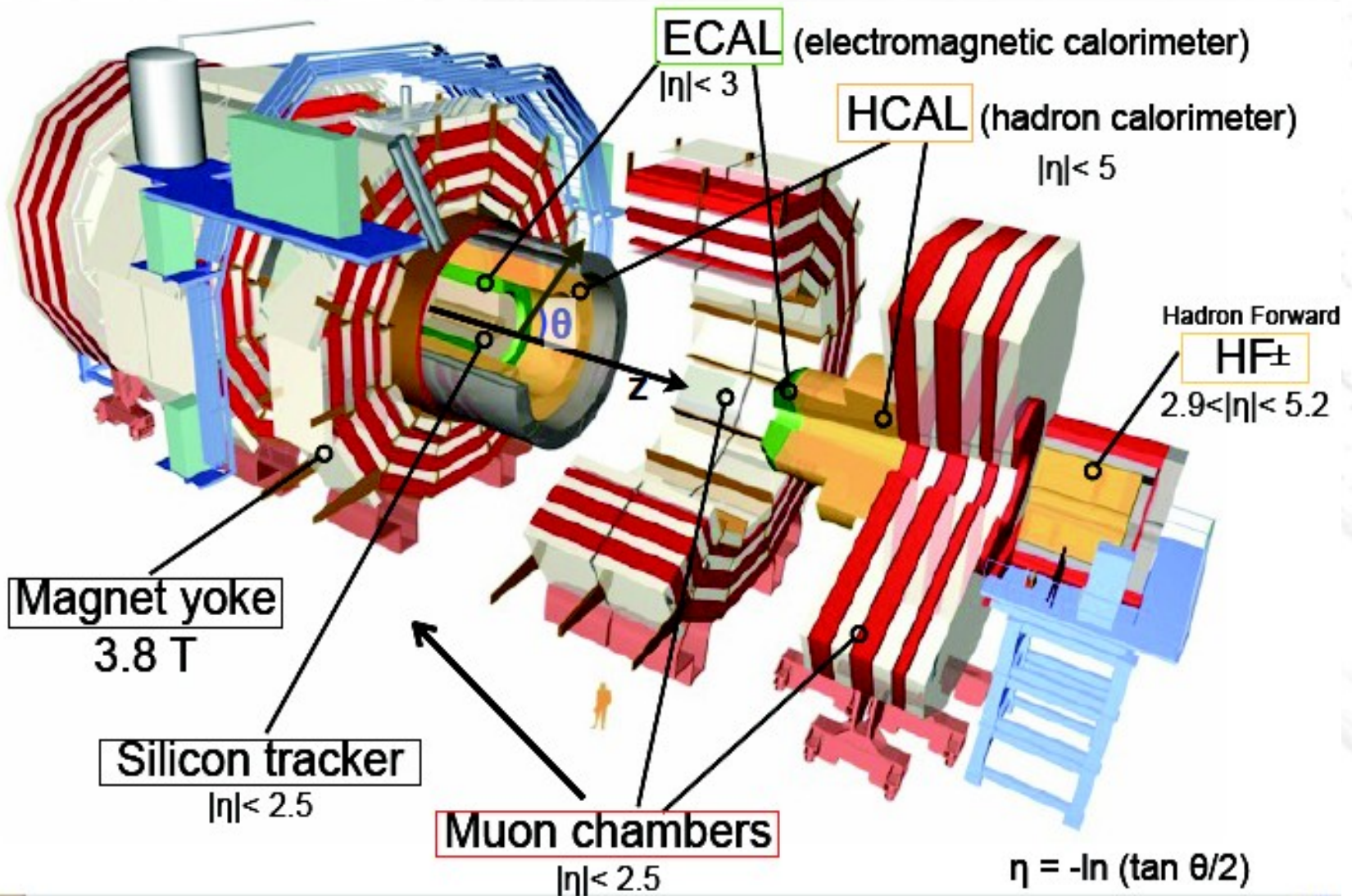
muon reconstruction

Forward Calorimeter (FCal)

$3.2 < |\eta| < 4.9$

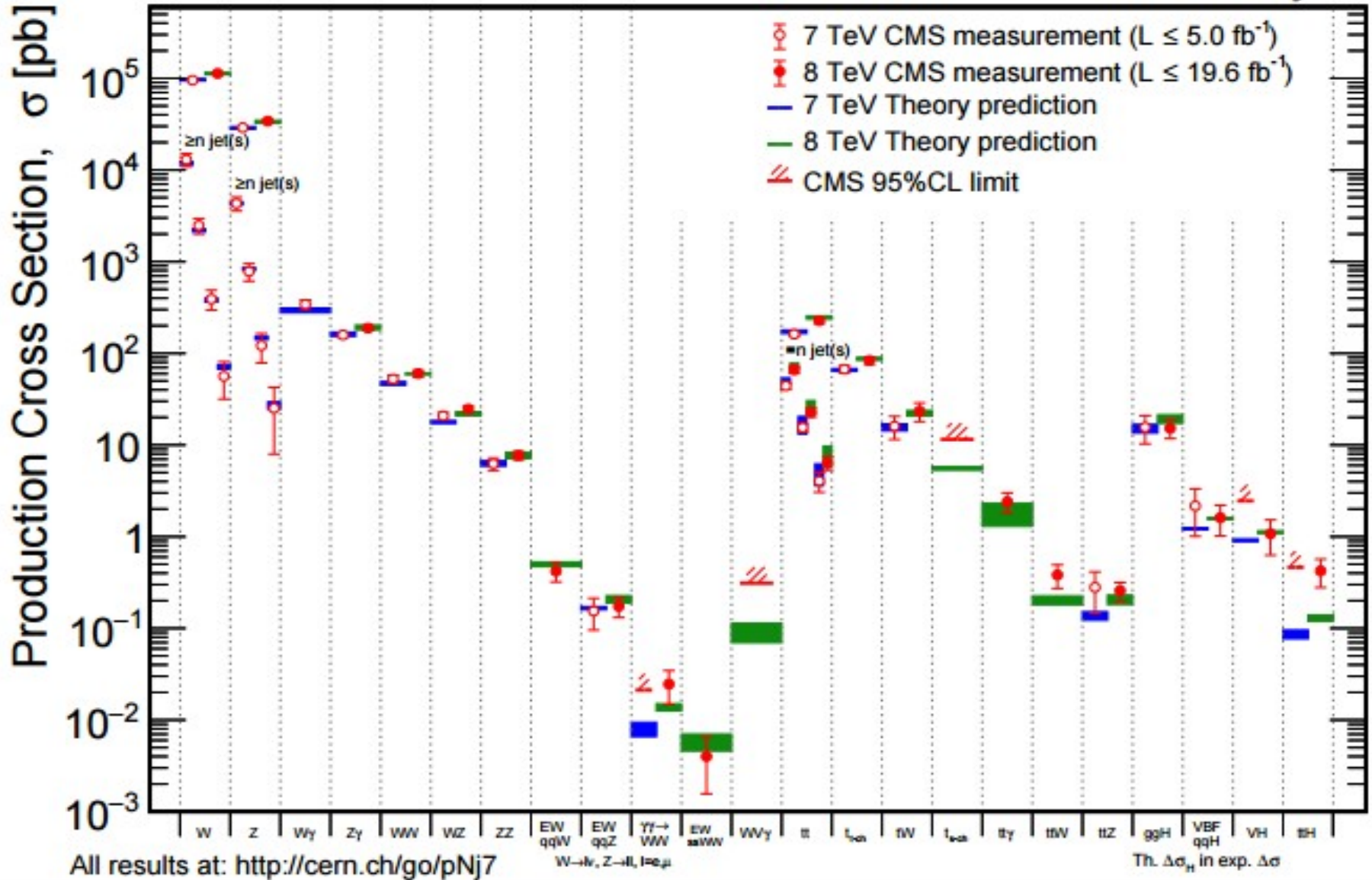
centrality determination

CMS Detector



July 2015

CMS Preliminary



- The ATLAS-epWZ12 NNLO fit (NLO and LO also performed): PRL 109, 012001 (2012)

The W charge asymmetry data help to constrain the u and d valence distributions

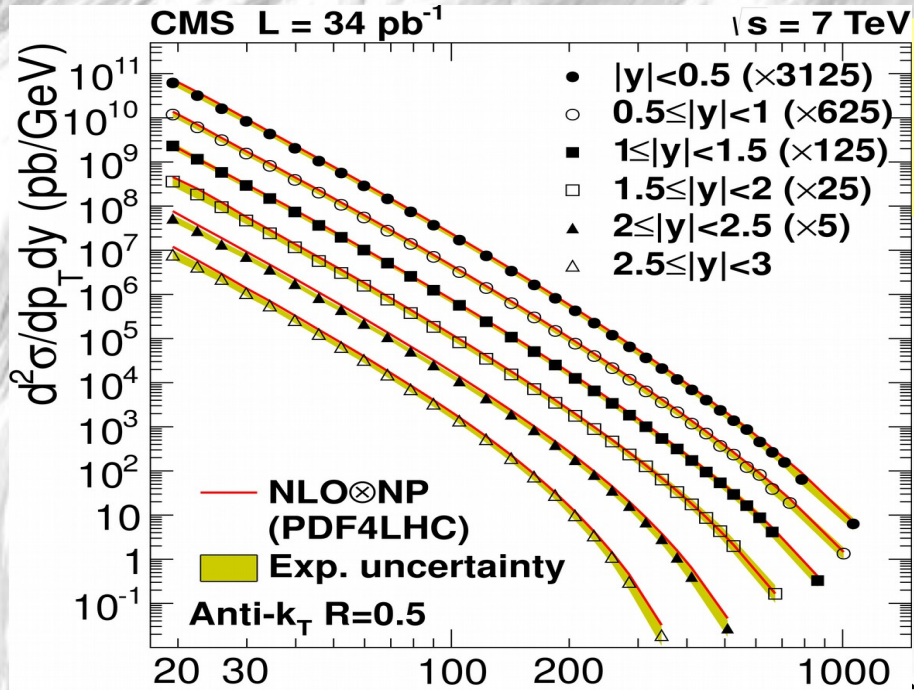
Z data provides some constraint on the strange distribution

- The CMS fit, uses W asymmetry data and W+c to constrain the strange quark distribution: arXiv:1312.6283v2

MCFM calculation at the bare charm level - fit uses data unfolded using charm fragmentation fractions for comparison

- ATLAS "eigenvector" fit to the new ATLAS W+c data: arXiv:1402.6263v1

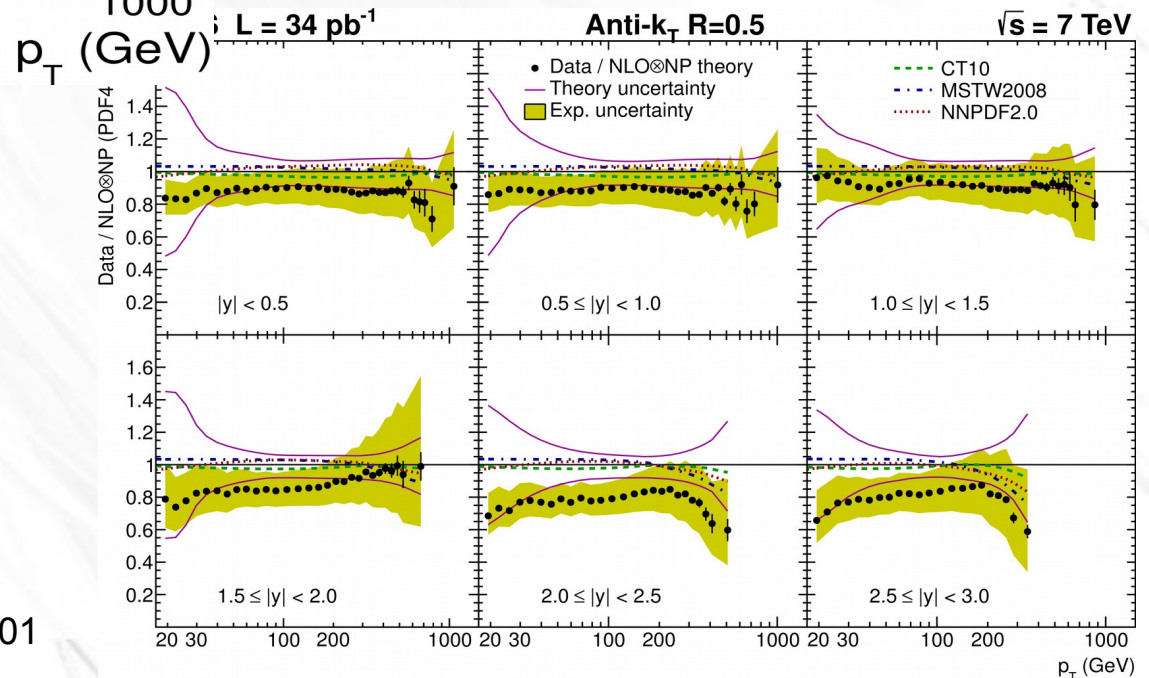
Using combination of cross section predictions from the eigenvector sets of the HERA PDF1.5 in **aMC@NLO** including full parton shower and fragmentation



Sezioni d'urto inclusive jet (7 TeV)

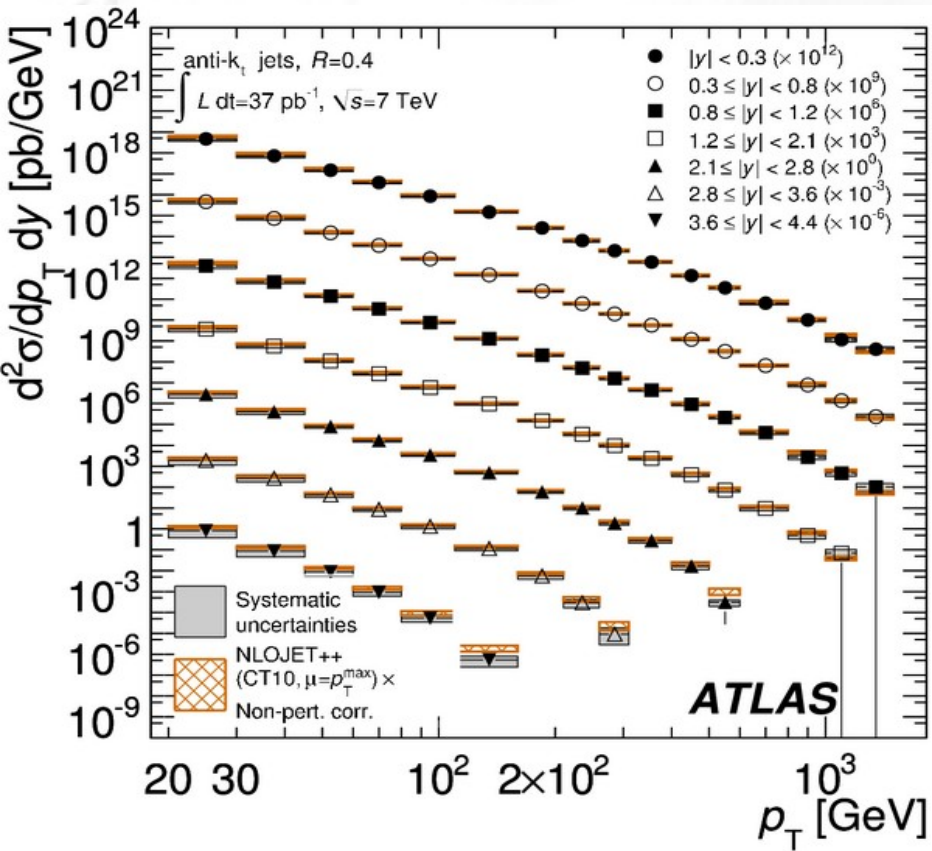
Sezione d'urto inclusiva di produzione di jet

Confronto con previsioni teoriche e diversi set di PDF



CMS: Phys. Rev. Lett. 107 (2011) 132001

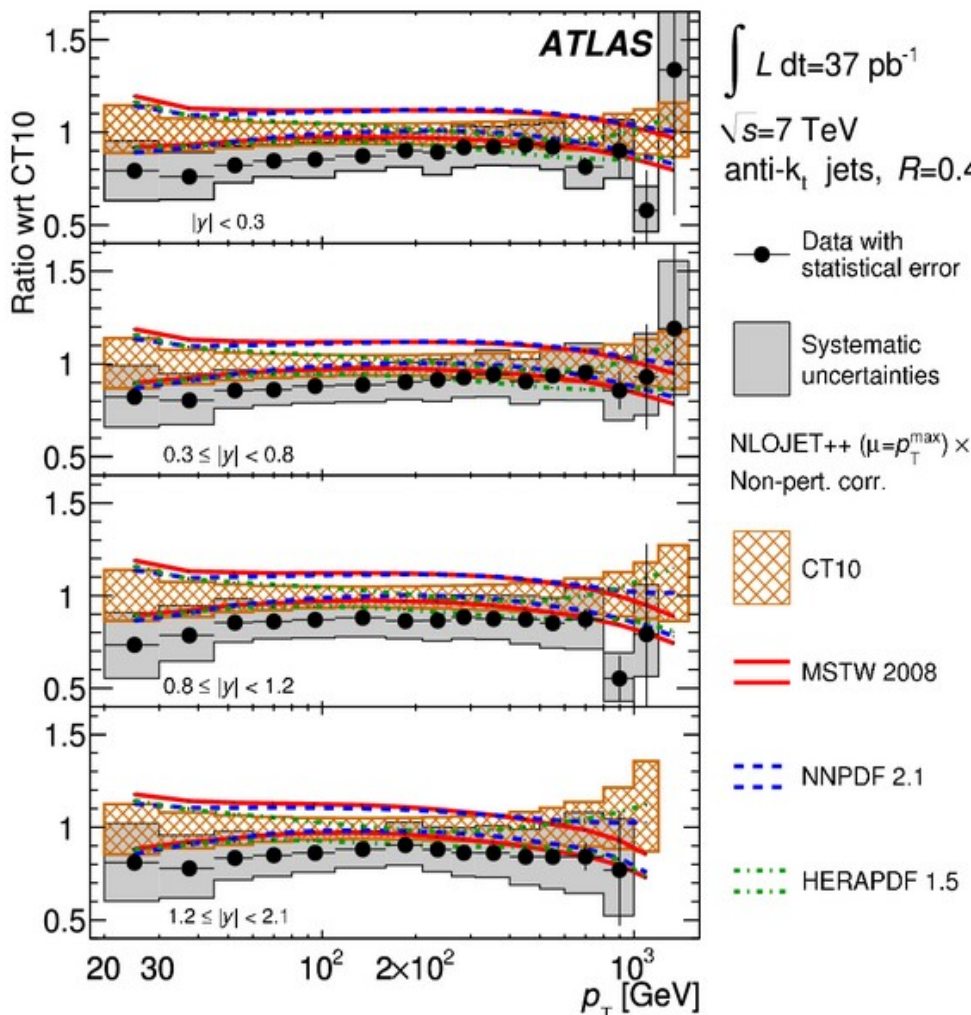
Sezioni d'urto jet inclusive (7 TeV) (2012)



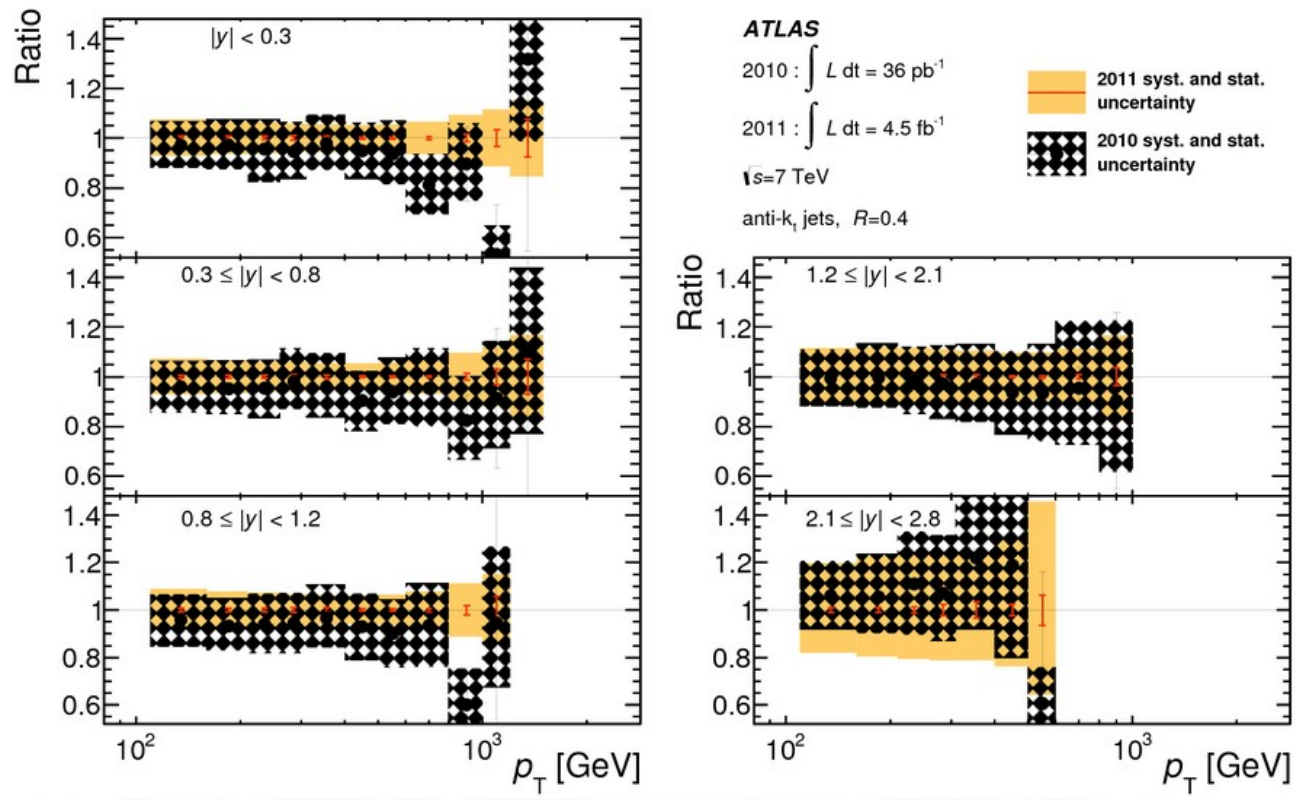
Confronto con previsioni teoriche e diversi set di PDF

ATLAS :Phys.Rev. D86 (2012) 014022

Sezione d'urto inclusiva di produzione di jet

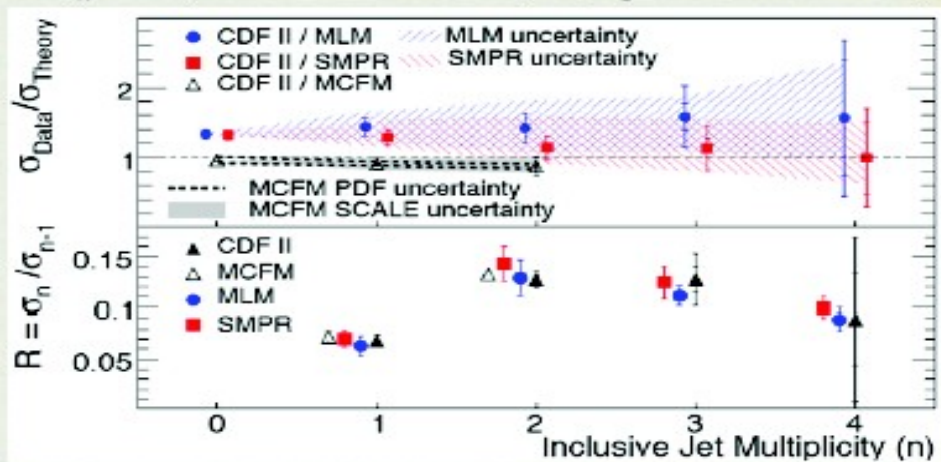


Sezioni d'urto jet inclusive (7 TeV) (2012)

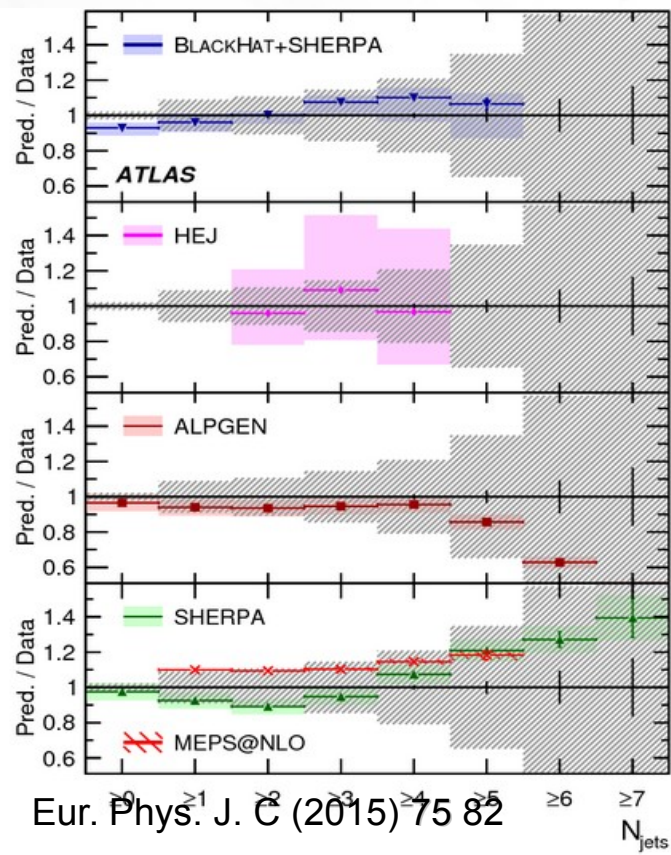
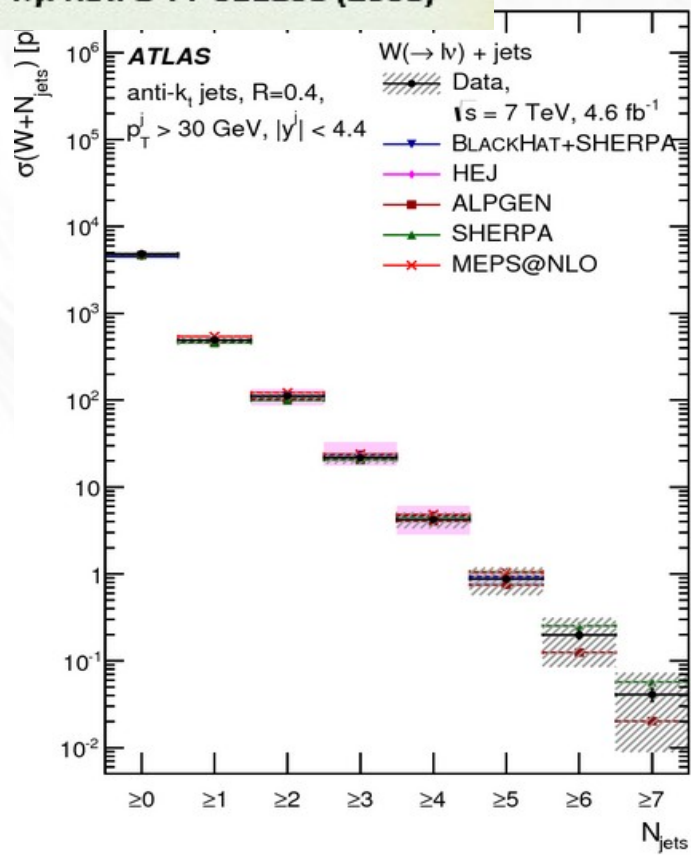


ATLAS :JHEP02(2015)153

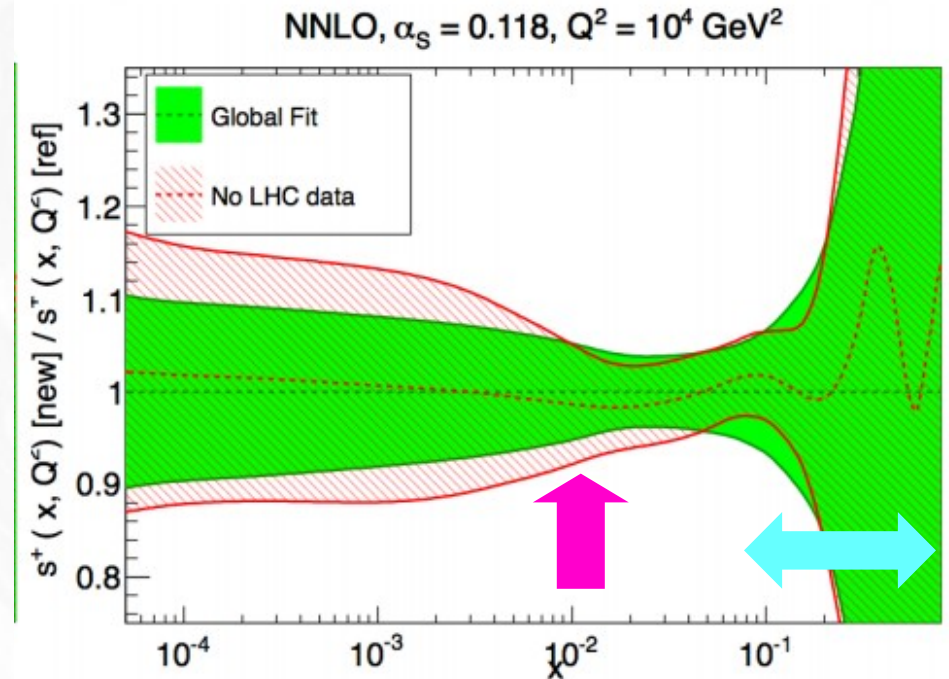
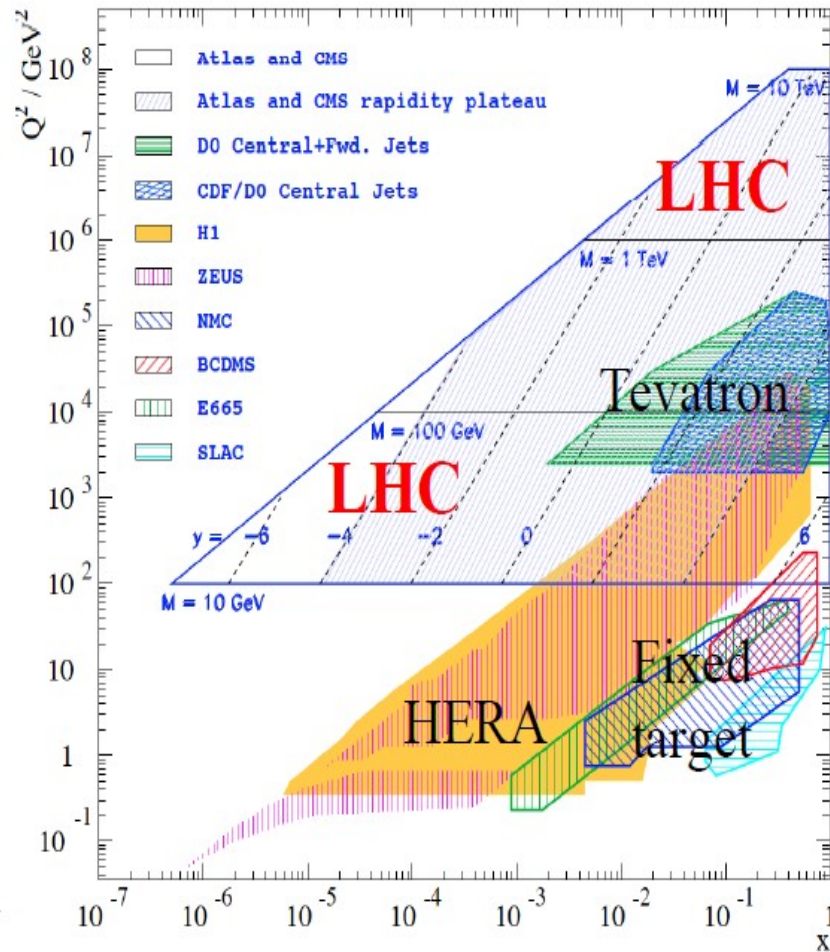
$$\sigma_n = \sigma(W \rightarrow ev + \geq n - \text{jet}; E_T^{\text{nth-jet}} > 25\text{GeV})$$



Results from CDF Phys. Rev. D 77 011108 (2008)



PDF per il Run2



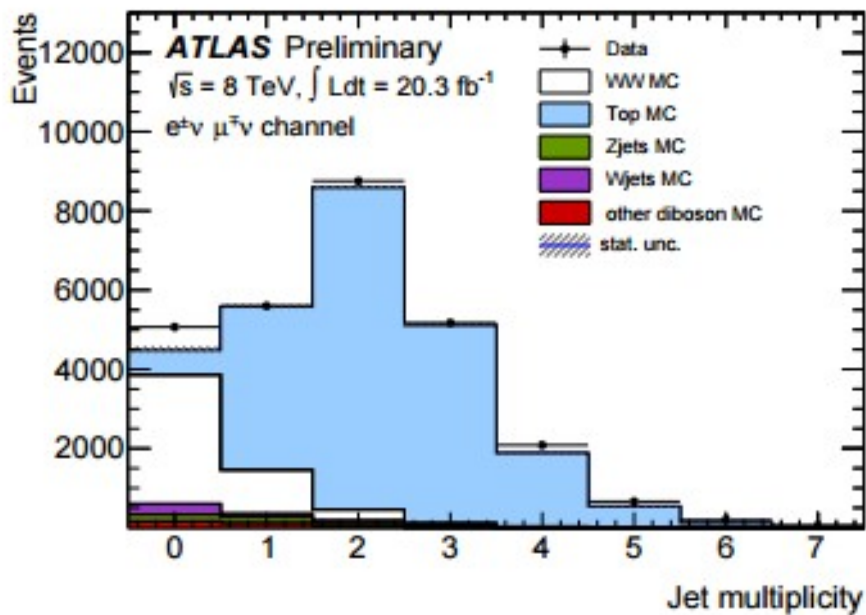
Higgs Production ($gg \rightarrow H$)

New physics searches

S. Glazov, Braz.J.Ph. **37** (2007) 793

NNPDF Coll: JHEP 1504 (2015) 040

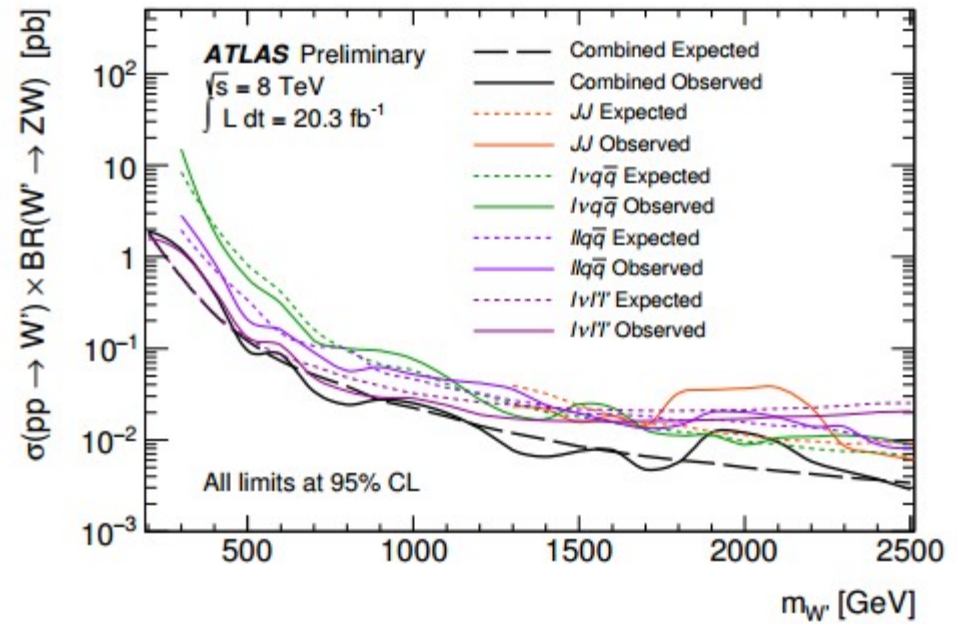
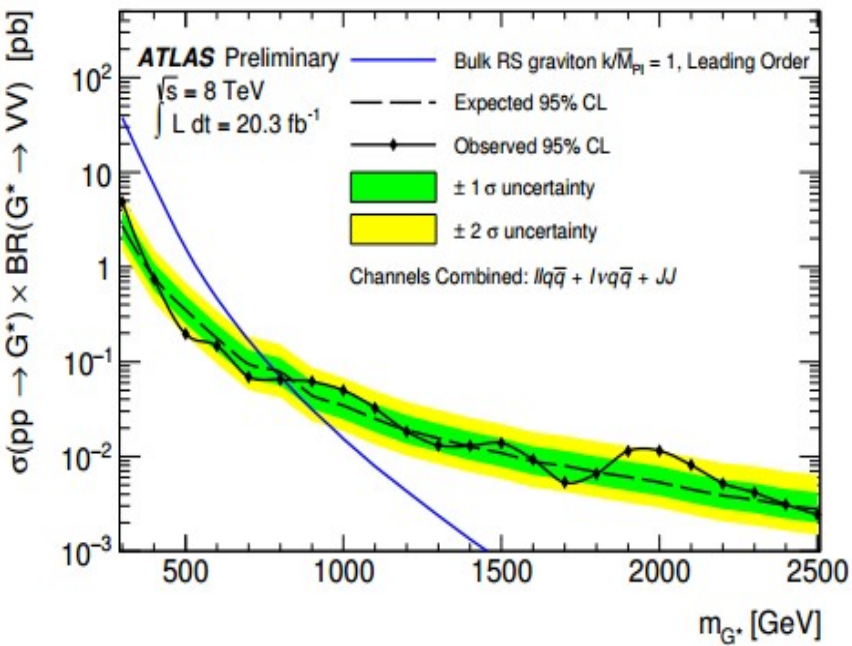
Sezione d'Urto di Produzione WW



Jet Veto

8 TeV

ATLAS: ATLAS-CONF-2014-033



ATLAS-CONF-2015-045