Physics with first data at the LHC

- LHC aims and basics
- Rediscovery of SM
- Search for new physics

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HGF workshop "Detector understanding with first data"

PHYSICS AT THE TERA SCALE
Helmholtz Alliance

References

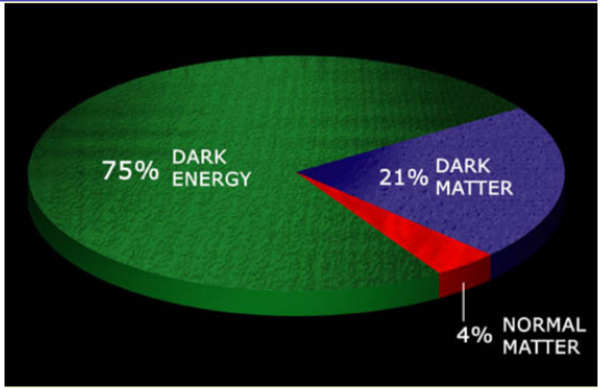
- ATLAS: „Expected Performance of the ATLAS Experiment
  - CERN-OPEN-2008-020 or arXiv 0901.0512
- CMS: „Physics TDR“
  - CERN-LHCC-2006-001 or J.Phys. G 34 (2007) 995-1579
- CMS: „Post Physics TDR“ Results
  - https://twiki.cern.ch/twiki/bin/view/CMS/PhysicsResults

- only publically available ('blessed') results of simulation studies will be shown

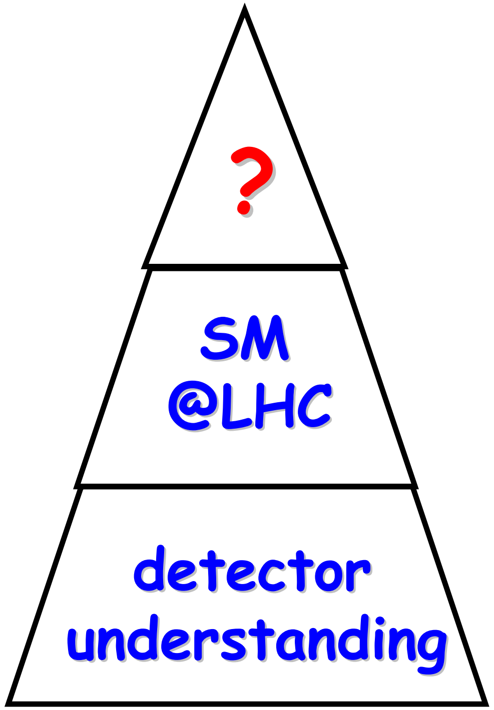
LHC aims and basics

LHC mission

- complete the Standard Model
  - → if Higgs boson does exist
- find evidence for physics beyond SM
  - → e.g. learn about composition of universe (dark matter)



- threefold approach (not fully sequentially)
  - → detector (and reconstruction) understanding with collision data
    - beyond extensive commissioning with cosmic muons
  - → rediscovery of Standard Model
    - establish how pp collisions really look like at LHC
    - followed later on by precision measurements
  - → search for new physics beyond the SM
    - and (precision) measurements of its properties

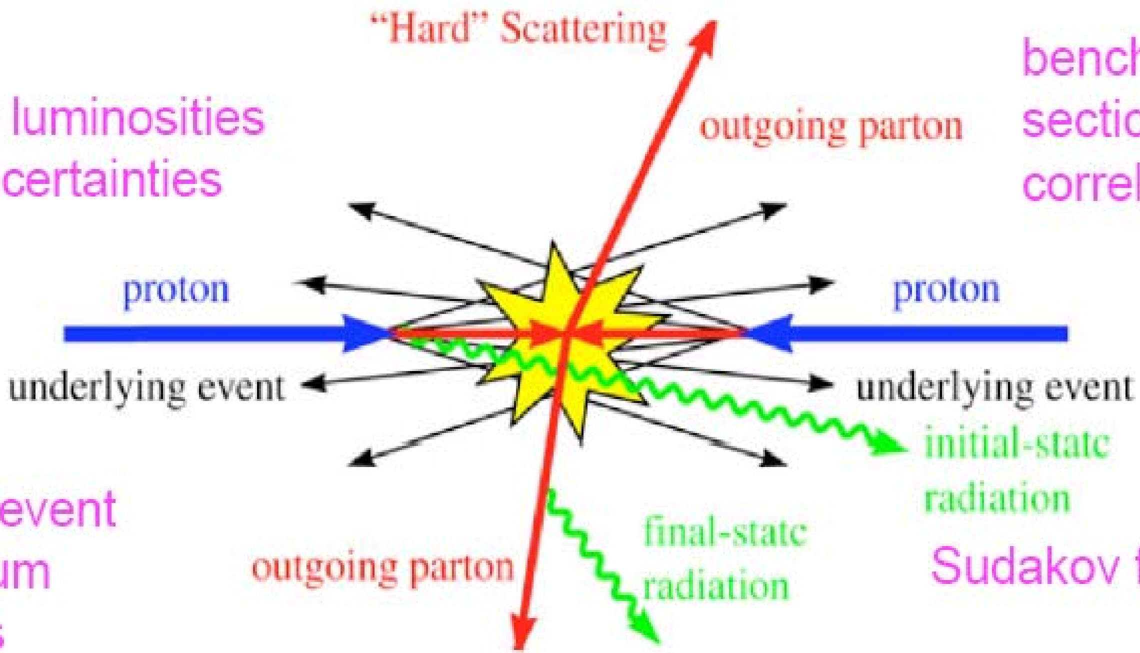


Schema of pp collision

LO, NLO and NNLO calculations
K-factors

PDF's, PDF luminosities
and PDF uncertainties

benchmark cross
sections and pdf
correlations



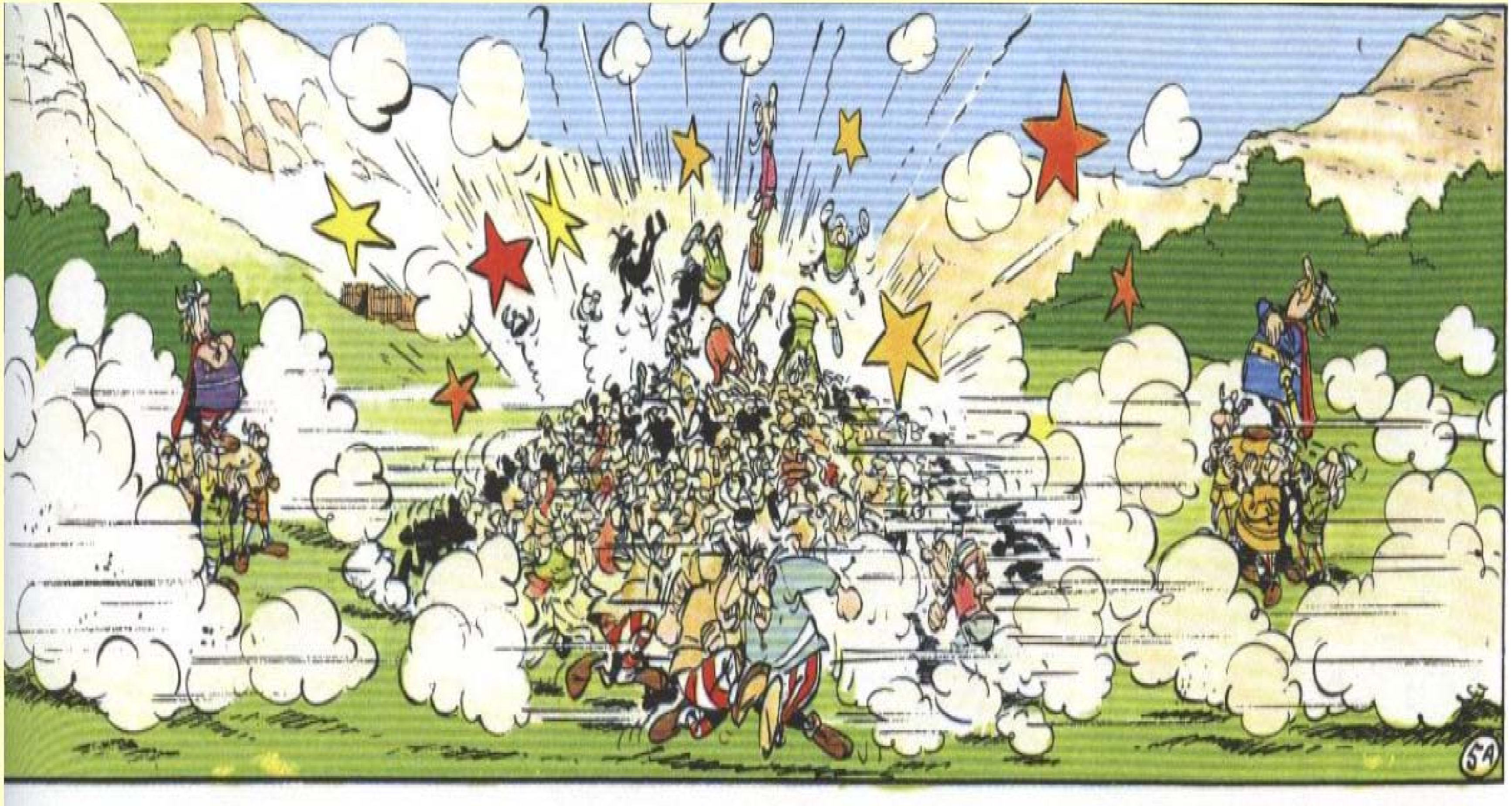
underlying event
and minimum
bias events

Sudakov form factors

jet algorithms and jet reconstruction

- the interesting part is the hard scatter
  - → but it does not come on its own alone

The complexity of pp at LHC

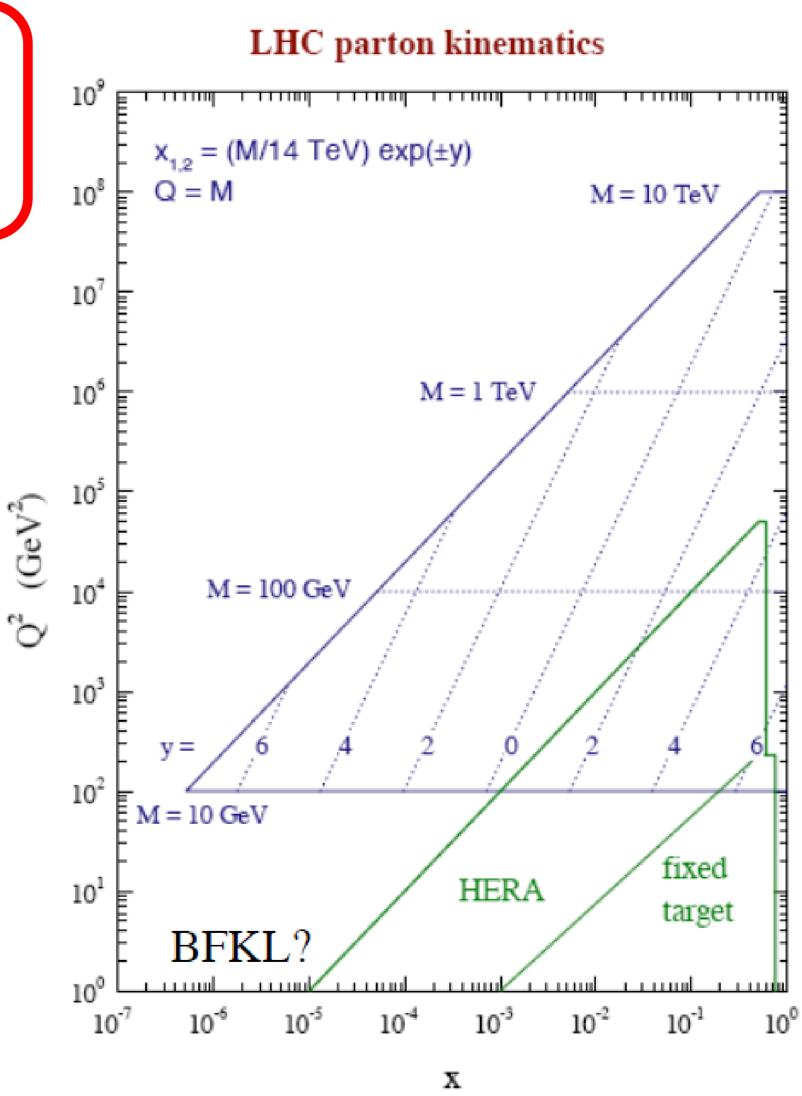


- Pile-up included or not yet ?

Cross-sections at LHC

$$\sigma_X = \sum_{a,b} \int_0^1 dx_1 dx_2 \, f_a(x_1, \mu_F^2) \, f_b(x_2, \mu_F^2)$$
$$\times \, \hat{\sigma}_{ab \to X} \left(x_1, x_2, \{p_i^\mu\}; \alpha_S(\mu_R^2), \alpha(\mu_R^2), \frac{Q^2}{\mu_R^2}, \frac{Q^2}{\mu_F^2} \right)$$

- not necessarily straight and simple extrapolation from Tevatron ("scaling")
- often partons at small(er) x involved in key processes
  - → scattering of gluons / sea quarks dominates
  - → larger phase space for gluon radiation (extra jets)
  - → larger QCD backgrounds
- need to make sure that these are well understood



Parton densities (and uncertainties)

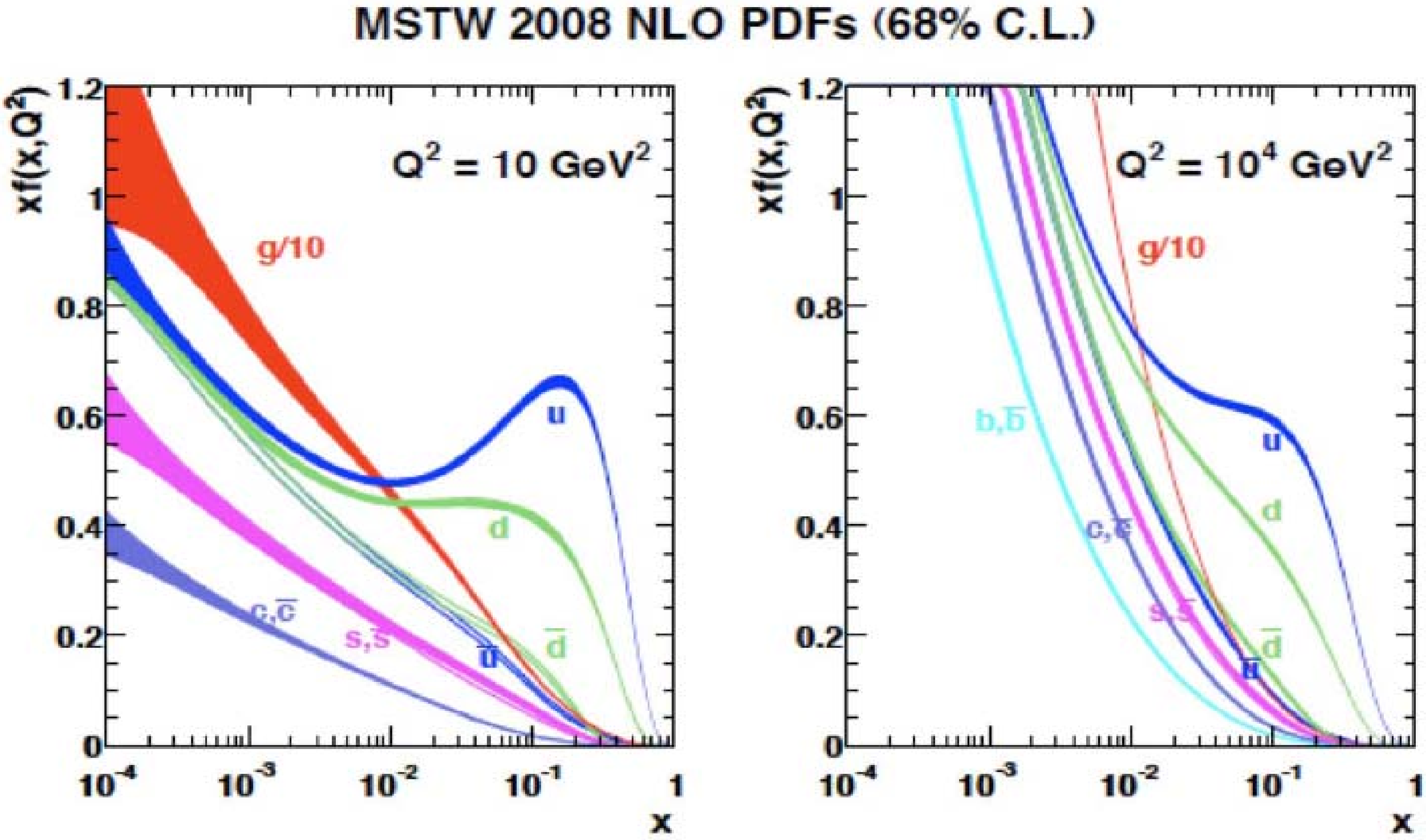
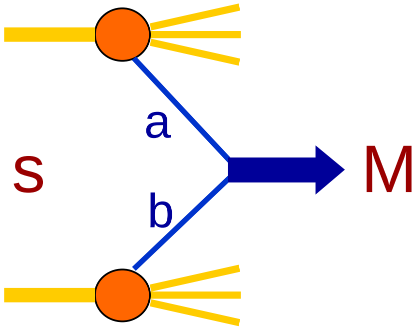


Figure 1: MSTW 2008 NLO PDFs at $Q^2 = 10$ GeV^2 and $Q^2 = 10^4$ GeV^2.

Parton-parton luminosity

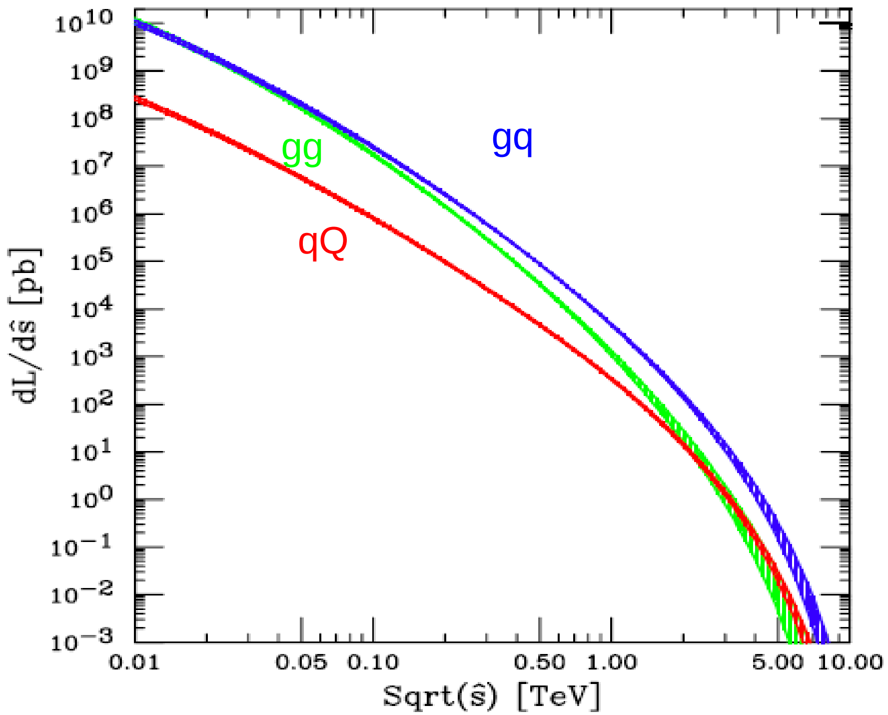


$$\hat{\sigma}_{ab\to X} = C_X \delta(\hat{s} - M^2)$$

$$\sigma_X = \int_0^1 dx_a dx_b \, f_a(x_a, M^2) f_b(x_b, M^2) \, C_X \, \delta(x_a x_b - \tau)$$

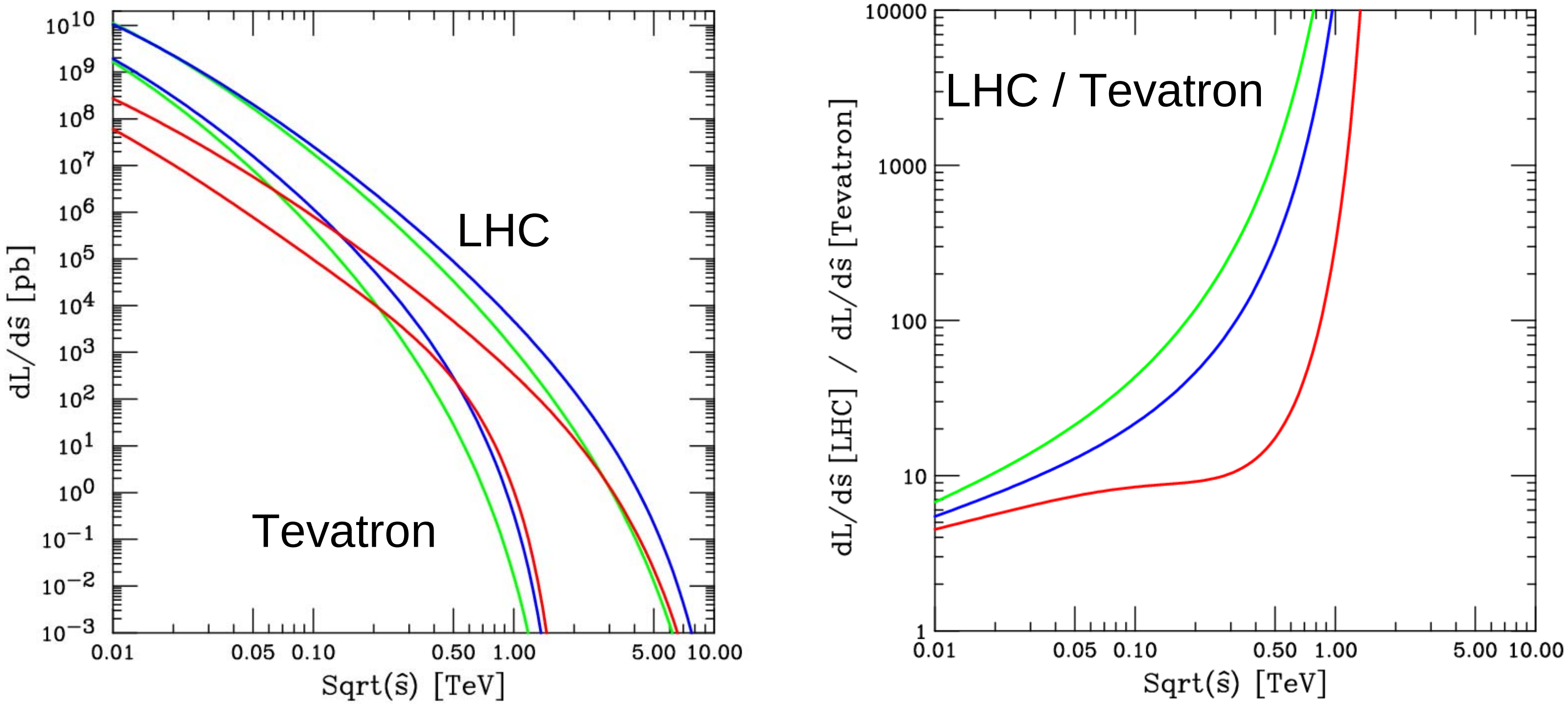
$$\equiv C_X \left[\frac{1}{s} \frac{\partial \mathcal{L}_{ab}}{\partial \tau}\right] \qquad (\tau = M^2/s)$$

$$\frac{\partial \mathcal{L}_{ab}}{\partial \tau} = \int_0^1 dx_a dx_b \, f_a(x_a, M^2) f_b(x_b, M^2) \, \delta(x_a x_b - \tau)$$



- process independent
- contains energy and mass dependencies
- practical assessment of pdf uncertainties

Tevatron vs. LHC



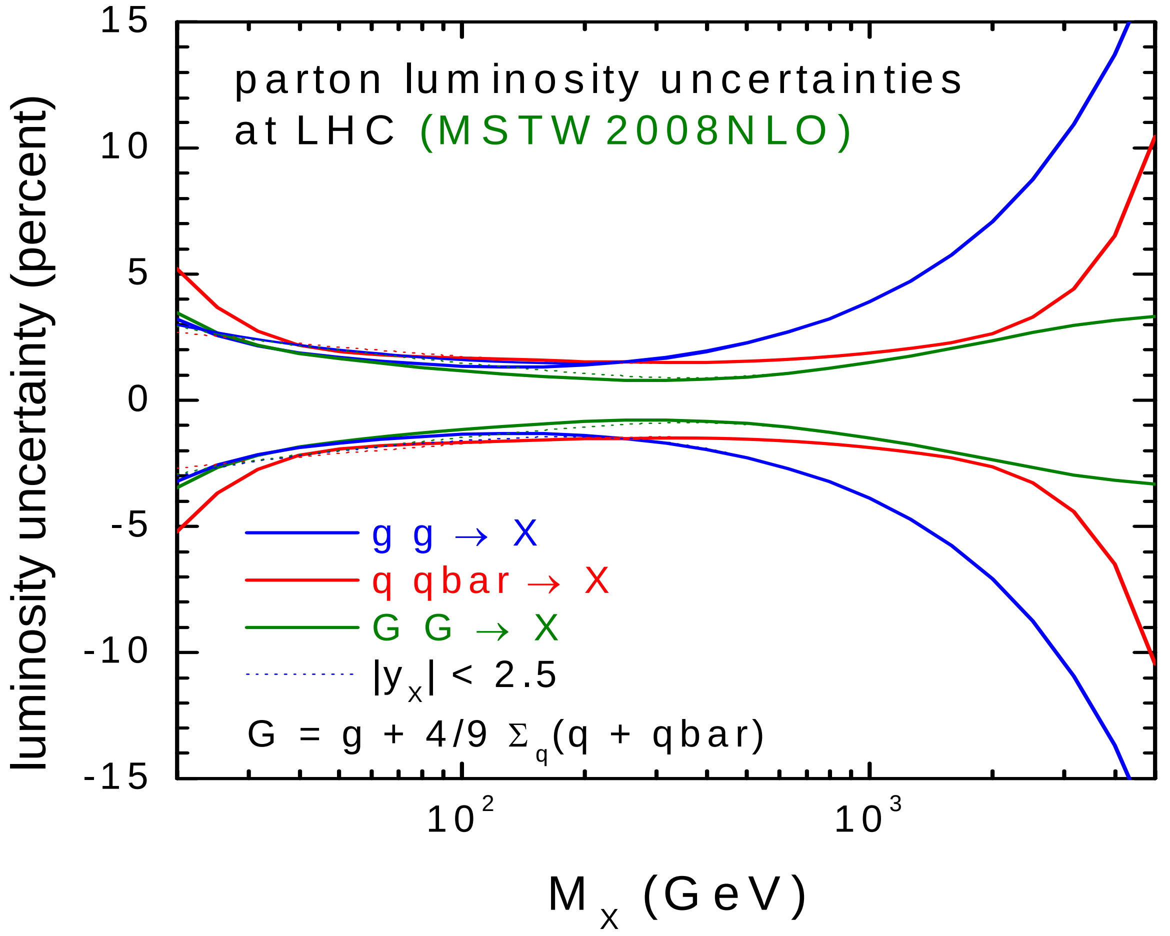
$$= gg$$

$$= \sum_i (gq_i + g\bar{q}_i + q_i g + \bar{q}_i g)$$

$$= \sum_i (q_i\bar{q}_i + \bar{q}_i q_i)$$

- gain from higher c.m.s. energy obvious

Parton-parton luminosity uncertainties



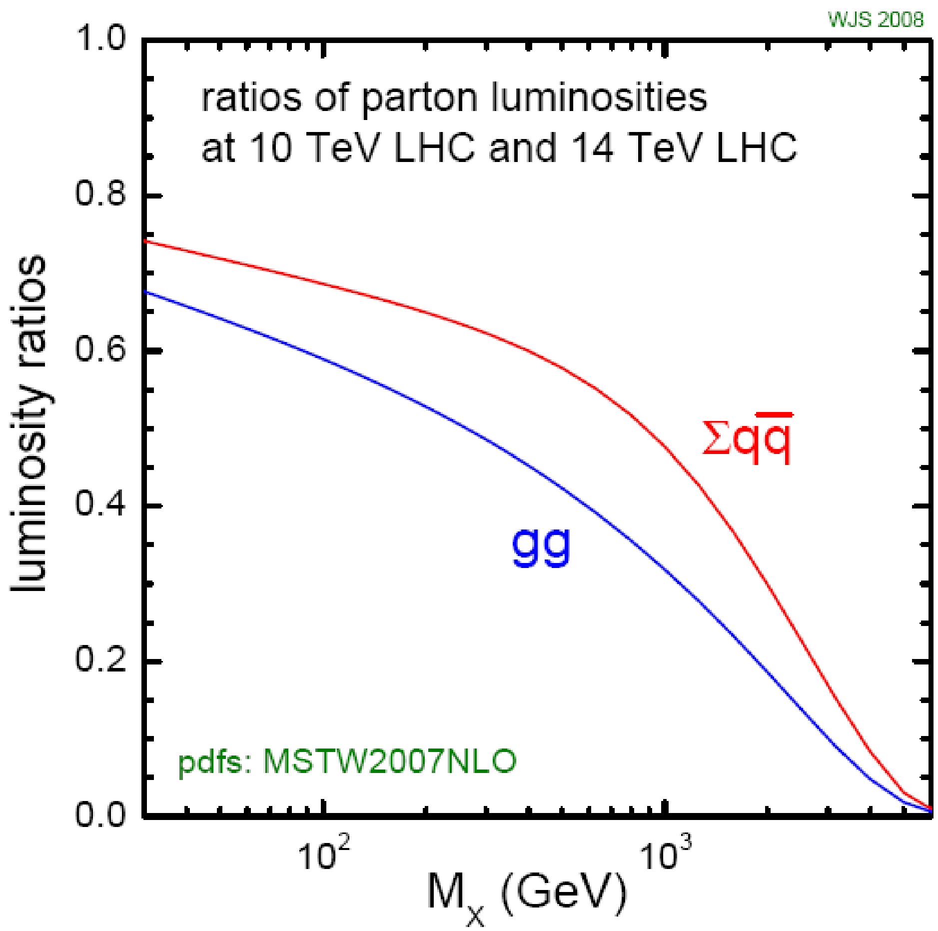
LHC start-up expectations

Month	No. Bunches	Protons per bunch	β* [m]	% Nom	Peak luminosity cm-2s-1	Integrated luminosity
1	Beam Commissioning					
2	43	3×10^{10}	4	0.4	1.2×10^{30}	100 – 200 nb^{-1}
3	43	5×10^{10}	4	0.7	3.4×10^{30}	~2 pb^{-1}
4	156	5×10^{10}	2	2.5	2.5×10^{31}	~13 pb^{-1}
5	156	7×10^{10}	2	3.3	4.9×10^{31}	~25 pb^{-1}
6	720	3×10^{10}	2	6.7	4.0×10^{31}	~21 pb^{-1}
7	720	5×10^{10}	2	11.2	1.1×10^{32}	~60 pb^{-1}
8	720	5×10^{10}	2	11.2	1.1×10^{32}	~60 pb^{-1}
9	720	5×10^{10}	2	11.2	1.1×10^{32}	~60 pb^{-1}
10	Ions					
Total						**200 – 300 pb^{-1}**

- unknown: fraction useable for physics

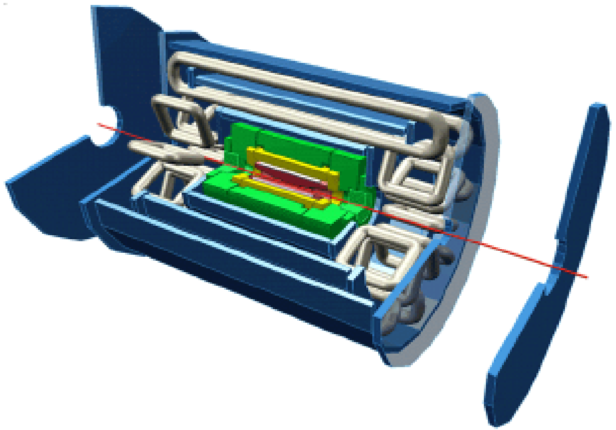
Different center-of-mass energies

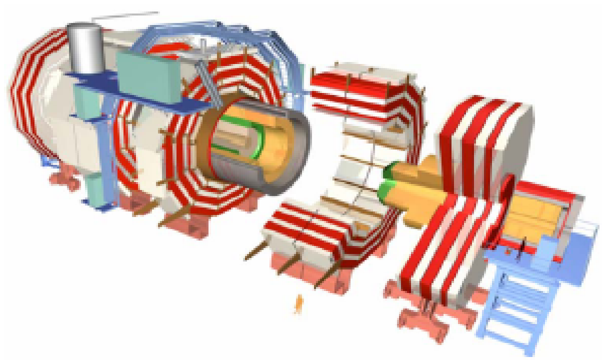
- first LHC run in 2009/2010
- c.m.s. energy of at most 10 TeV
    - → impact on cross-sections
- integrated luminosity of up to 200 pb^{-1}

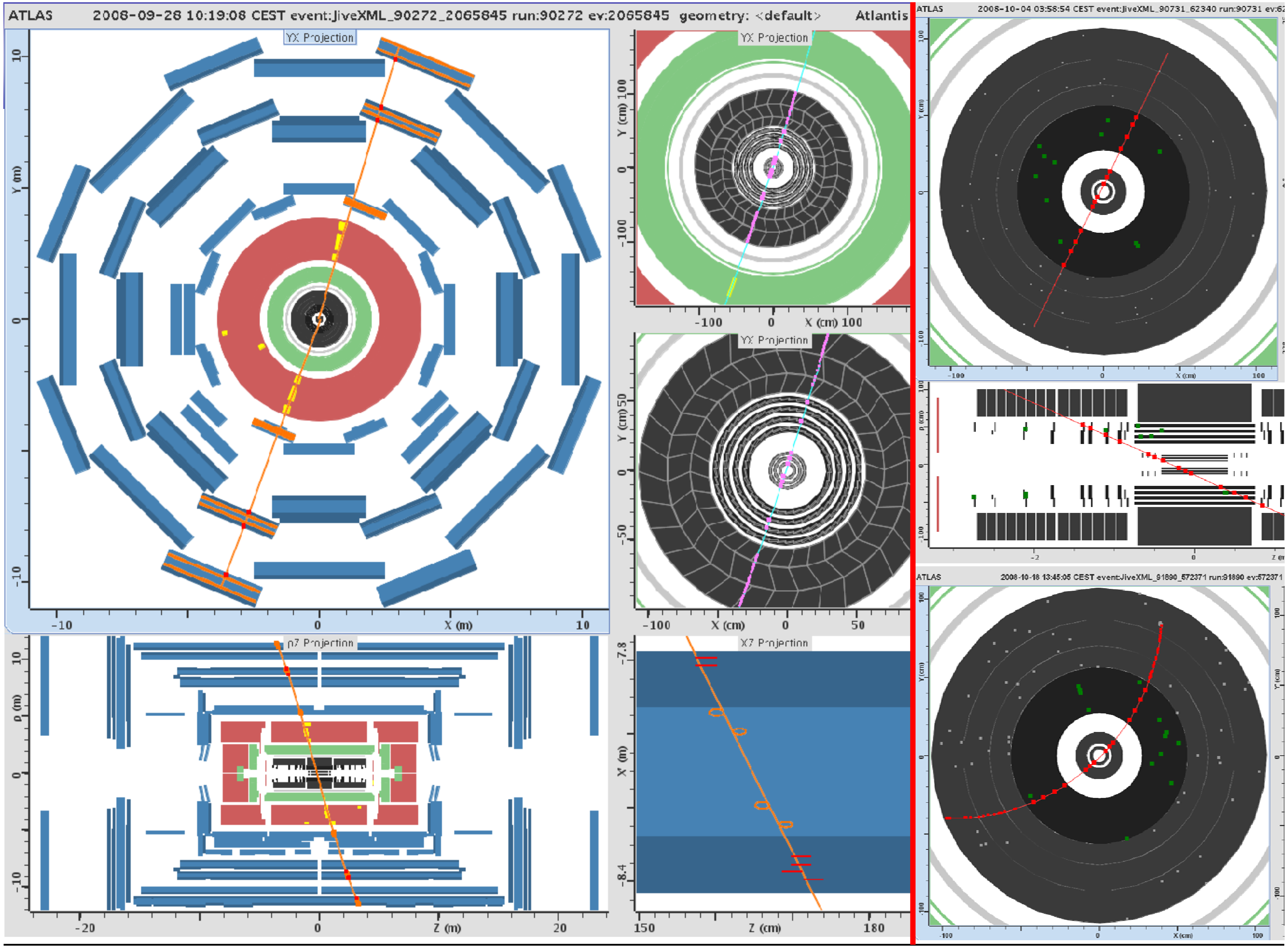


ATLAS and CMS

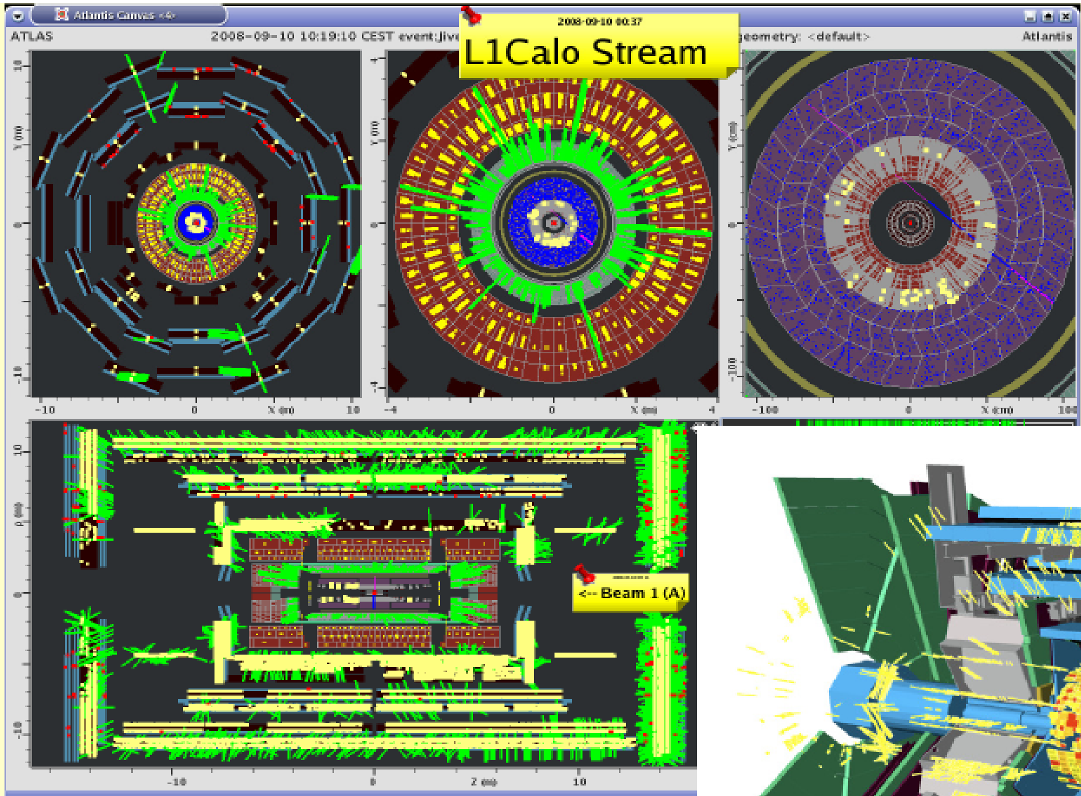
	ATLAS	CMS
Magnetic field	2 T solenoid + toroid (0.5 T barrel 1 T endcap)	4 T solenoid + return yoke
Tracker	Si pixels, strips + TRT $\sigma/p_T \approx 5\mathrm{x}10^{-4} p_T + 0.01$	Si pixels, strips $\sigma/p_T \approx 1.5\mathrm{x}10^{-4} p_T + 0.005$
EM calorimeter	Pb+LAr $\sigma/E \approx 10\%/\sqrt{E} + 0.007$	PbWO4 crystals $\sigma/E \approx 3\%/\sqrt{E} + 0.003$
Hadronic calorimeter	Fe+scint. / Cu+LAr (10λ) $\sigma/E \approx 50\%/\sqrt{E}$ + 0.03 GeV	Brass+scintillator (7 λ + catcher) $\sigma/E \approx 100\%/\sqrt{E}$ + 0.05 GeV
Muon	$\sigma/p_T \approx 2\%$ @ 50GeV to 10% @ 1TeV (ID +MS)	$\sigma/p_T \approx 1\%$ @ 50GeV to 10% @ 1TeV (DT/CSC+Tracker)
Trigger	L1 + RoI-based HLT (L2+EF)	L1+HLT (L2 + L3)



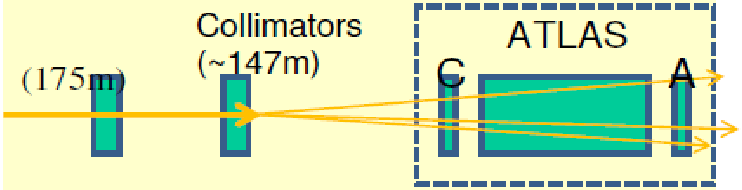


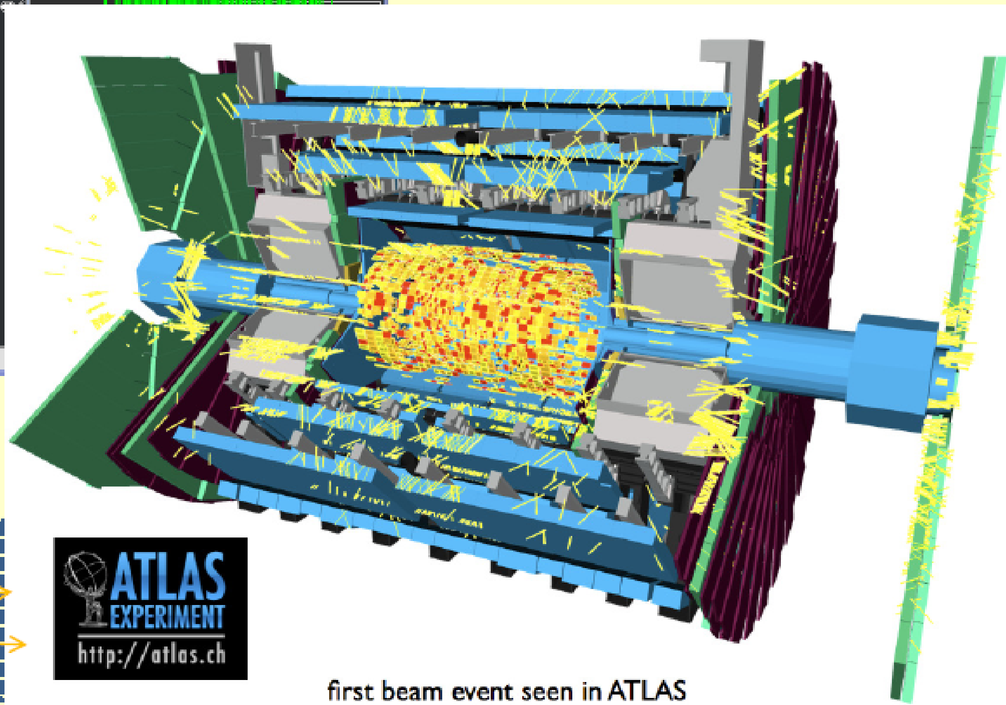

ATLAS
2008-09-28 10:19:08 CEST event:JiveXML_90272_2065845 run:90272 ev:2065845 geometry: <default>
Atlantis
YX Projection
Y (m)
X (m)
Y (cm)
X (cm)
ρZ Projection
ρ (m)
Z (m)
XZ Projection
X' (m)
Z (cm)
ATLAS
2008-10-04 03:58:54 CEST event:JiveXML_90731_62340 run:90731
ATLAS
2008-10-18 13:45:05 CEST event:JiveXML_91890_572371 run:91890 ev:572371

Experiments are functioning



The very first beam-splash event from the LHC in ATLAS on 10th September 2008, 10:19





first beam event seen in ATLAS

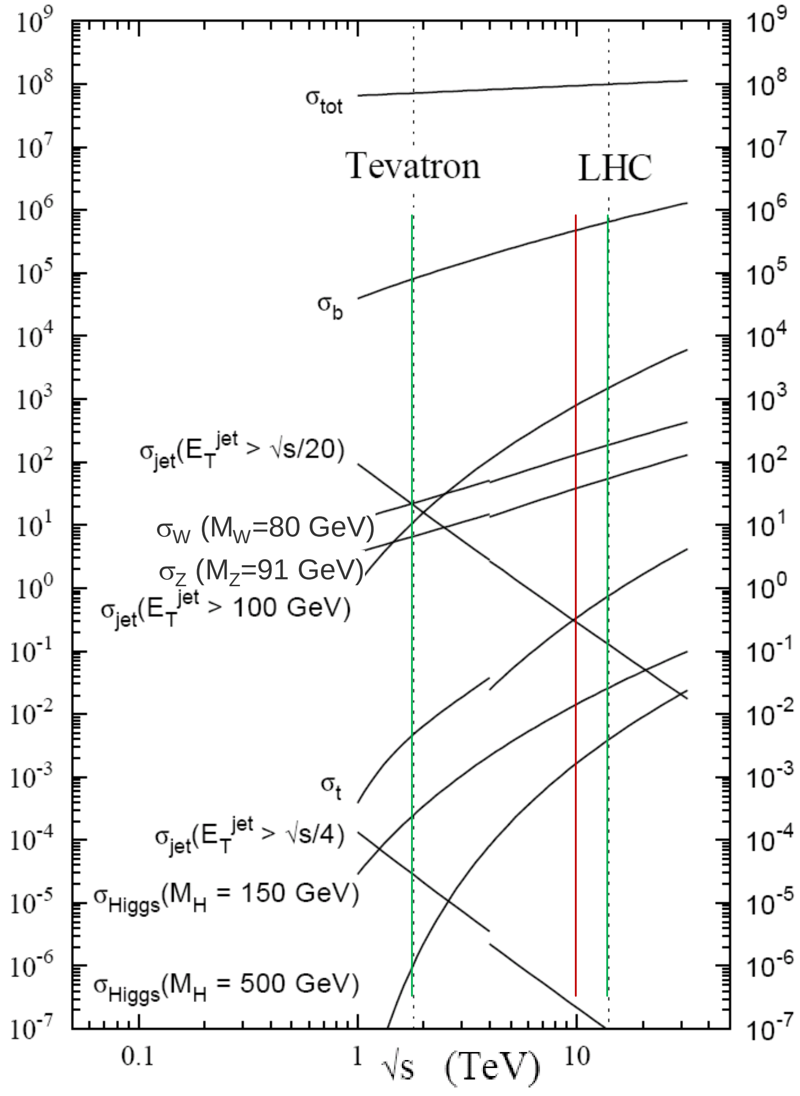
rediscovery of Standard Model (and more…)

The SM menu (sort of)

- minimum bias properties
- underlying event

} covered by A. Moraes

- jet production
  - → cross-section, di-jet mass and angular distribution, shapes
- direct photon production
- W/Z production
  - → incl. in association with jets
- Drell-Yan lepton pair production
  - → incl. low mass resonances
- di-boson production
  - → gauge boson self coupling
- top quark production



„Roadmap“ for first data

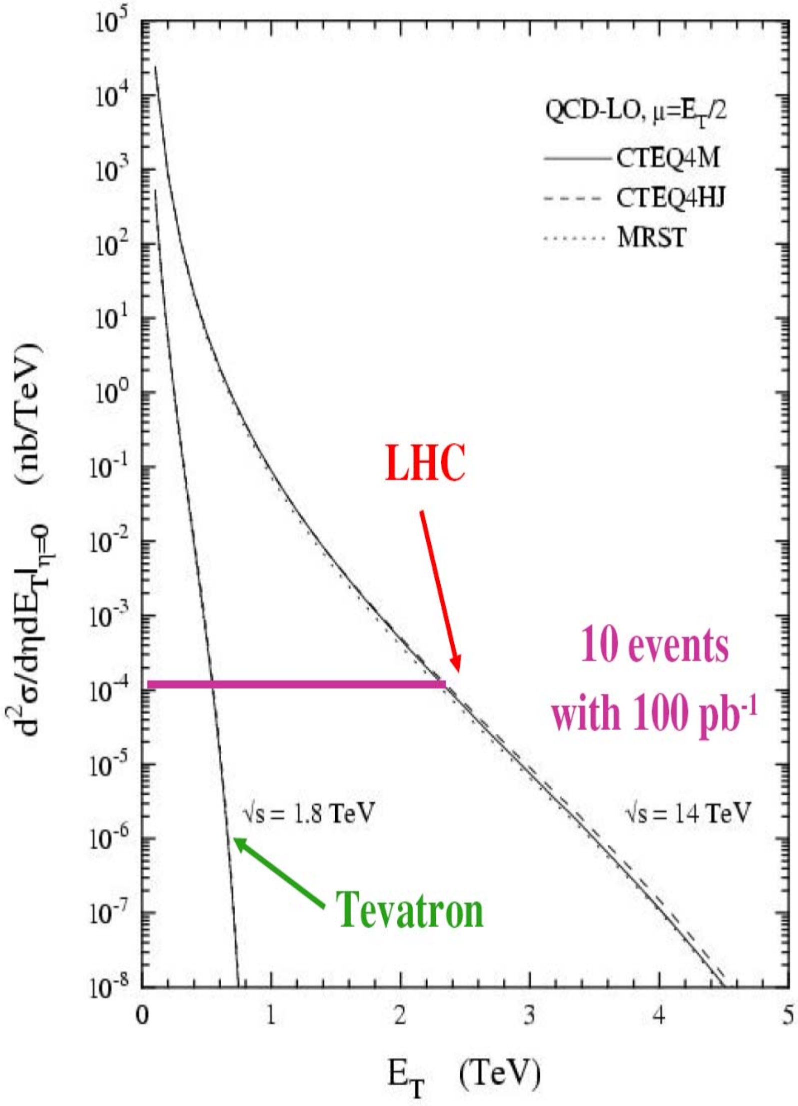
- 1-10 pb^{-1}: calibration and alignment with collision data, first measurements ("minimum bias", …)

- ~100 pb^{-1}: refinement of calibration and alignment, re-discovery and measurement of SM processes, first serious sensitivity for new physics
  - expected statistics, scaled to 10 TeV (and 100 pb^{-1})

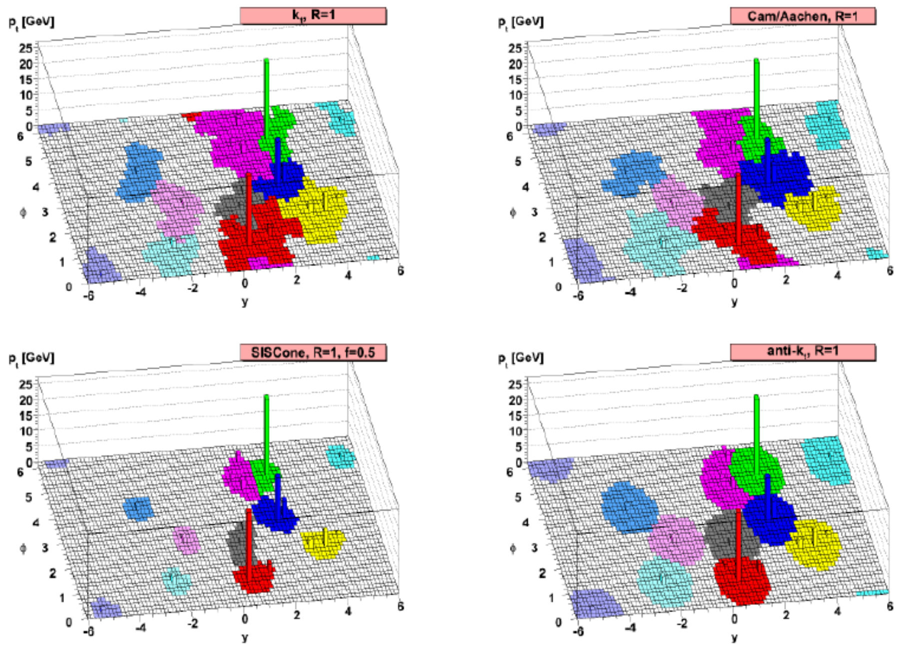
$>5*10^6$	"minimum bias" events (after trigger)
10^8	jet events (after Trigger)
$5*10^6$	direct photon events
$2.5*10^5$	$W \rightarrow l\nu$ events
$2.5*10^4$	$Z \rightarrow ll$ events
$>10^4$	Drell-Yan events (small invariant masses)

- ~1 fb^{-1}: sensitivity for Higgs boson discovery, supersymmetry, new resonances (O(TeV))

Jet production



- need to define what a jet is → jet algorithm
- challenge: jet energy scale determination



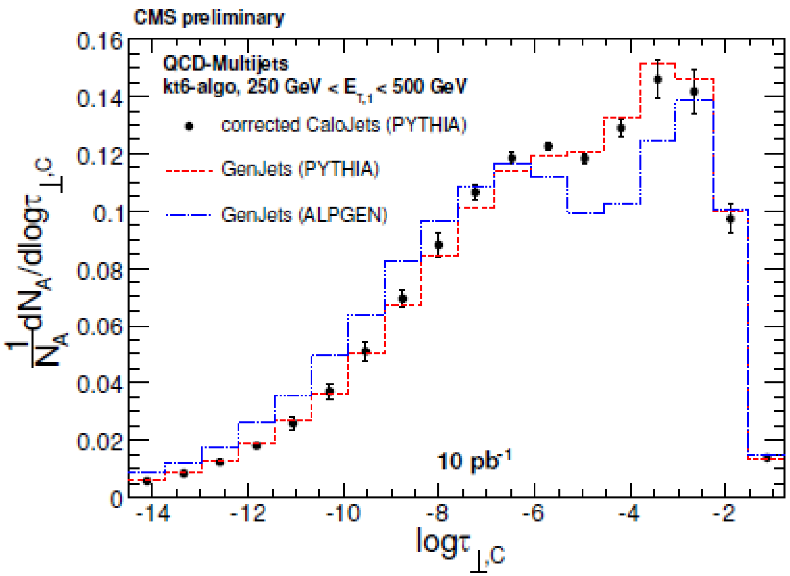
Jet shape measurements

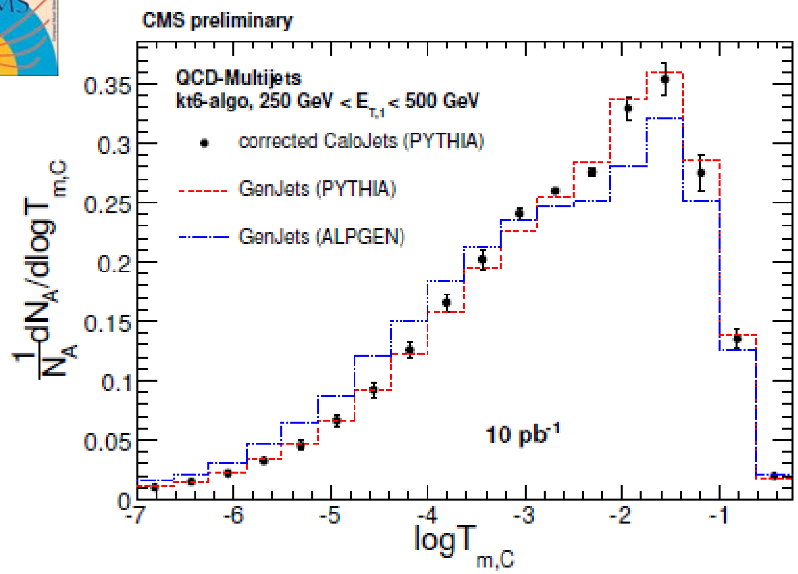
- global transverse thrust
  → ½ for homogenous event

global thrust minor
deviation from thrust axis

$$T_{\perp,g} \equiv \max_{\vec{n}_T} \frac{\sum_i |\vec{p}_{\perp,i} \cdot \vec{n}_T|}{\sum_i p_{\perp,i}} \qquad \tau_{\perp,g} \equiv 1 - T_{\perp,g}.$$

$$T_{m,g} \equiv \frac{\sum_i |p_{x,i}|}{\sum_i p_{\perp,i}} = \frac{\sum_i |(\vec{p} \times \vec{n}_B) \times \vec{n}_T|}{\sum_i p_{\perp,i}}.$$

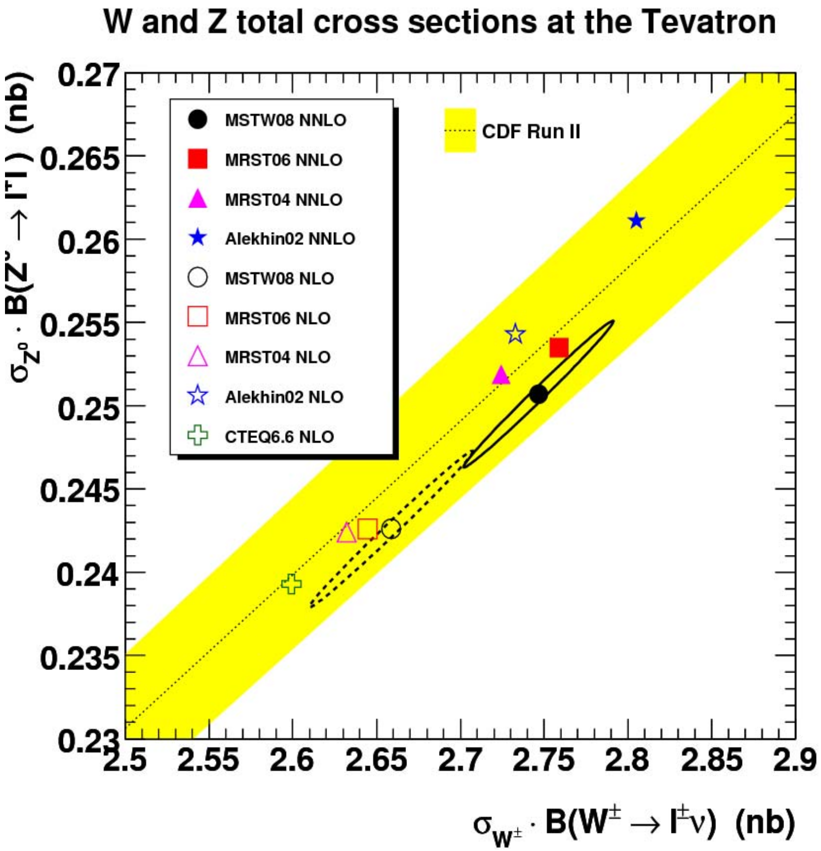


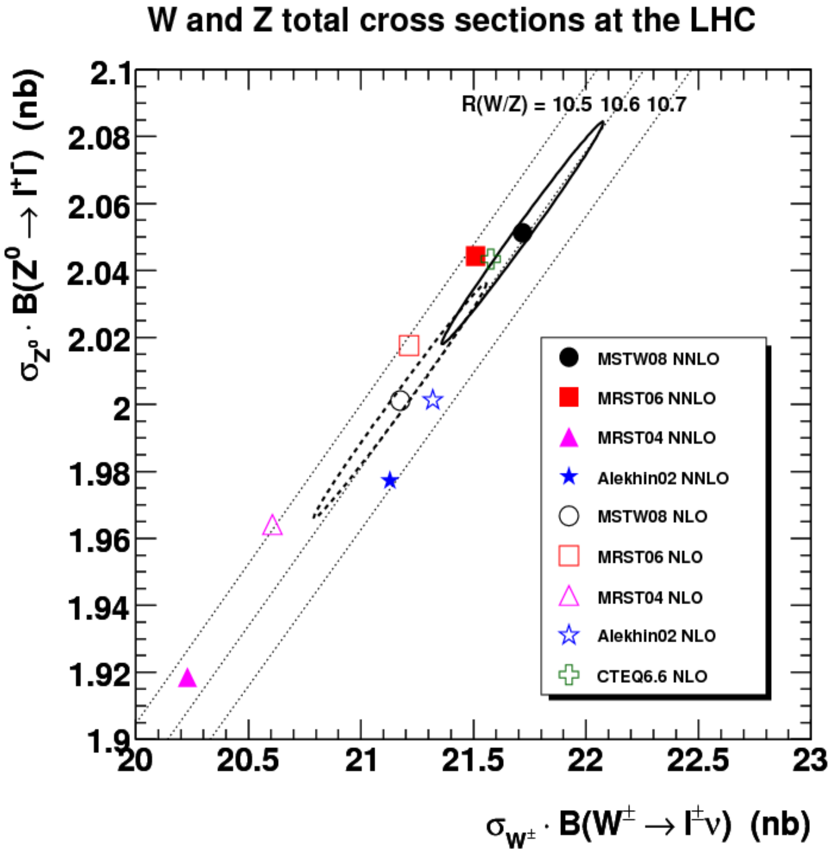


- sensitivity to modeling of multi-jet events
  → insensitive to jet algorithm and energy scale corrections
  → input for MC tuning

W/Z cross-section ratio

- some systematic uncertainties (e.g. luminosity) cancel

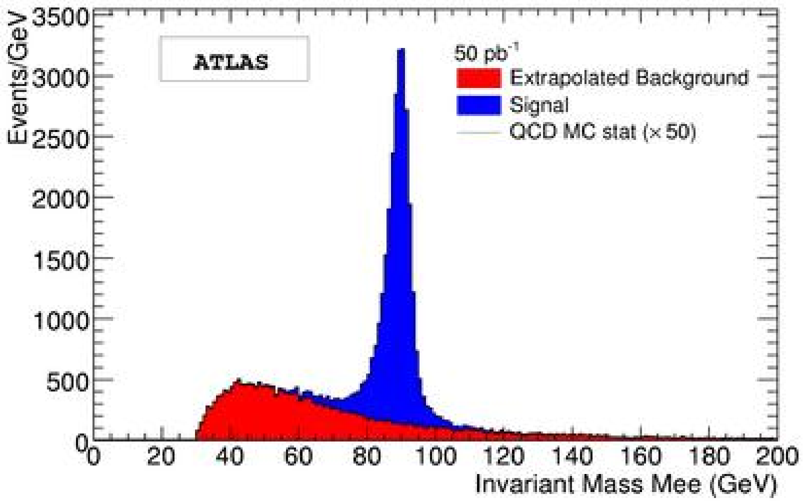




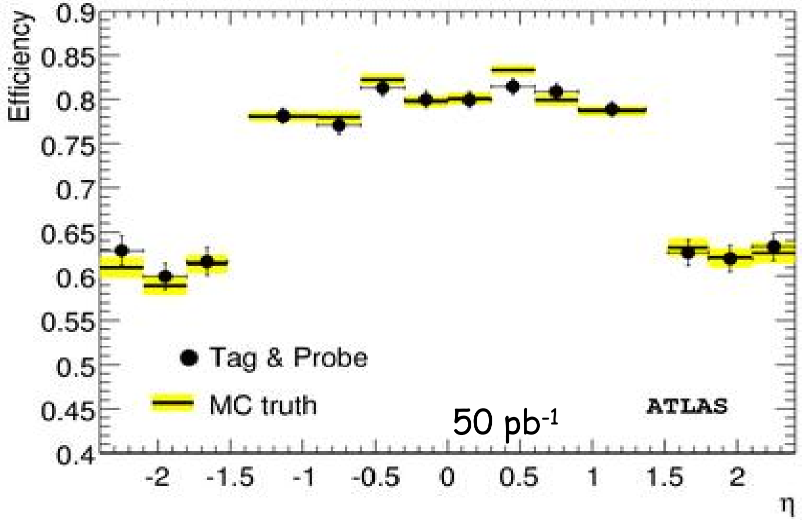
CDF 2007: $R = 10.84 \pm 0.15\ (\text{stat}) \pm 0.14\ (\text{sys})$

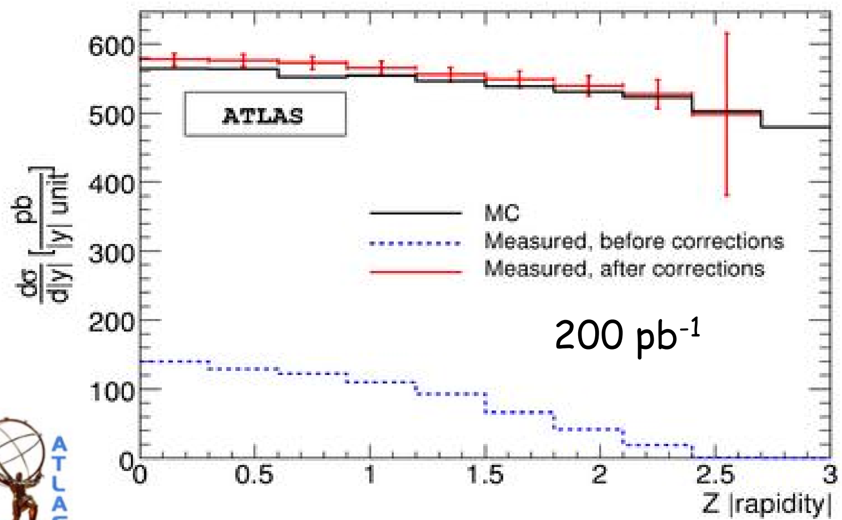
Z(ee) production

- efficiency determination
  - → "tag & probe" method (data)



- Z → ee signal in 50 pb^{-1}
  - → selection via
    - 2 electrons E_T>15 GeV
    - soft identification criteria
  - → accuracy on inclusive cross-section (no luminosity uncert.)
    - 2-4% (stat) and 2-4% (syst.)



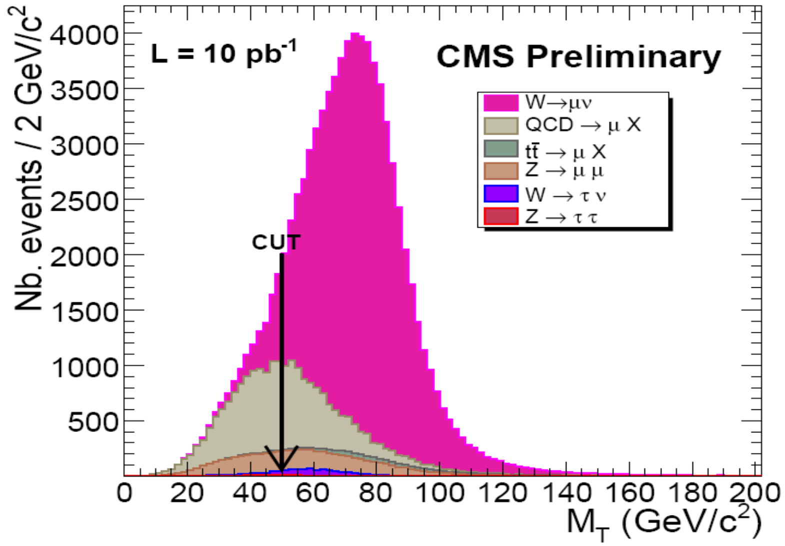


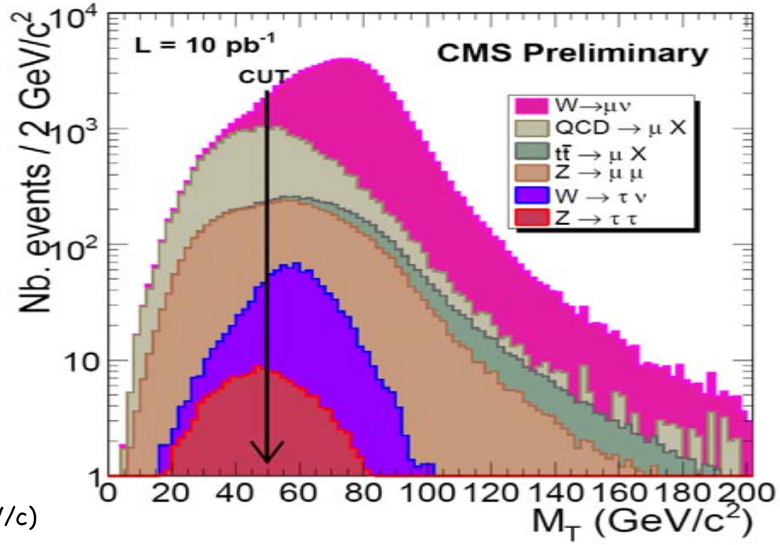
W(μν) production

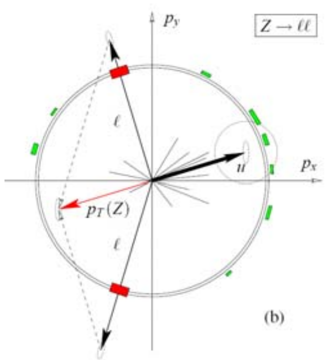
- W selection
  - → single muon with p_T>25 GeV and |η|<2
    - as well as isolation
- background suppression by cut on m_T:

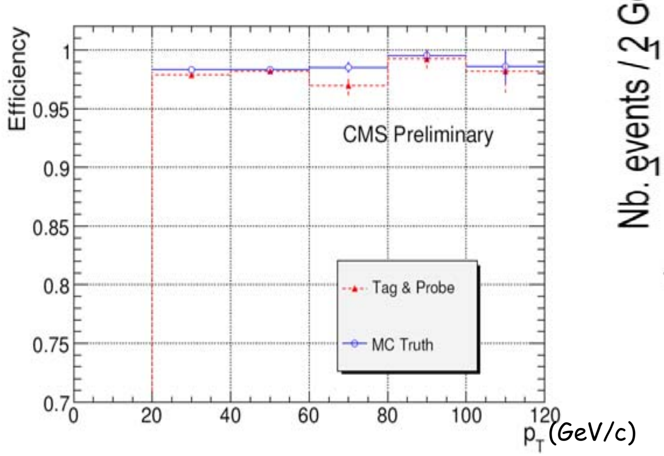
$$m_T^W = \sqrt{2 p_T^l p_T^\nu (1 - \cos\Delta\phi)}$$

- reconstruction efficiency via "tag & probe" also for muons









$W^{+/-}$ production

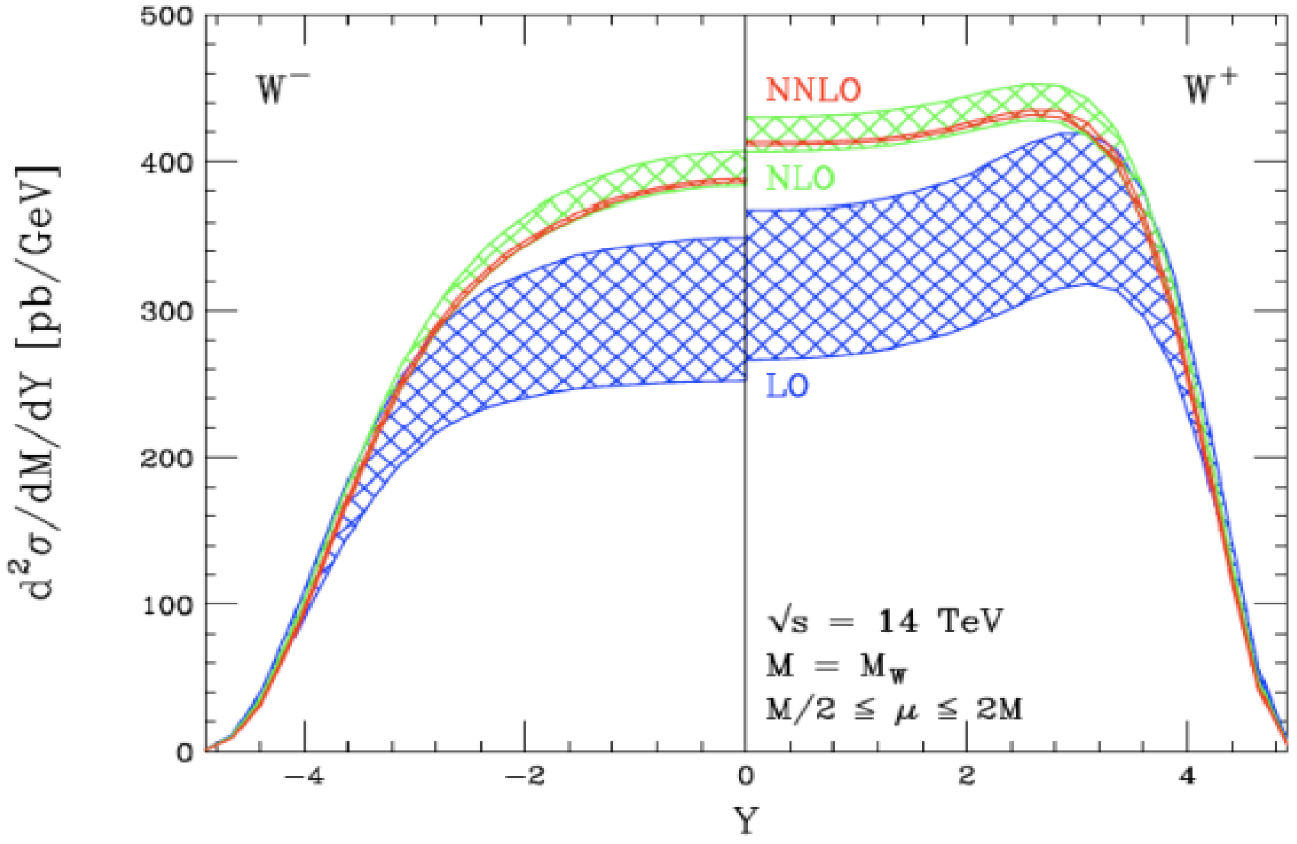
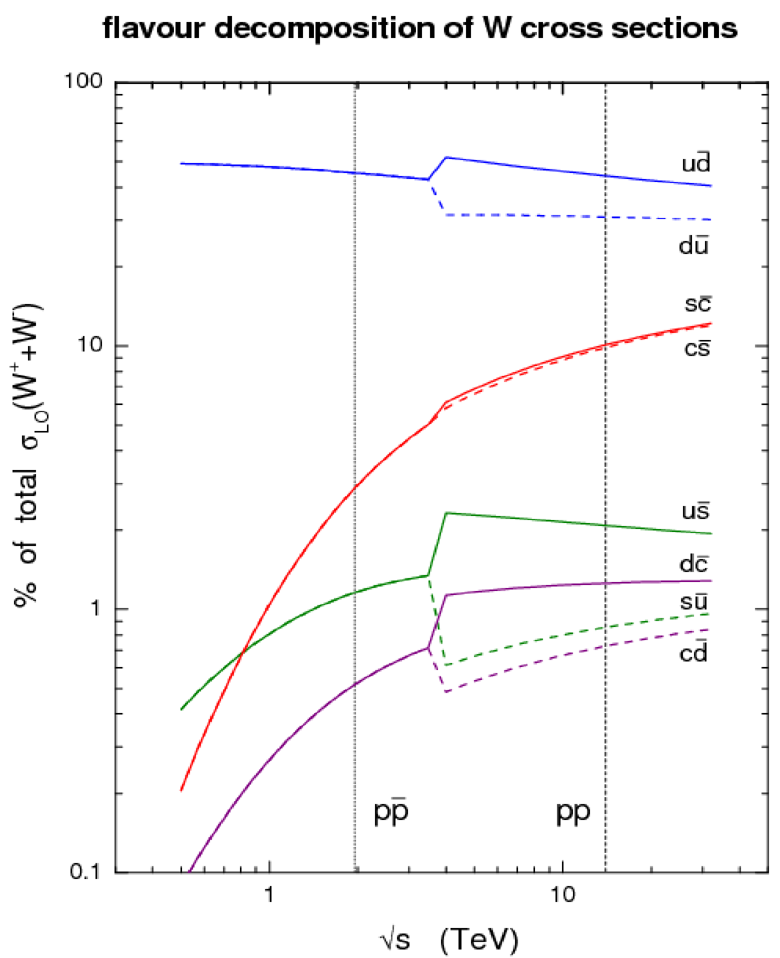
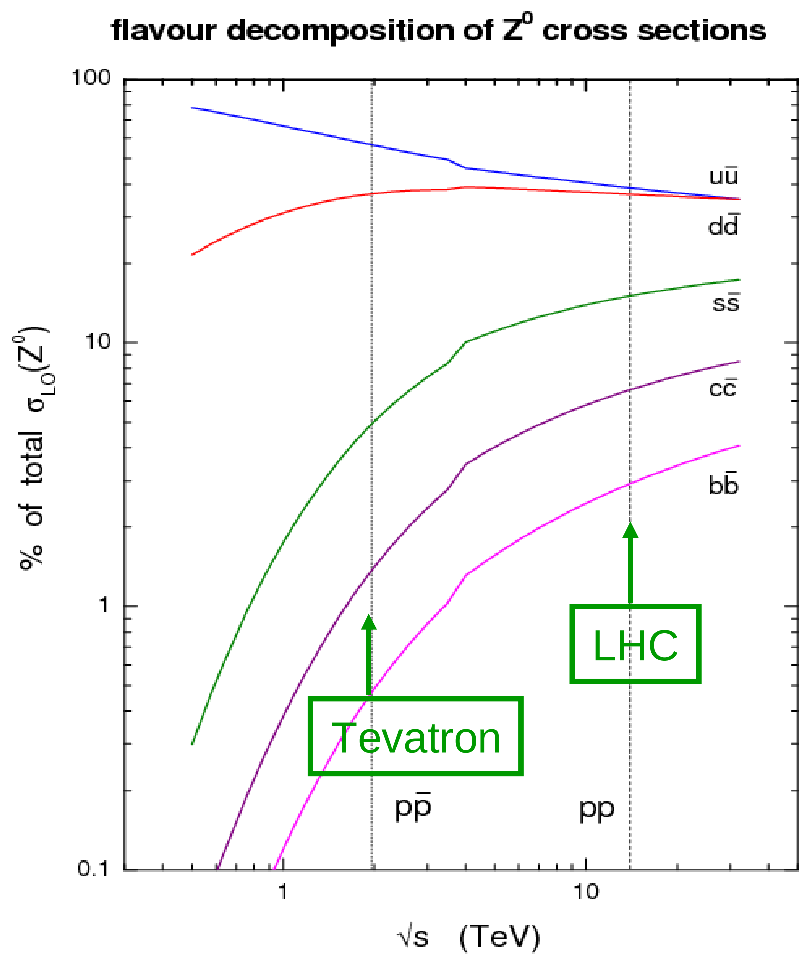


Figure 13: The CMS rapidity distributions for production of an on-shell W^- boson (left) and on-shell W^+ boson (right) at the LHC, at LO, NLO, and NNLO, for the MRST PDF sets. Each distribution is symmetric in Y; we only show half the rapidity range in each case. The bands indicate the common variation of the renormalization and factorization scales in the range $M_W/2 \leq \mu \leq 2M_W$.

Flavour composition of W/Z production



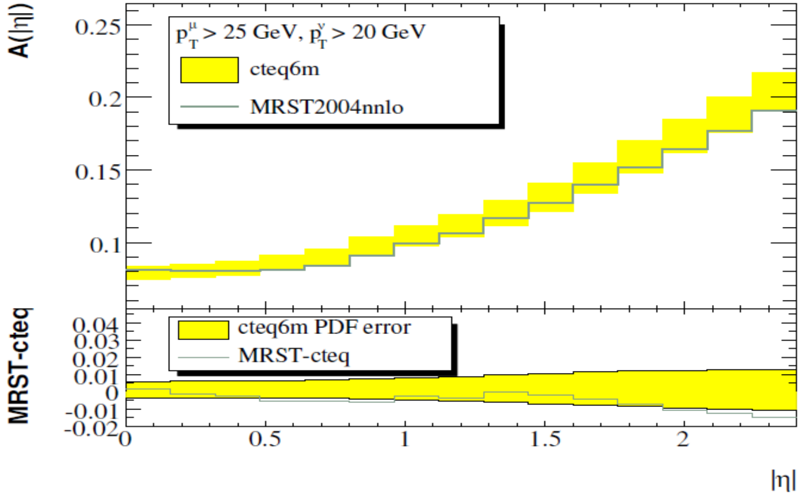


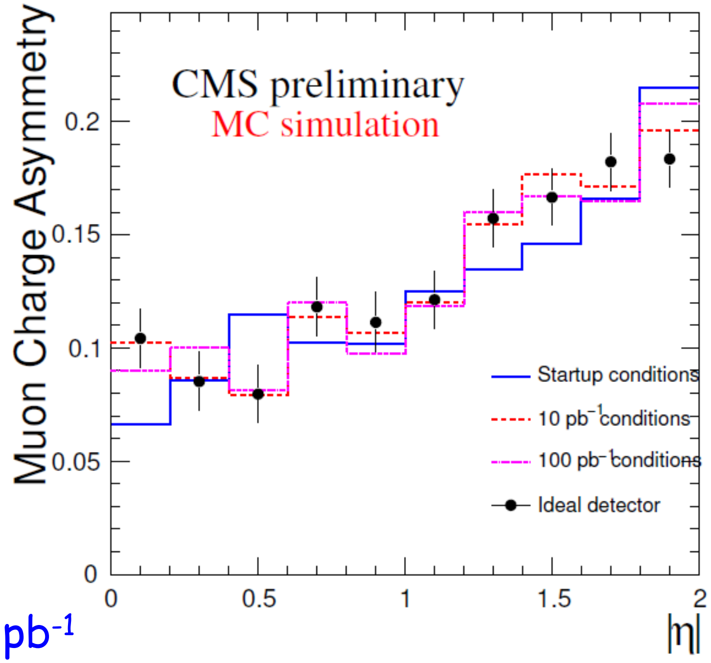
- 30% of LHC total W/Z cross-section involves s,c,b quarks

Measurement of μ charge asymmetry

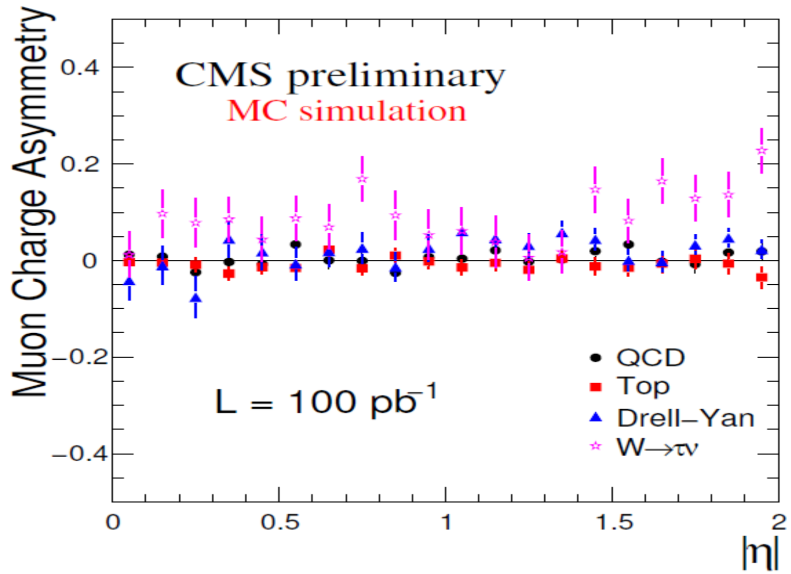
$$A(\eta) = \frac{\frac{d\sigma}{d\eta}(W^+ \to \mu^+ \bar{\nu}_\mu) - \frac{d\sigma}{d\eta}(W^- \to \mu^- \nu_\mu)}{\frac{d\sigma}{d\eta}(W^+ \to \mu^+ \bar{\nu}_\mu) + \frac{d\sigma}{d\eta}(W^- \to \mu^- \nu_\mu)}$$

- sensitive to u and d quark pdf
- only few systematic uncertainties





10 pb^{-1}

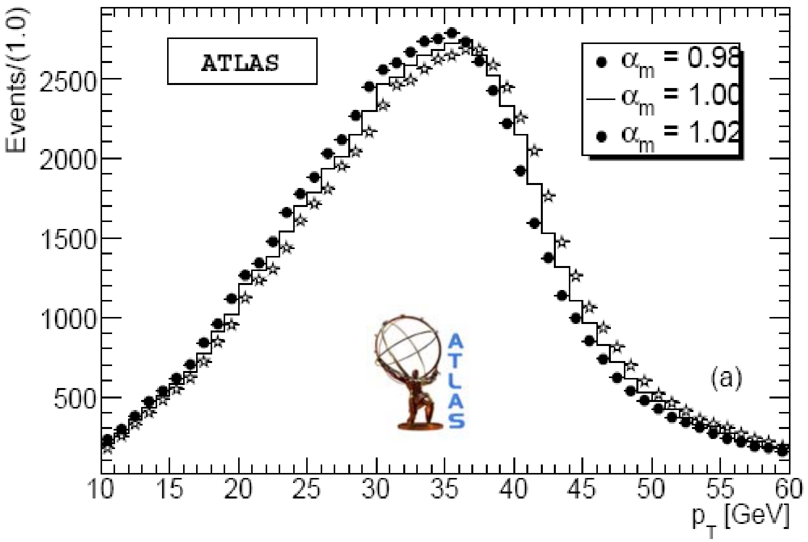


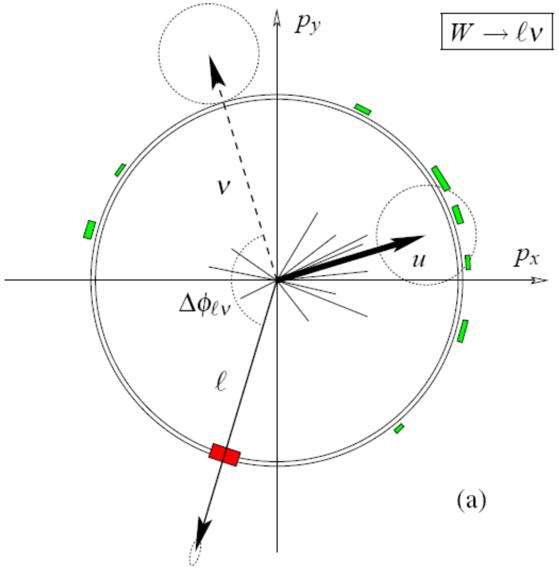
W mass determination

- with initial data (15 pb^{-1})
  - → $p_T(e)$: 120 ⊕ 117 MeV
    - ➔ energy scale dominates
  - → $M_T(\mu)$: 57 ⊕ 231 MeV
    - ➔ recoil modeling dominates

$$m_T^W = \sqrt{2 p_T^l p_T^\nu (1 - \cos \Delta\phi)}$$

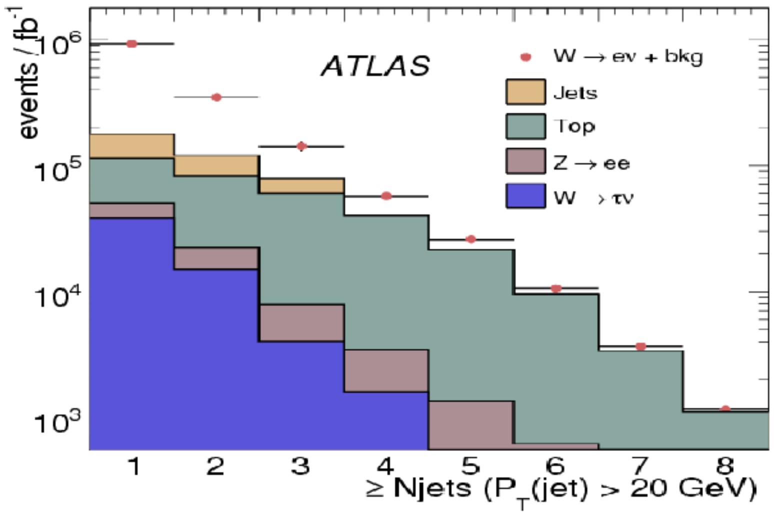
- precision measurement: with higher integrated luminosity



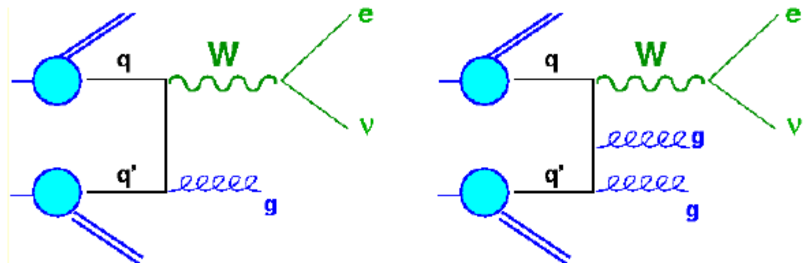


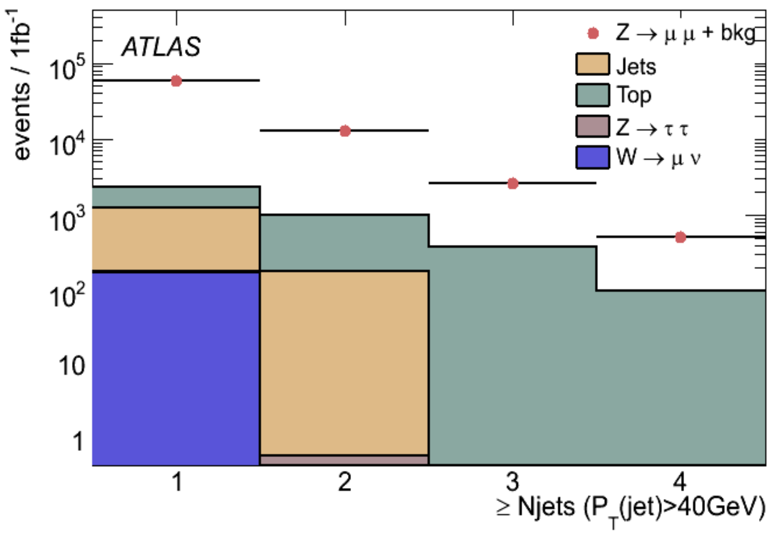
Method	$p_T(e)$ [MeV]	$p_T(\mu)$ [MeV]	$M_T(e)$ [MeV]	$M_T(\mu)$ [MeV]
δm_W (stat)	120	106	61	57
δm_W (α_E)	110	110	110	110
δm_W (σ_E)	5	5	5	5
δm_W (tails)	28	< 28	28	< 28
δm_W (ε)	14	–	14	–
δm_W (recoil)	–	–	200	200
δm_W (bkg)	3	3	3	3
δm_W (exp)	114	114	230	230
δm_W (PDF)	25	25	25	25
Total	167	158	239	238

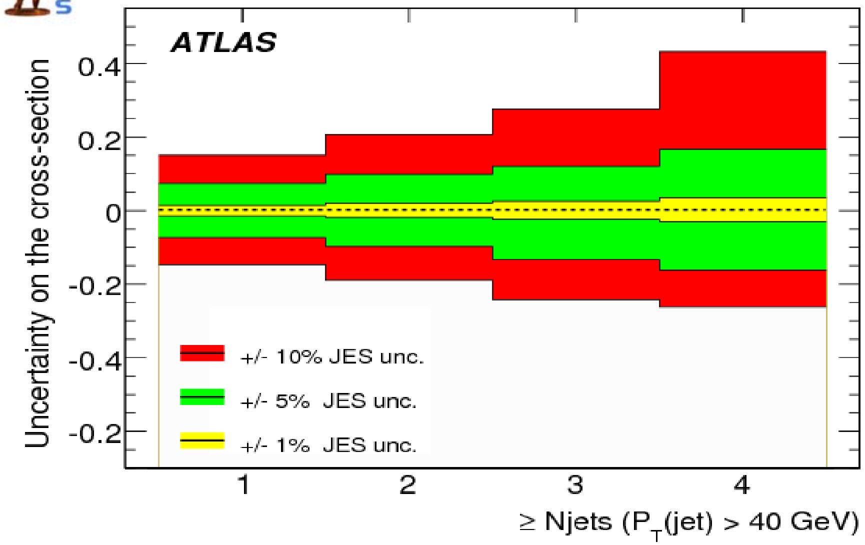
W/Z+jet production



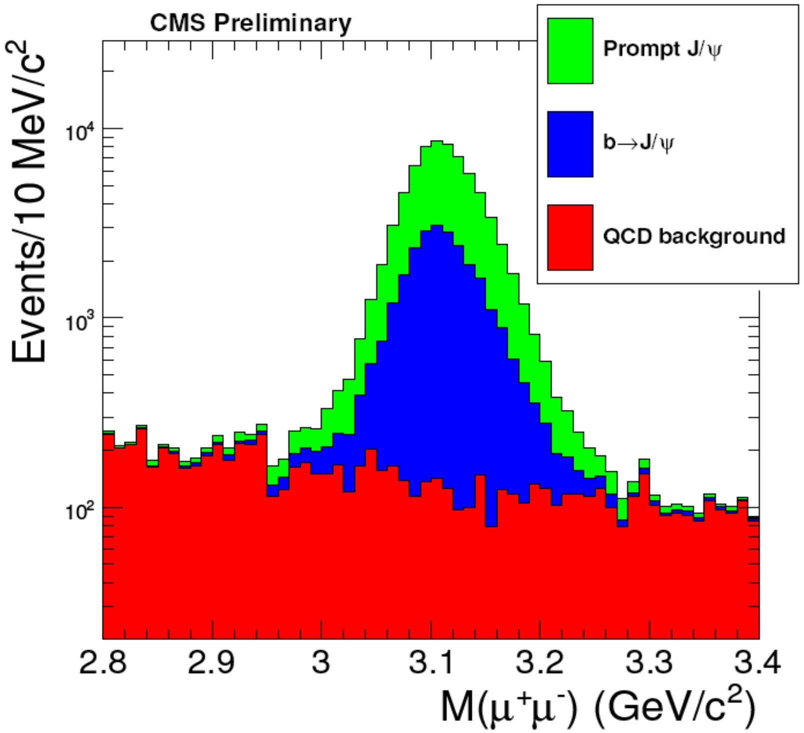
- important background for many other physics processes
  - → top production, SUSY searches, …

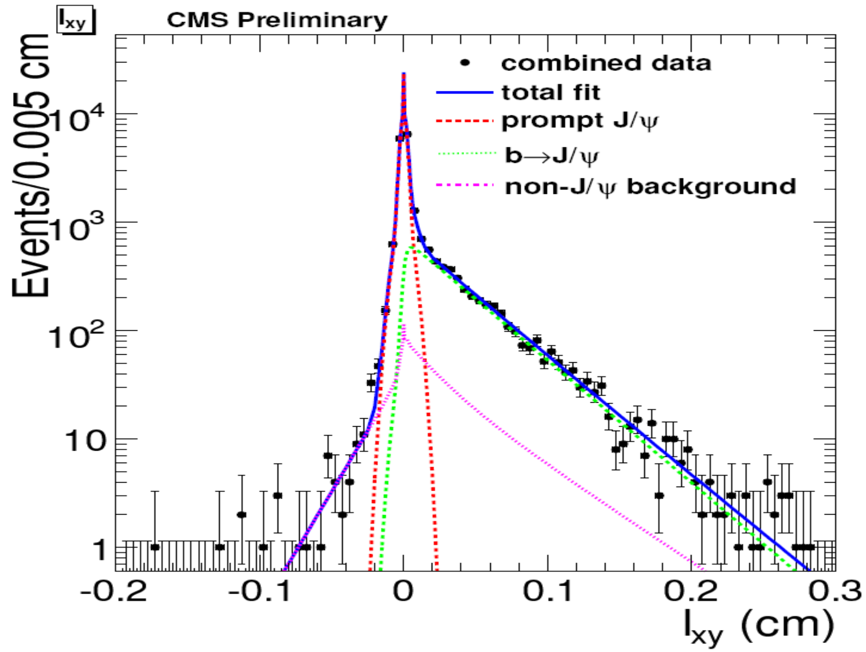






J/ψ production

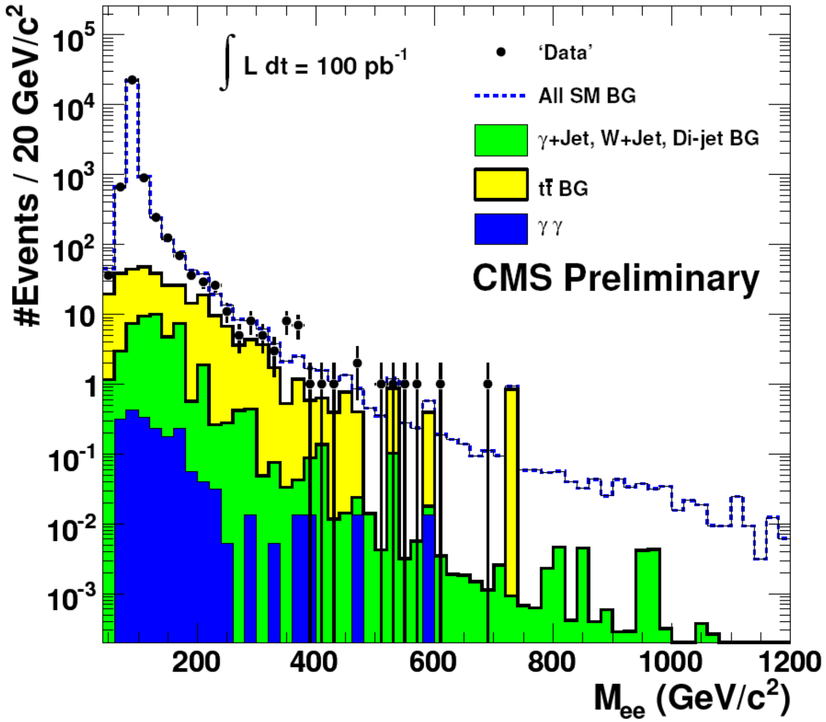


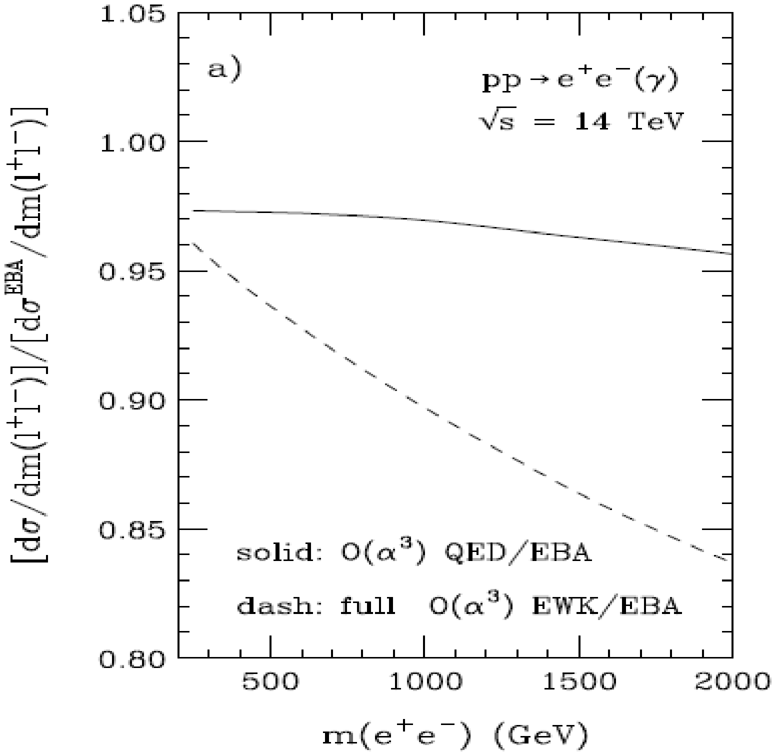


Parameter affected	Source	$\Delta\sigma/\sigma$
Luminosity	Luminosity	$\sim$ 10 %
Number of J/ψ	J/ψ mass fit	1.0 - 6.3 %
Number of J/ψ	Momentum scale	$\sim$ 1 %
Total efficiency	J/ψ polarization	1.8 - 7.0%
Total efficiency	J/ψ p_T binning	0.1 - 10 %
Total efficiency	MC statistics	0.5 - 1.7 %
$\lambda_{reconstruction}$	Non-perfect detector simulation	$\sim$ 5 %
$\lambda_{trigger}$	Non-perfect detector simulation	$\sim$ 5 %
B fraction	ℓ_{xy} resolution model	0. - 1.9 %
B fraction	B-hadron lifetime model	0.01 - 0.05 %
B fraction	Background	0.1 - 3.0 %
B fraction	Misalignment	0.7 - 3.5 %
Total systematic uncertainty 13-19 %		

- distributions for integrated luminosity of only 3 pb^{-1}
  - → decay length l_{xy} for $9 < p_T/GeV < 10$

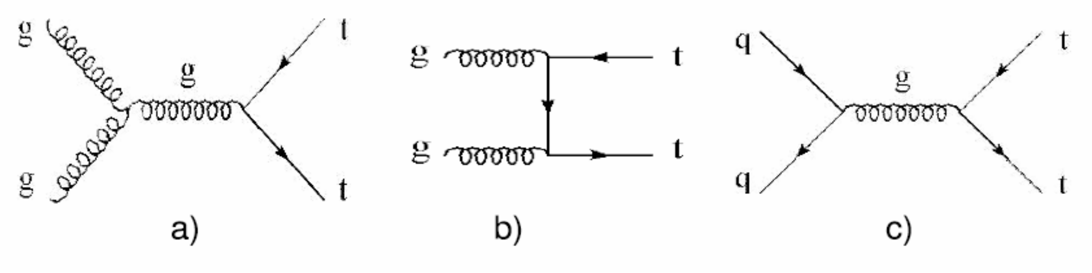
Drell-Yan lepton pair production

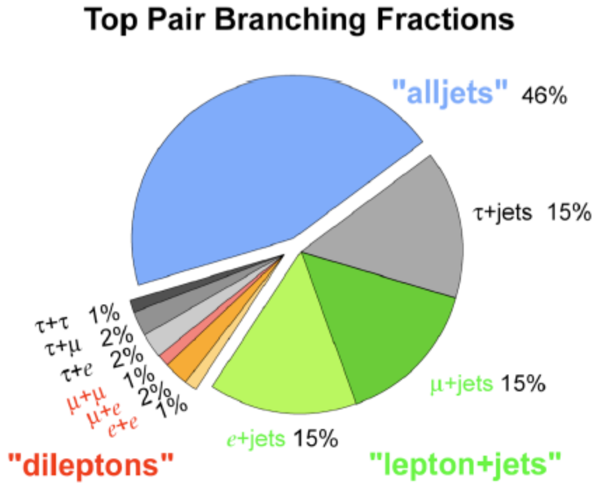


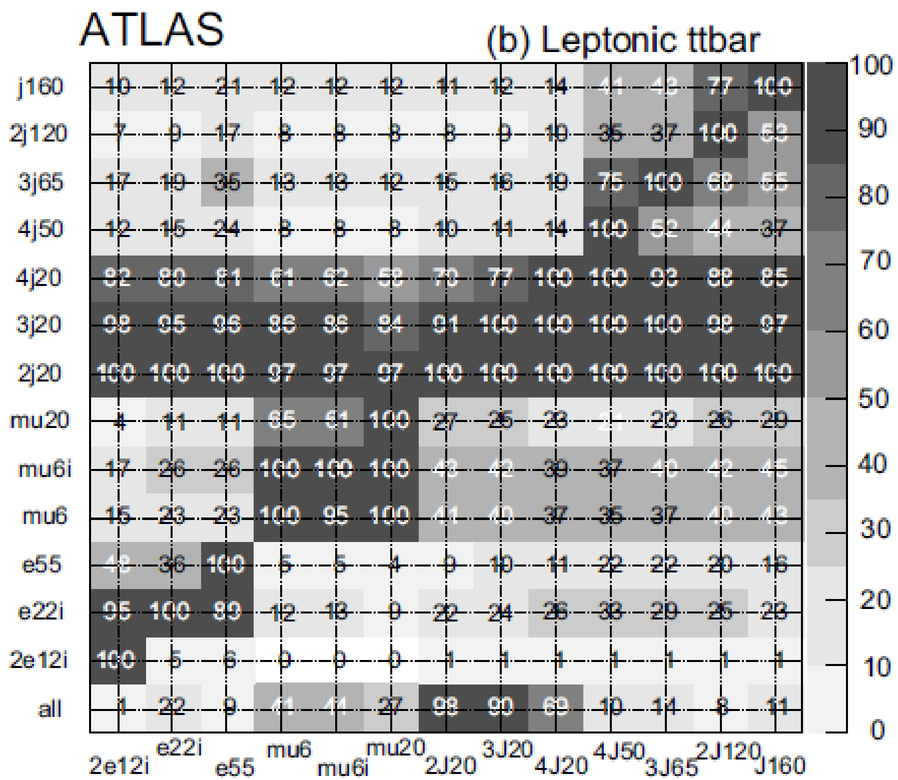


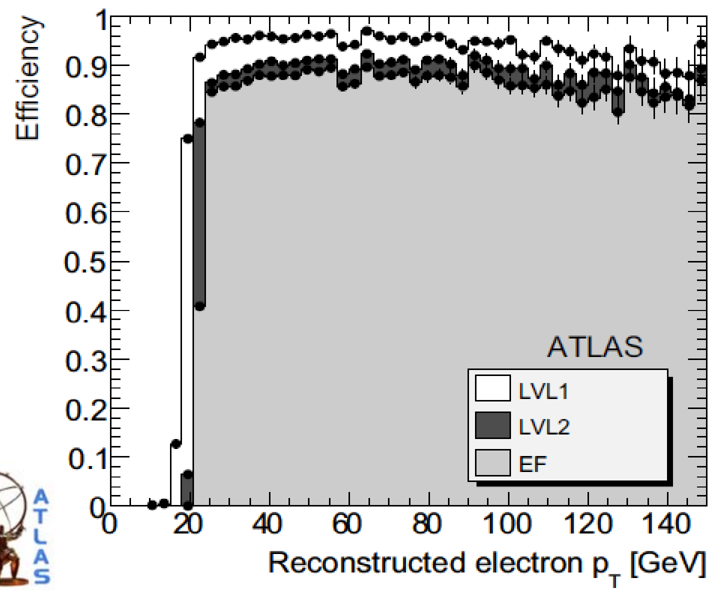
- two electrons with E_T > 30 GeV and $|\eta|$<2.5
  - → with identification criteria
  - → not required: opposite charges
- beware of electroweak corrections
  - → beyond simple PYTHIA !

Top pair production

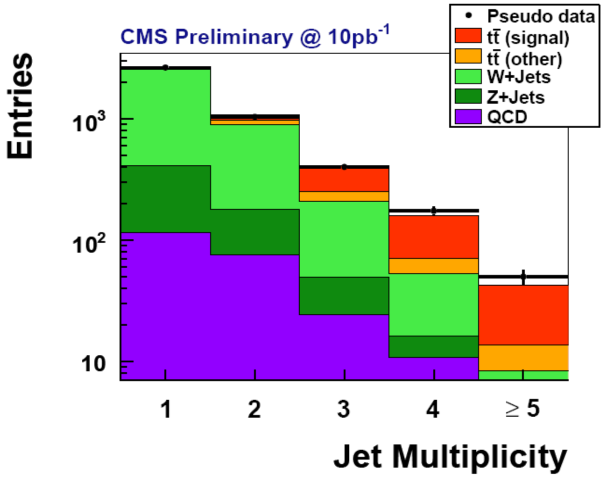




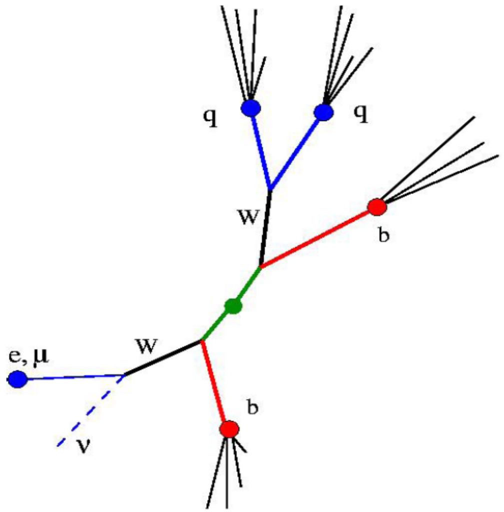


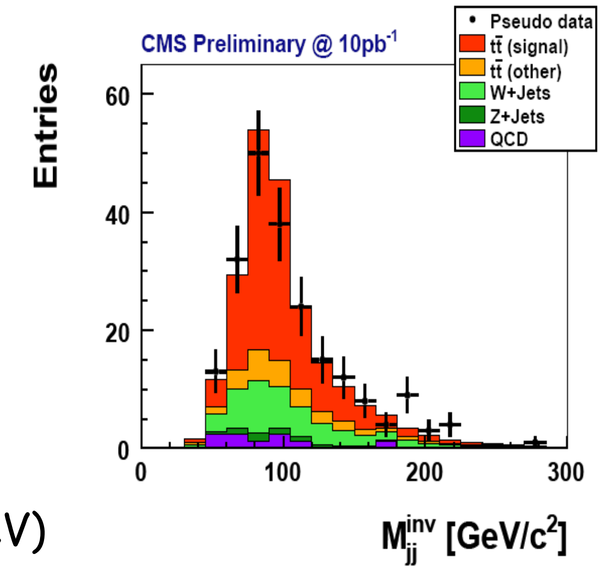


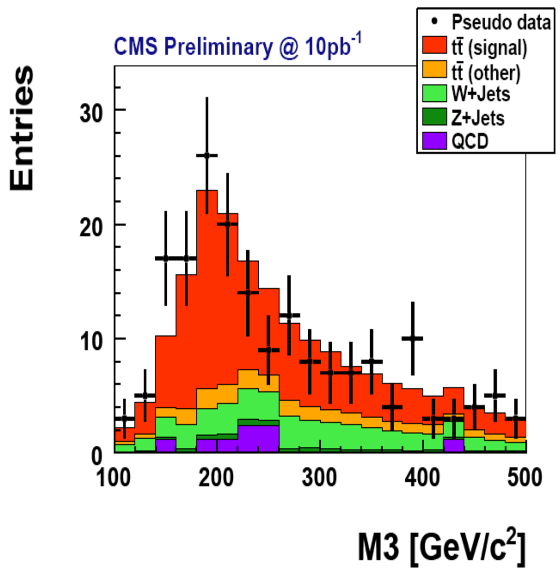
Rediscovery of top quark



- **pre-selection**
  - → 1 isolated muon: $E_T > 30$ GeV
  - → ≥4 jets: $E_T > 65/40/40/40$ GeV
    - no b-tagging
- **final selection**
  - → muon: $E_T > 40$ GeV and isolation criteria
  - → efficiency: 10.3 %
  - → 128 signal events in 10 pb^{-1}
    - 88 background events

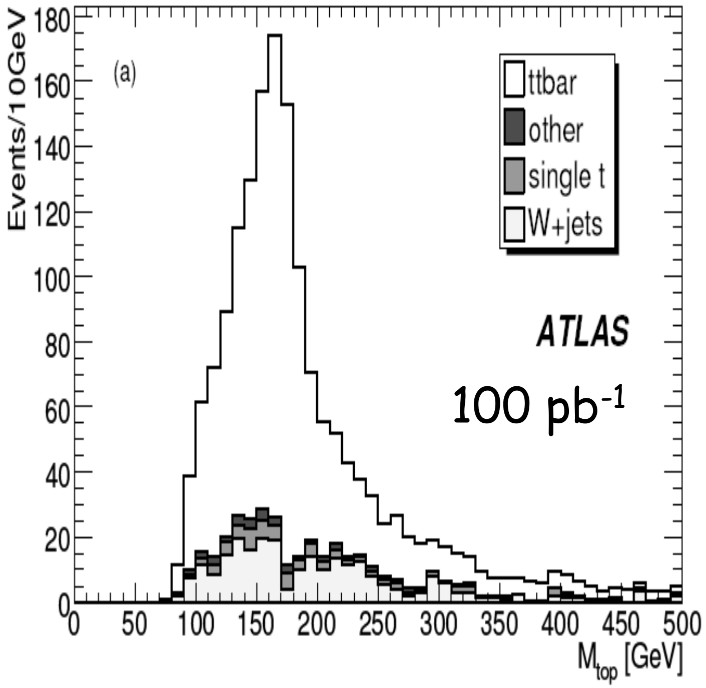


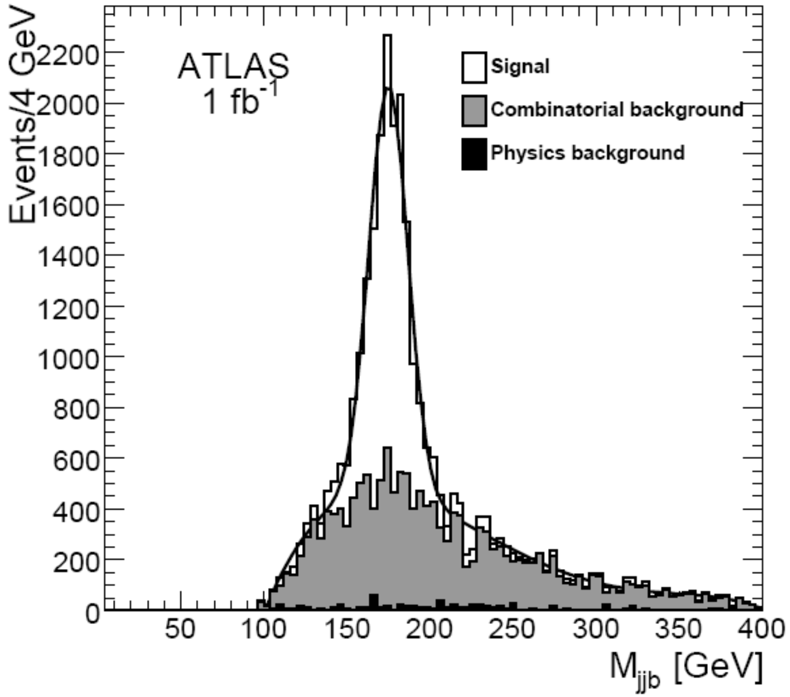




$\sigma_{tt}(14\ \text{TeV}) \approx 2 * \sigma_{tt}(10\ \text{TeV})$

Top quark measurements





- cross section
  - semi-leptonic channel
  - assumption: no b-tagging

→ accuracy expected on $\Delta\sigma/\sigma$

  ➔ counting experiment

  - 3(stat)⊕16(syst) ⊕3(pdf)⊕5 (lumi) %

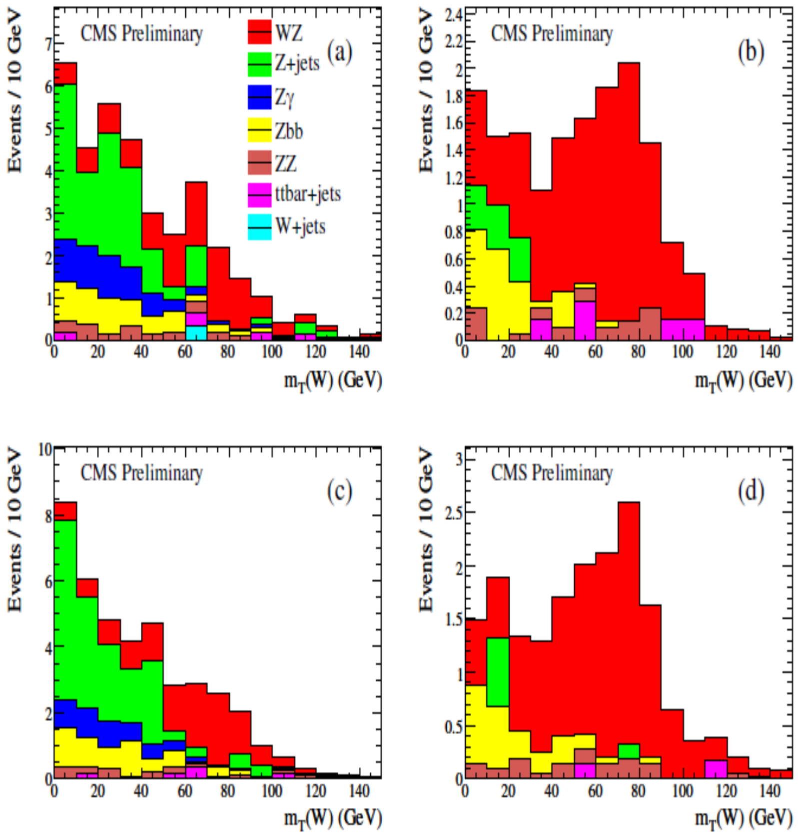
- top quark mass
  - semi-leptonic channel

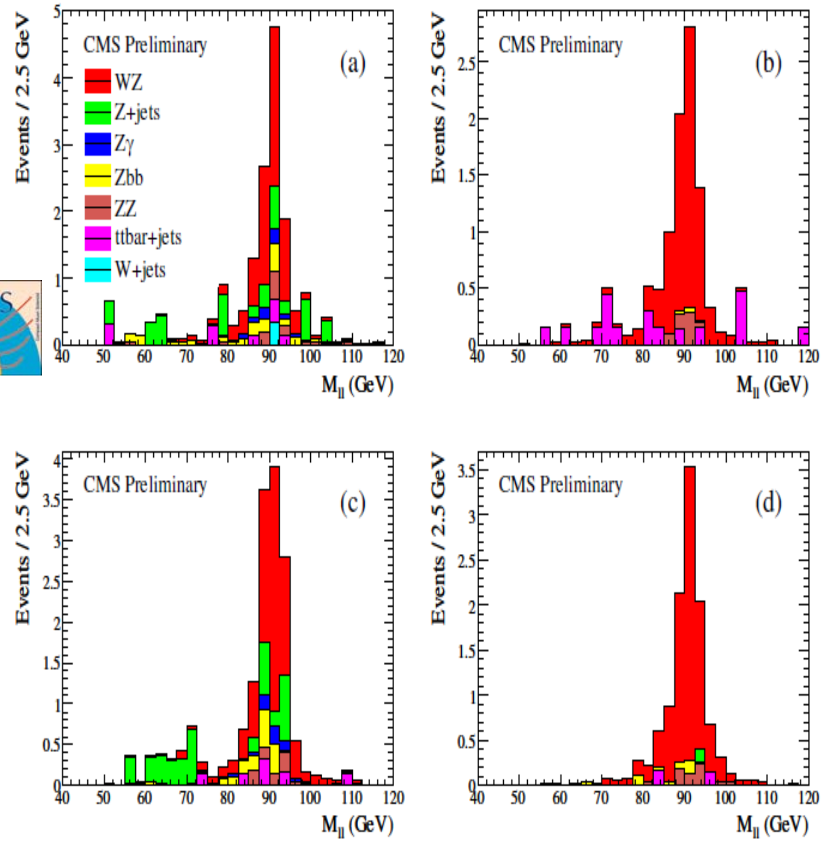
→ accuracy: 1 – 3.5 GeV

  - for absolute energy scale knowledge 1-5%

→ with b-tagging

WZ production

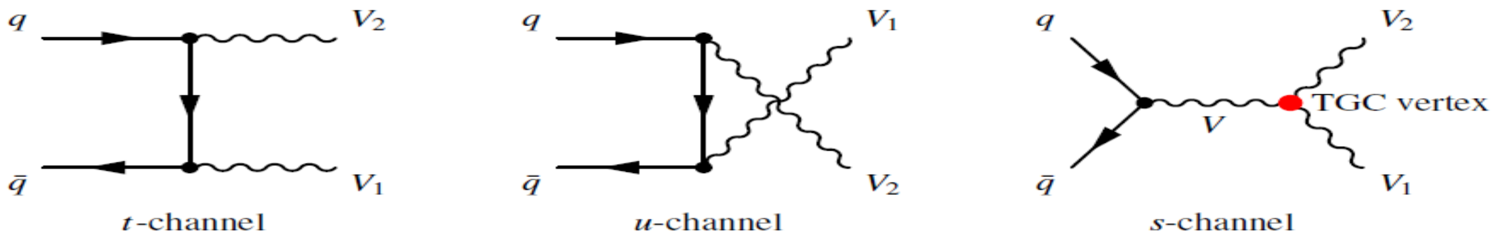




- W transverse mass & Z mass ($300\ pb^{-1}$)
  → for final states 3e (a), 2e1μ (b), 1e2μ (c), 3μ (d)

WZ production

- measure and test triple gauge boson coupling

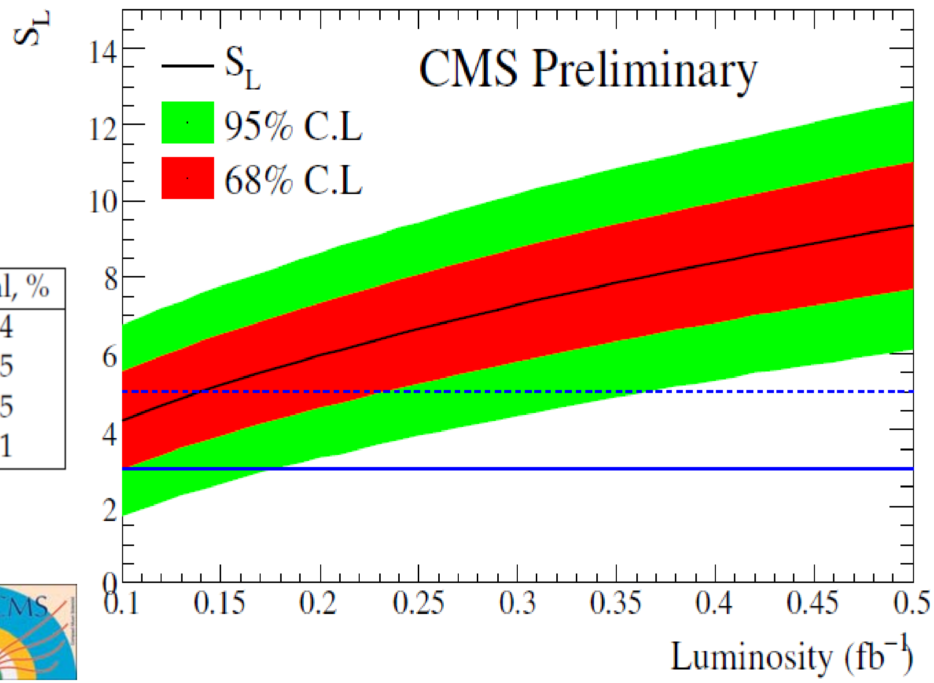


→ data driven back-ground extraction

- systematic uncertainties

Channels	Modeling, %	Background estimation, %	Total, %
$3e$	21	27	34
$2e1\mu$	19	16	25
$2\mu 1e$	17	31	35
3μ	17	12	21

→ 5σ significance for 350 pb^{-1}



Gauge boson pair production

Diboson mode	Signal	Background	Signal eff.	σ_{stat}^{signal}	p-value	Sig.
$W^+W^- \to e^\pm \nu \mu^\mp \nu$	347 ± 3	64 ± 5	12.6% (BDT)	5.4%	3.6×10^{-166}	27.4
$W^+W^- \to \mu^+ \nu \mu^- \nu$	70 ± 1	17 ± 2	5.2% (BDT)	12.0%	8.8×10^{-30}	11.3
$W^+W^- \to e^+ \nu e^- \nu$	52 ± 1	11 ± 2	4.9% (BDT)	13.9%	1.9×10^{-24}	10.1
$W^+W^- \to \ell^+ \nu \ell^- \nu$	103 ± 3	17 ± 2	2.0% (cuts)	9.9%	1.4×10^{-54}	15.5
$W^\pm Z \to \ell^\pm \nu \ell^+ \ell^-$	128 ± 2	16 ± 3	15.2% (BDT)	8.8%	3.0×10^{-76}	18.4
	53 ± 2	8 ± 1	6.3% (cuts)	13.7%	3.1×10^{-30}	11.4
$ZZ \to 4\ell$	17 ± 0.5	2 ± 0.2	7.7% (cuts)	24.6%	6.0×10^{-12}	6.8
$ZZ \to \ell^+ \ell^- \nu \bar{\nu}$	10 ± 0.2	5 ± 2	2.6% (cuts)	31.3%	7.7×10^{-4}	3.2
$W\gamma \to e \nu \gamma$	1604 ± 65	1180 ± 120	5.7% (BDT)	2.5%	significance > 30	
$W\gamma \to \mu \nu \gamma$	2166 ± 88	1340 ± 130	7.6% (BDT)	2.1%	significance > 30	
$Z\gamma \to e^+ e^- \gamma$	367 ± 12	187 ± 19	5.4% (BDT)	5.2%	1.2×10^{-91}	20.3
$Z\gamma \to \mu^+ \mu^- \gamma$	751 ± 23	429 ± 43	11% (BDT)	3.6%	5.9×10^{-171}	27.8

- expected number of events for 1 fb^{-1} (14 TeV)
  - → final states with l = e, μ

Triple gauge boson couplings

- Lagrangian for charged interactions

$$L/g_{WWV} = ig_1^V(W^*_{\mu\nu}W^\mu V^\nu - W_{\mu\nu}W^{*\mu}V^\nu) + i\kappa^V W^*_\mu W_\nu V^{\mu\nu} + \frac{\lambda^V}{M_W^2} W^*_{\rho\mu} W^\mu_\nu V^{\nu\rho}$$

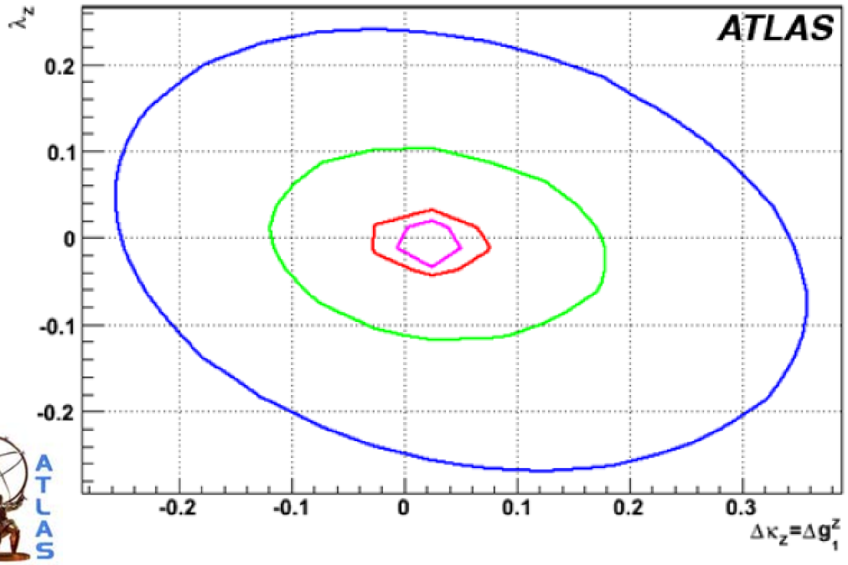
- anomalous coupling parameters

$$\Delta g_1^Z \equiv g_1^Z - 1, \quad \Delta\kappa_\gamma \equiv \kappa_\gamma - 1, \quad \Delta\kappa_Z \equiv \kappa_Z - 1, \quad \lambda_\gamma, \quad \text{and} \quad \lambda_Z$$

→ SM: $g_1^V = \kappa_V = 1$ and $\lambda_V = 0$

- expected sensitivity
  - → study $m_T(WZ)$ and $p_T(Z)$
  - → with systematics

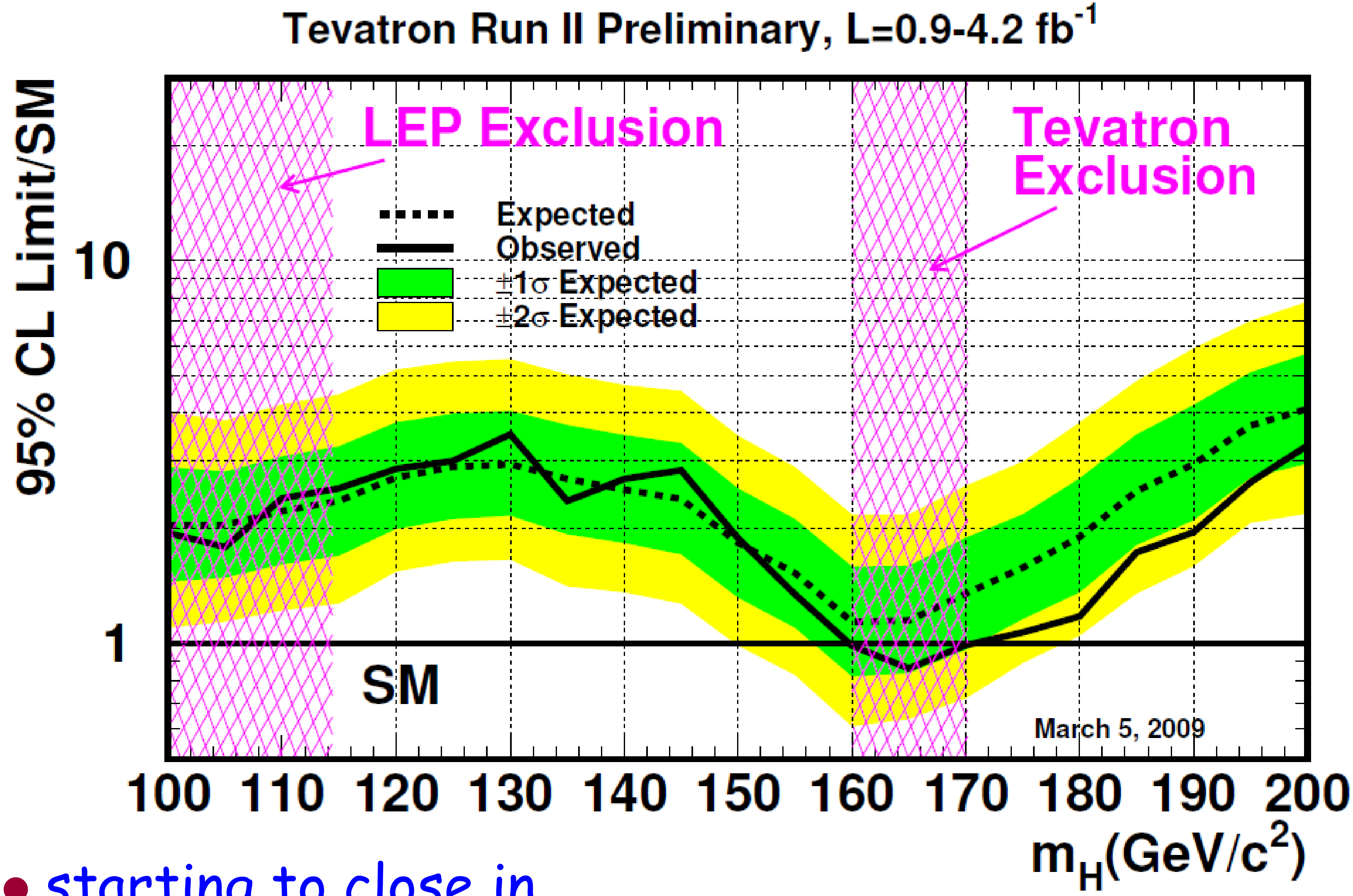
    $\sigma_S = 9.2\%, \ \sigma_B = 18.3\%$
  - → luminosity of
    - 0.1 → 1 → 10 → 30 fb^{-1}



rediscovery of Standard Model

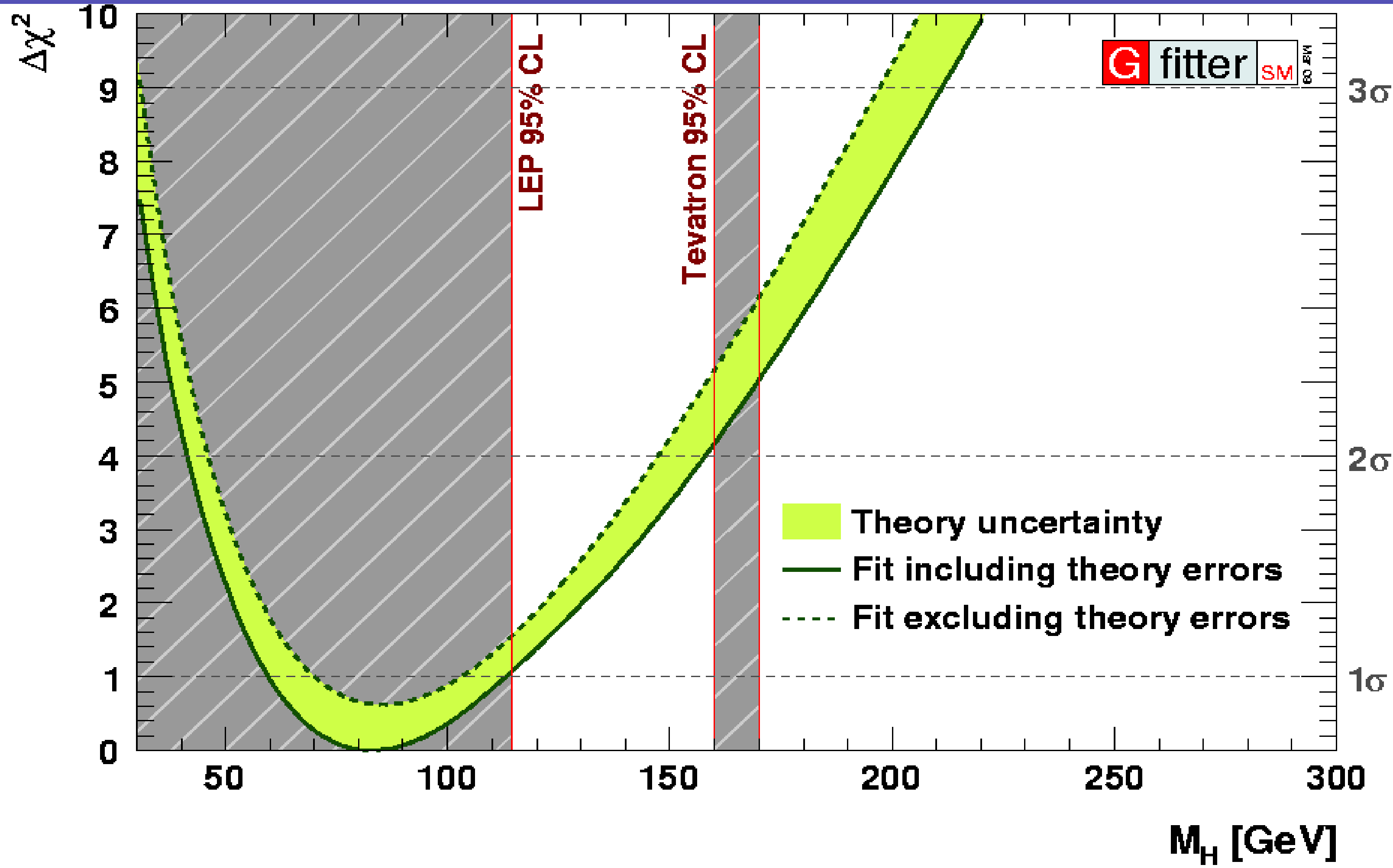
(and more...)

Status of Tevatron Higgs search



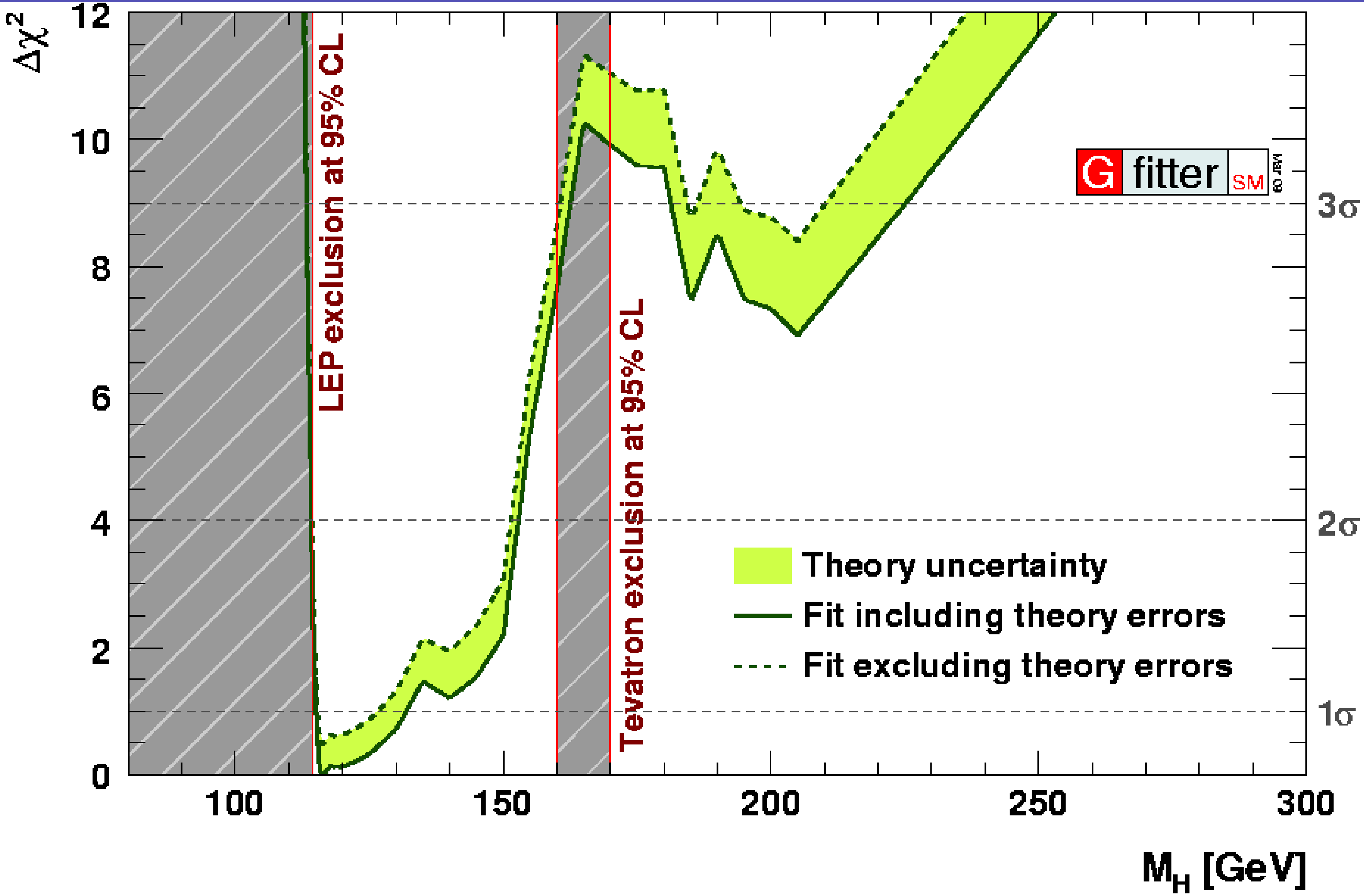
- starting to close in …

Present situation on Higgs boson



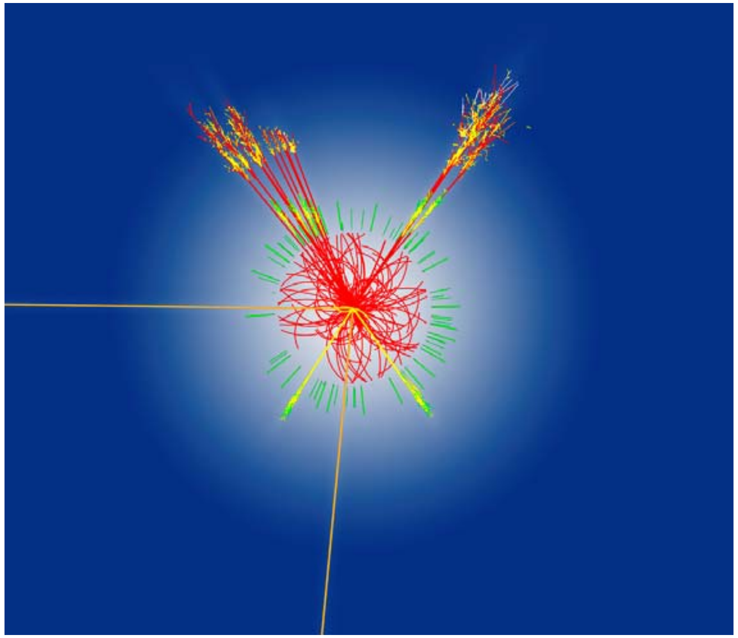
- indirect evidence for a light Higgs boson

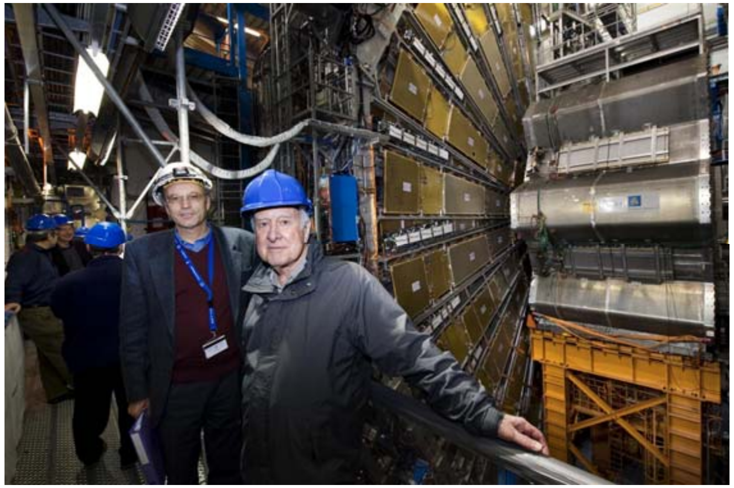
Present situation on Higgs boson

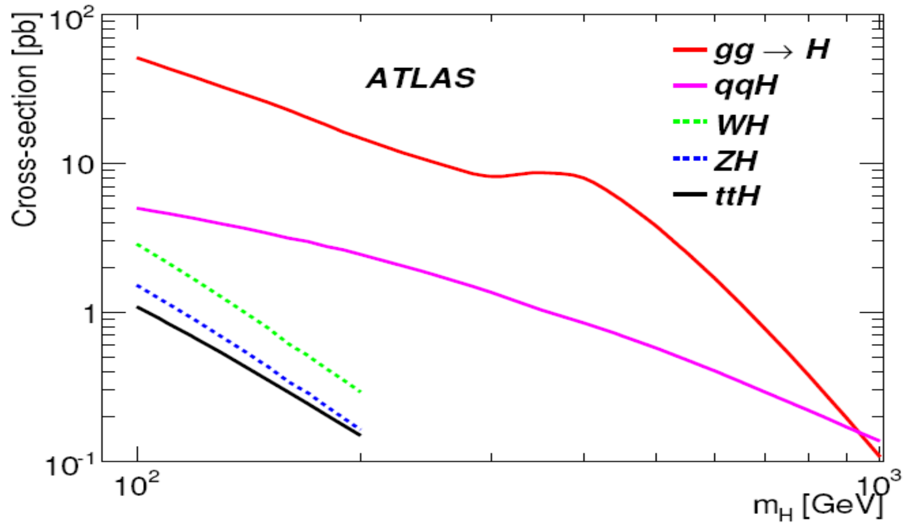


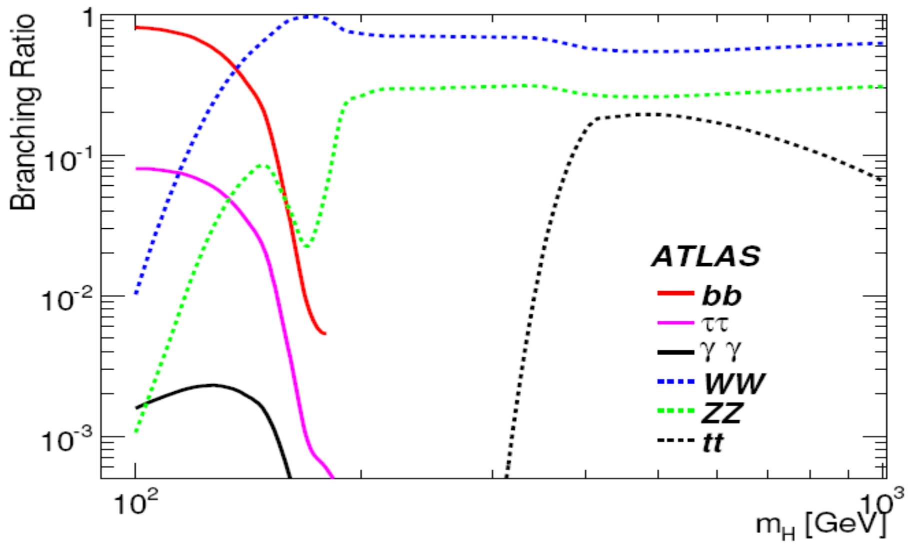
- indirect evidence for a light Higgs boson

Search for the Higgs boson at LHC

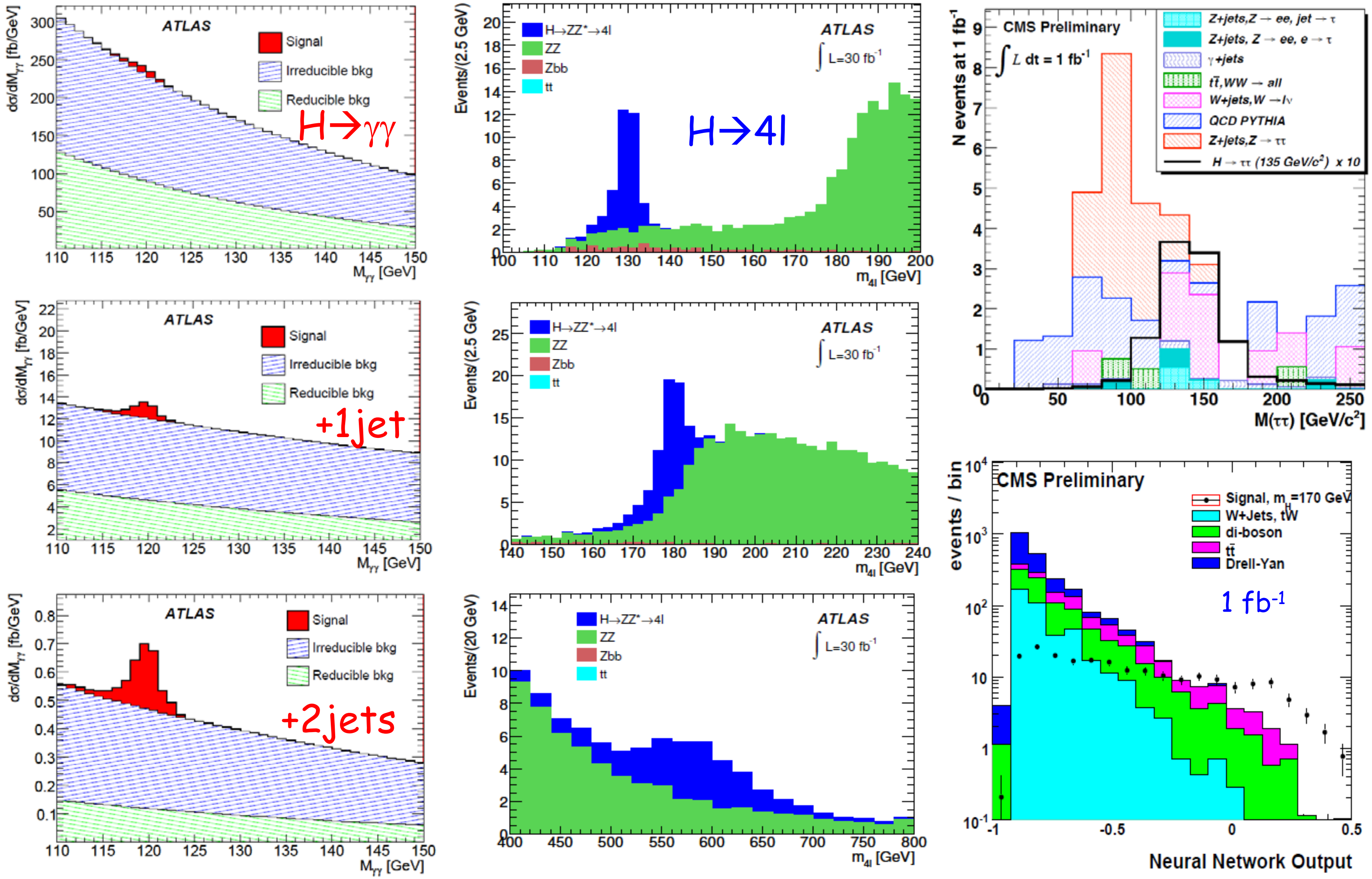




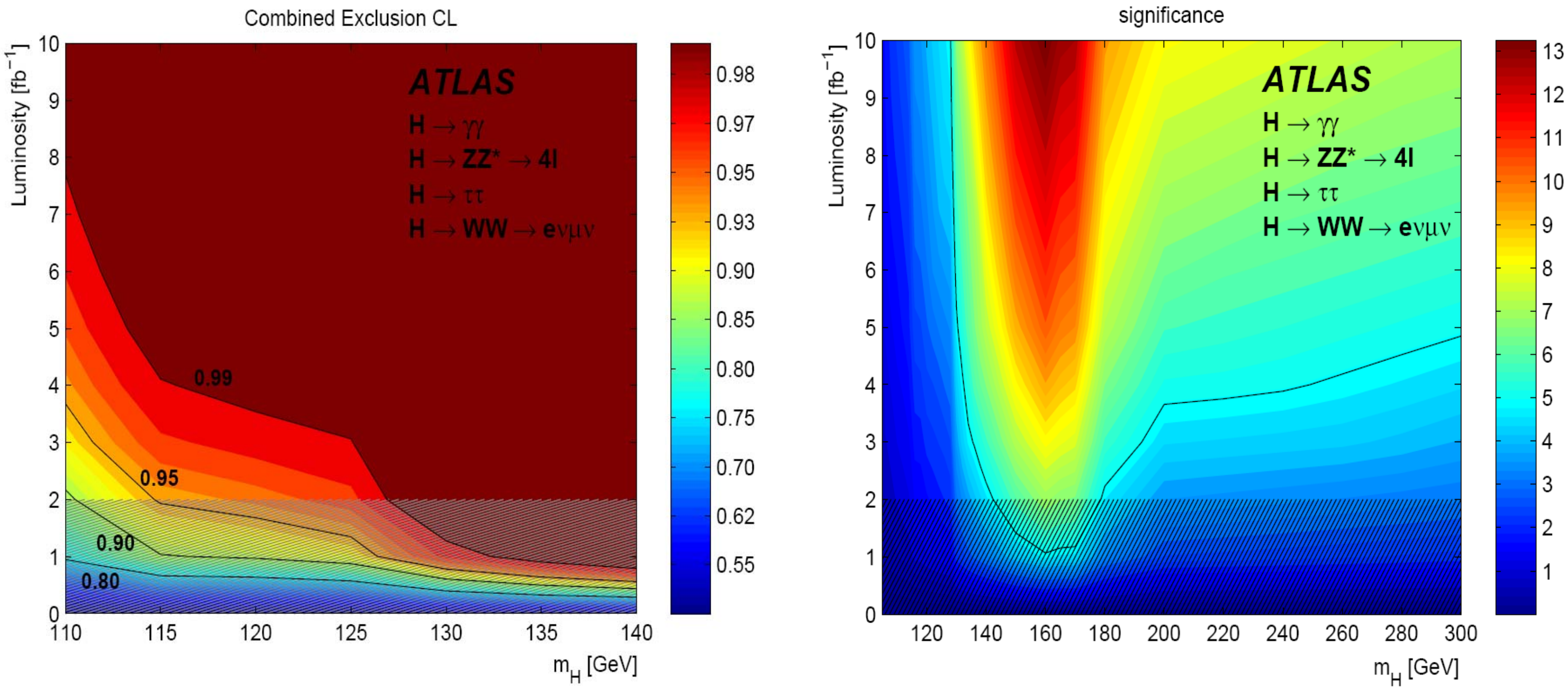




Examples of Higgs signals



Discovery potential Higgs boson



- for an integrated luminosity of 2 fb^{-1} ($\sqrt{s}$=14 TeV)
  - → 5σ sensitivity for discovery: 143 GeV < M_H < 179 GeV
  - → expected upper limit (95% C.L.) on M_H: 115 GeV
    - ❍ studies valid only for $L \geq 2$ fb^{-1}
    - ❍ not all relevant channels have been included

search for new physics beyond the Standard Model

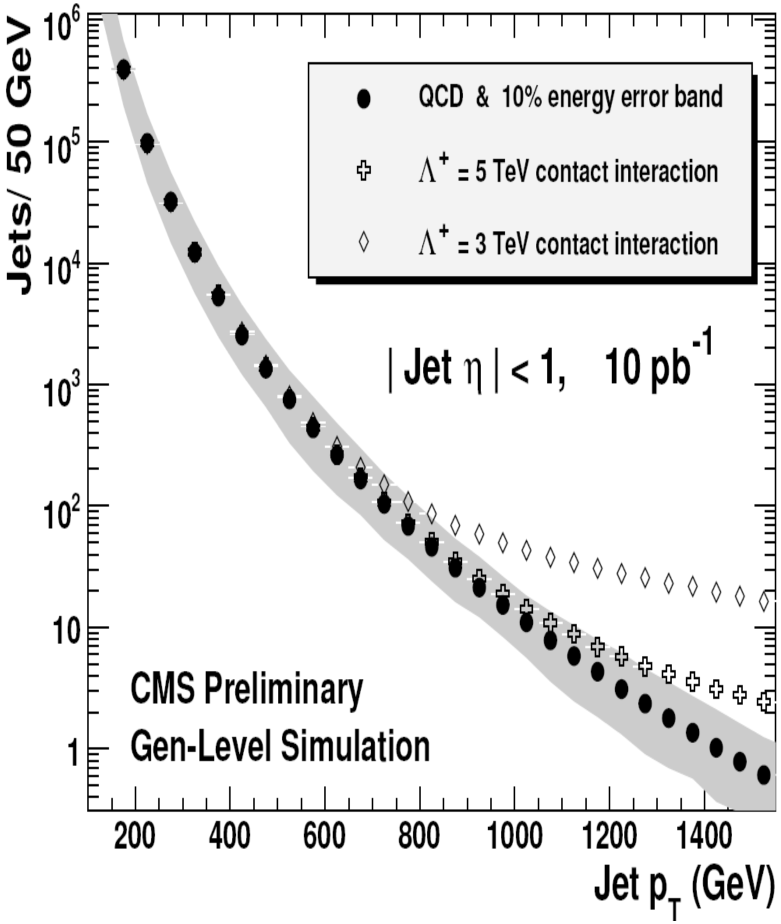
On the way to Terra Incognita …

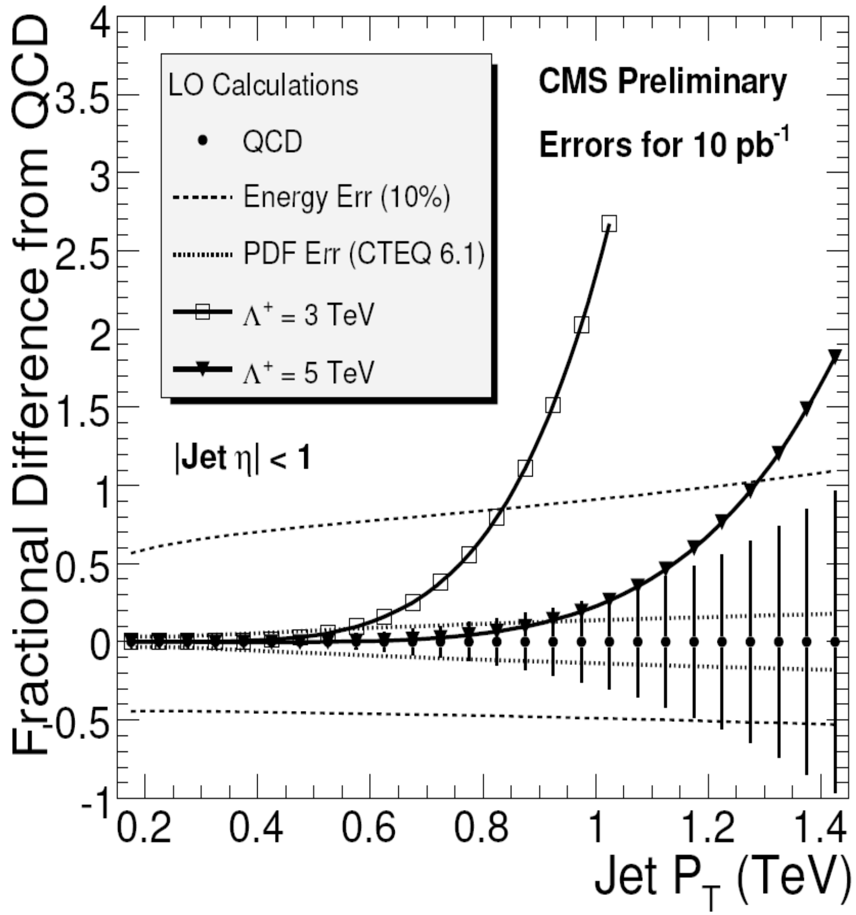
Recipe (checklist) for discoveries

- to find a deviation is easy …
  - → to prove that it stems from new physics is harder
  - → simple-minded recipe
    - find variable(s) discriminating between signal and background
    - cut away most background (maximing signal significance)
    - estimate remaining background events → look at yield …
- need to care/worry about
  - → is the detector behavior really understood ?
    - efficiencies, fake rates, energy/momentum scales, non-Gaussian resolution, …
      - → try to obtain as much information as possible from data
  - → is the SM prediction really understood ?
    - cross-section, kinematic distributions, underlying event, …
      - → must know sources for uncertainties on these

Compositeness

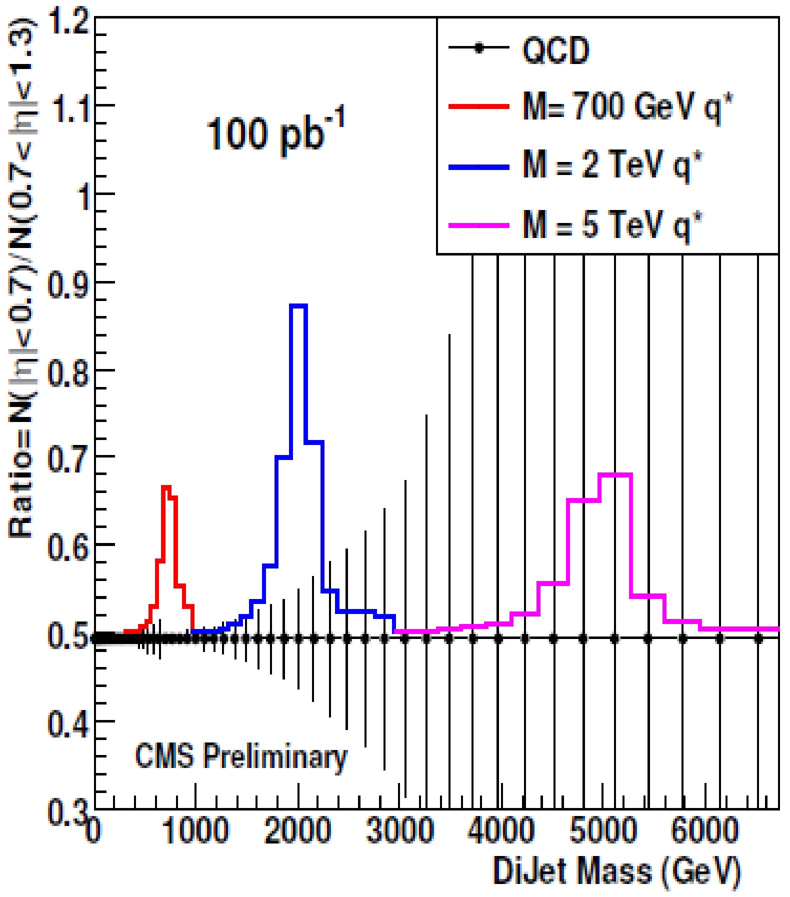
- present exclusion limit (Tevatron) Λ^{+}: ~2.7 TeV

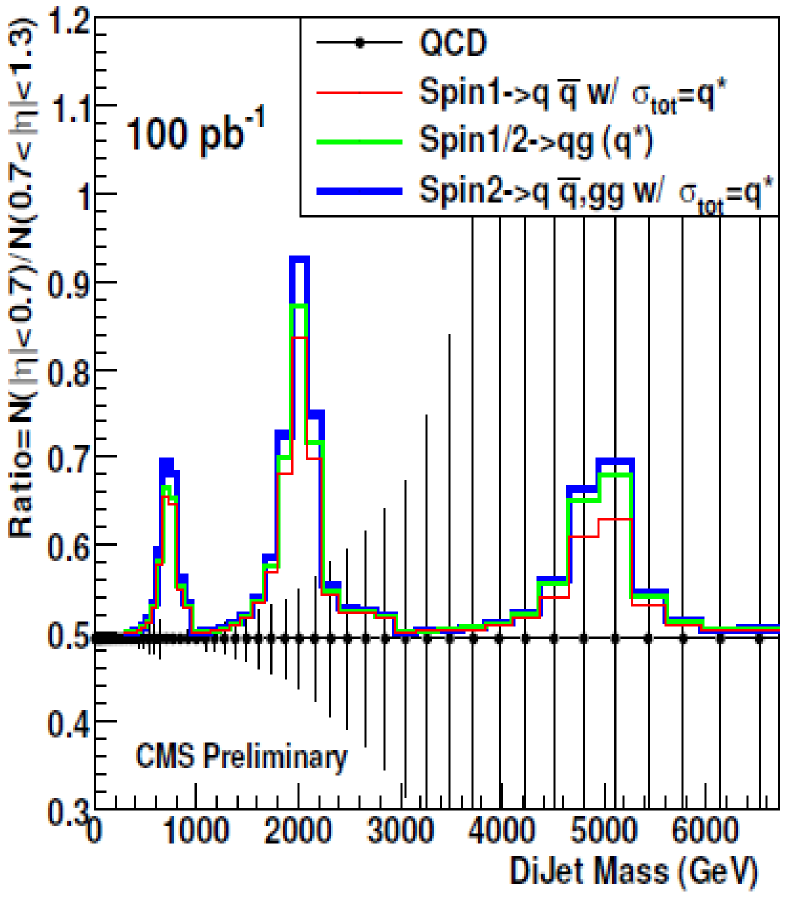




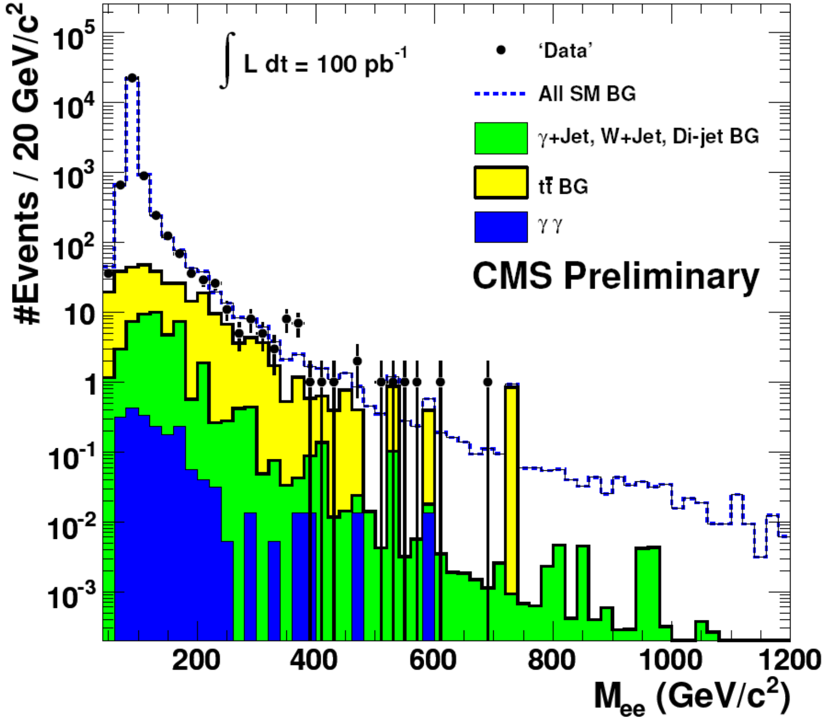
Resonances in dijets

- present exclusion limit (Tevatron) dijet mass: ~ 0.8 TeV



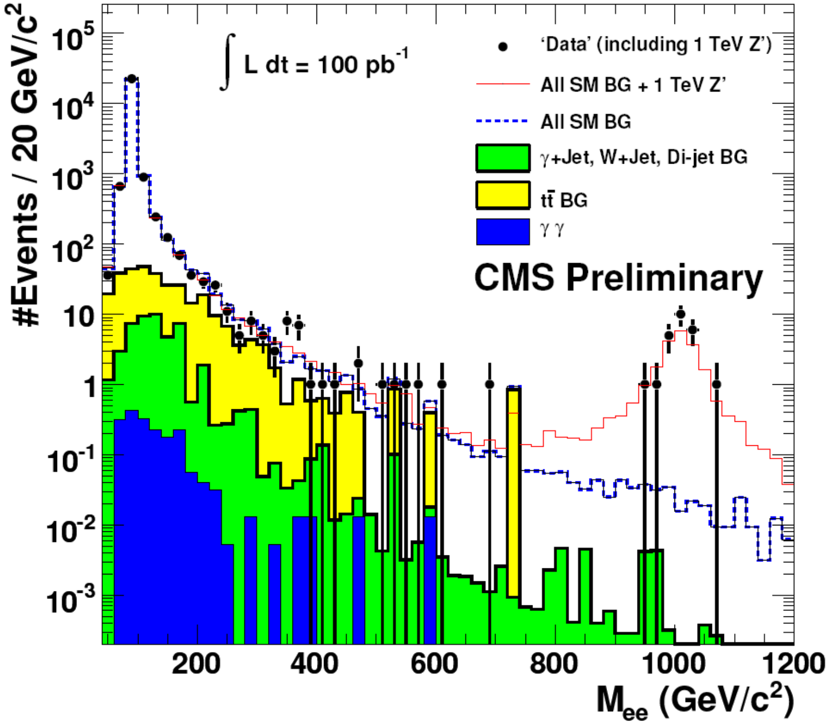


Drell-Yan lepton pair production



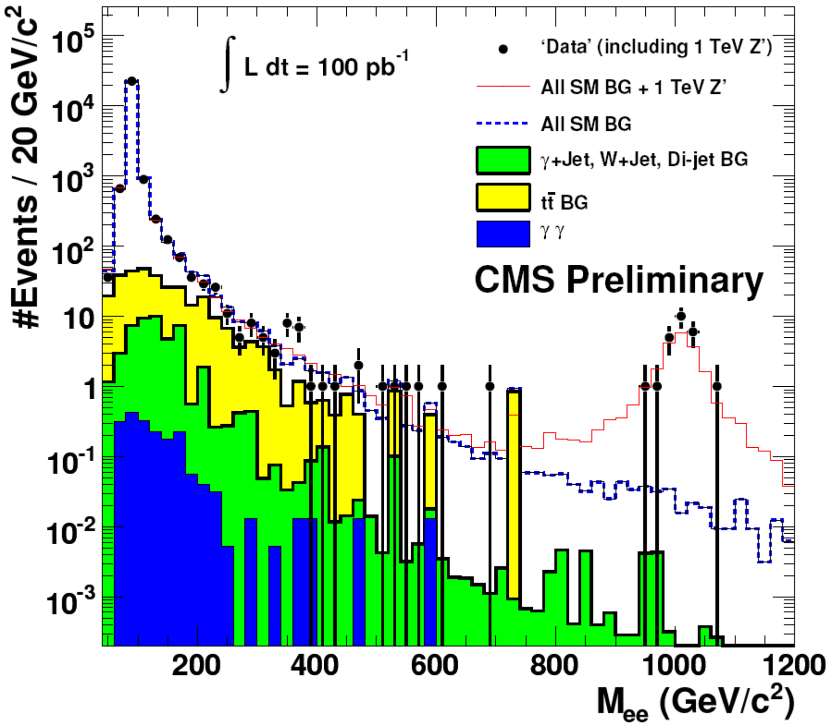
- two electrons with $E_T > 30$ GeV and $|\eta|<2.5$
  - → with identification criteria
  - → not required: opposite charges

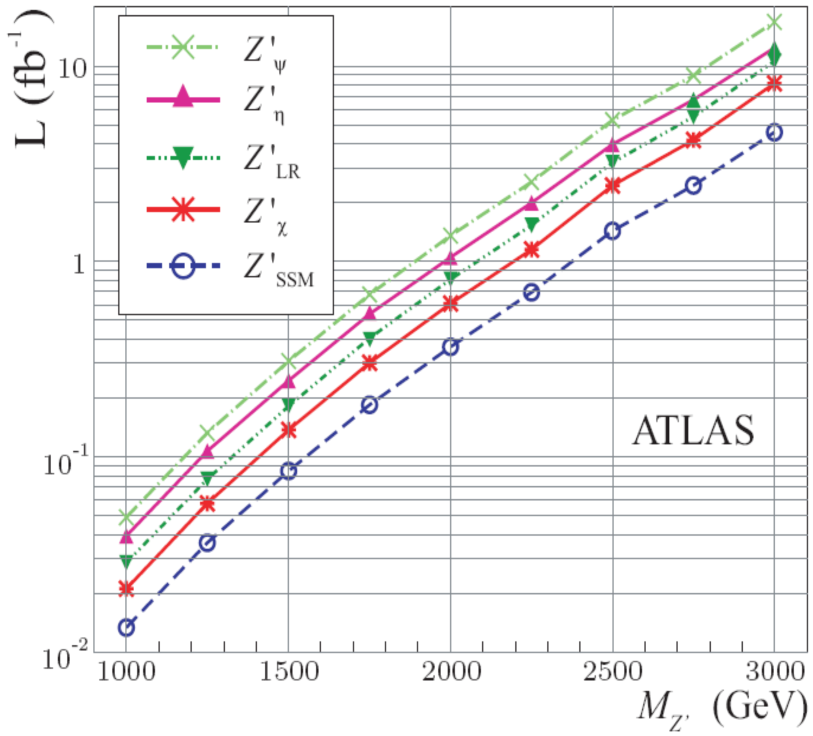
Search for new gauge bosons: Z'



- two electrons with E_T > 30 GeV and $|\eta|$<2.5
  - → with identification criteria
  - → not required: opposite charges

Search for new gauge bosons: Z'





- two electrons with E_T > 30 GeV and $|\eta|<2.5$
  - → with identification criteria
  - → not required: opposite charges

- Z' discovery potential
  - 2 electrons (p_T > 65 GeV)
  - → exclusion limit (95% C.L.) ~ 1 TeV by Tevatron

Beware of mis-alignments

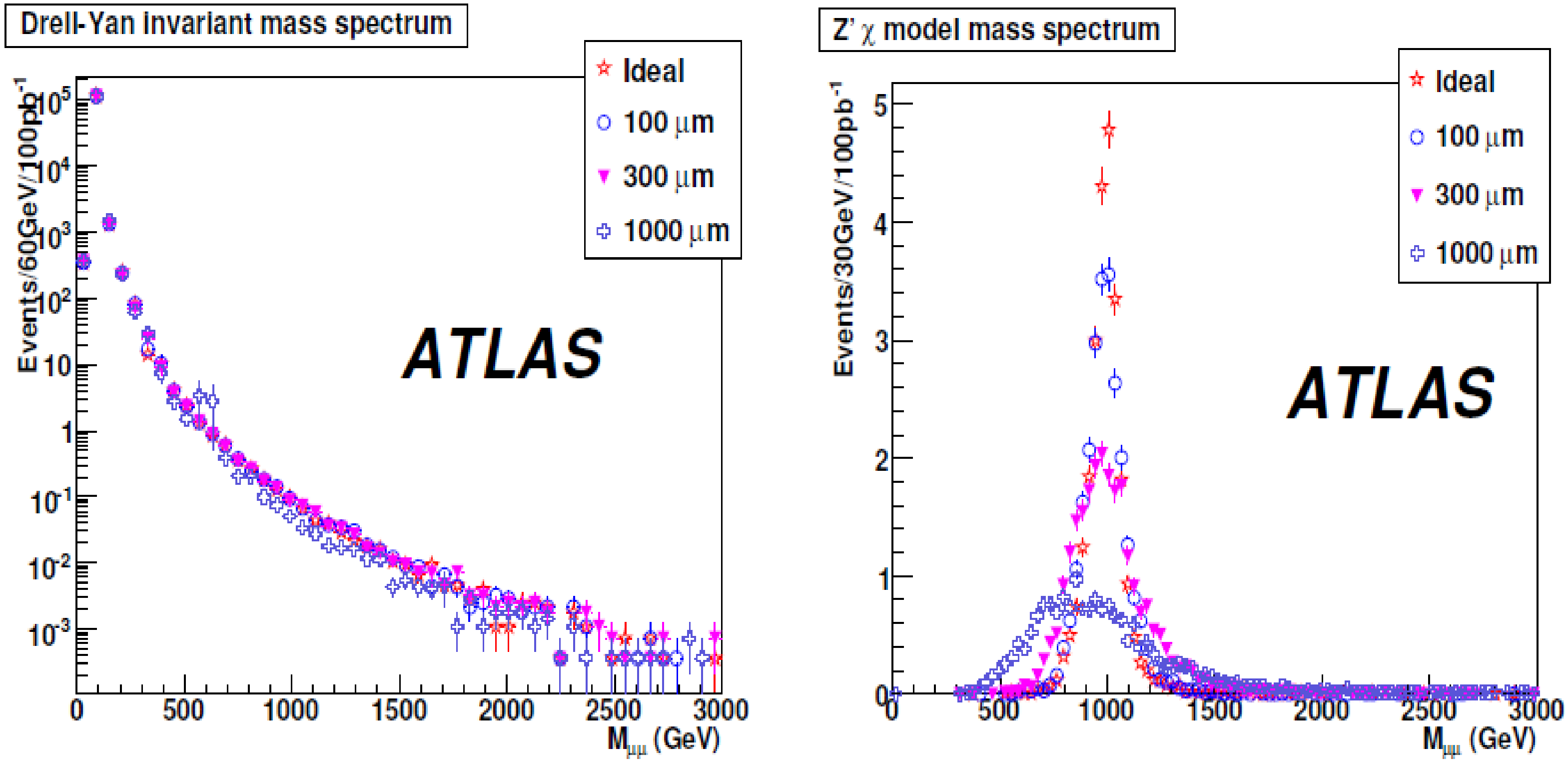


Figure 6: Left: reconstructed invariant mass distribution of Drell-Yan events for different misalignment hypotheses. The numbers corresponds to an integrated luminosity of 100 pb^{-1}. Right: reconstructed invariant mass of the Z'_χ model for the seven misalignment scenarios.

Impact on discovery potential for Z'

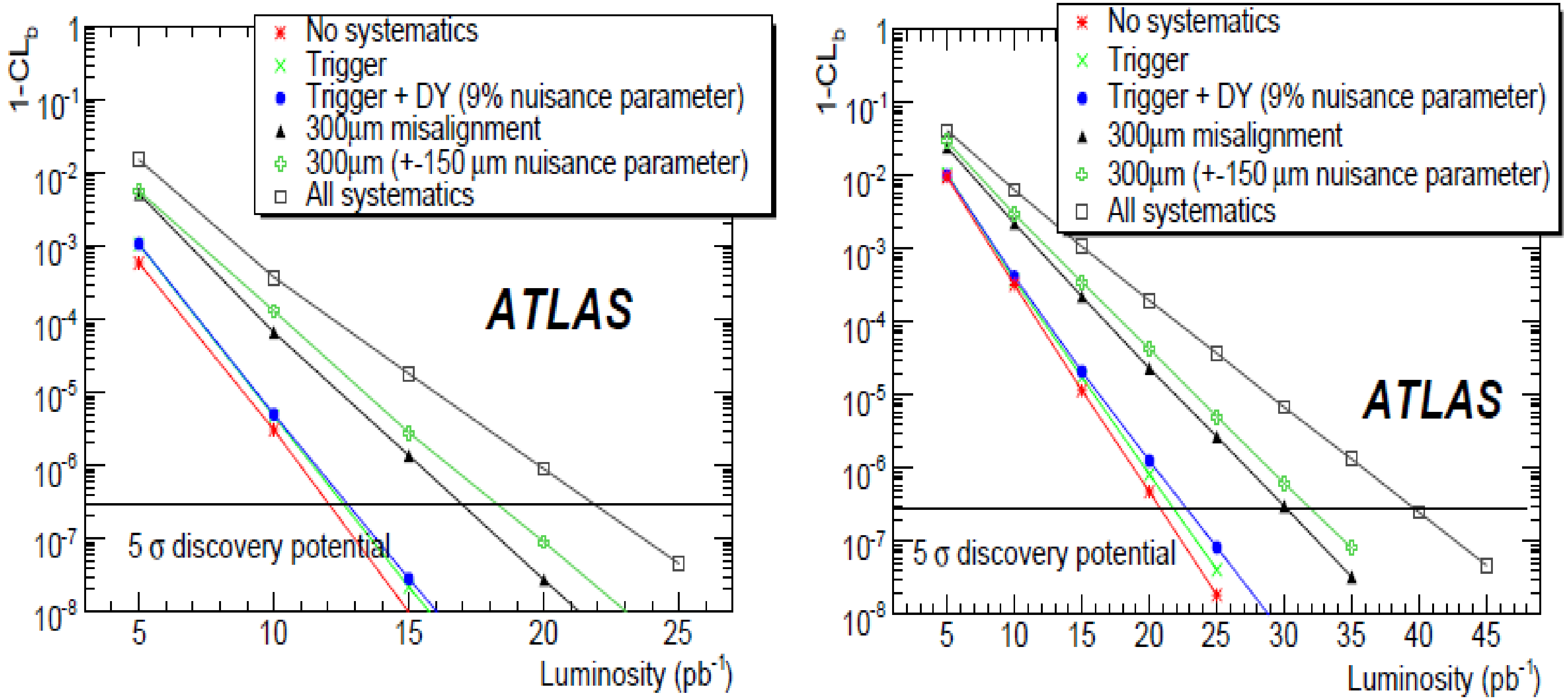


Figure 10: Results of the FFT computation of $1-CL_b$ for $m = 1$ TeV Z'_{SSM} (left) and Z'_{χ} (right) bosons. The horizontal line indicates the $1-CL_b$ value corresponding to 5σ.

Discovery potential for W'

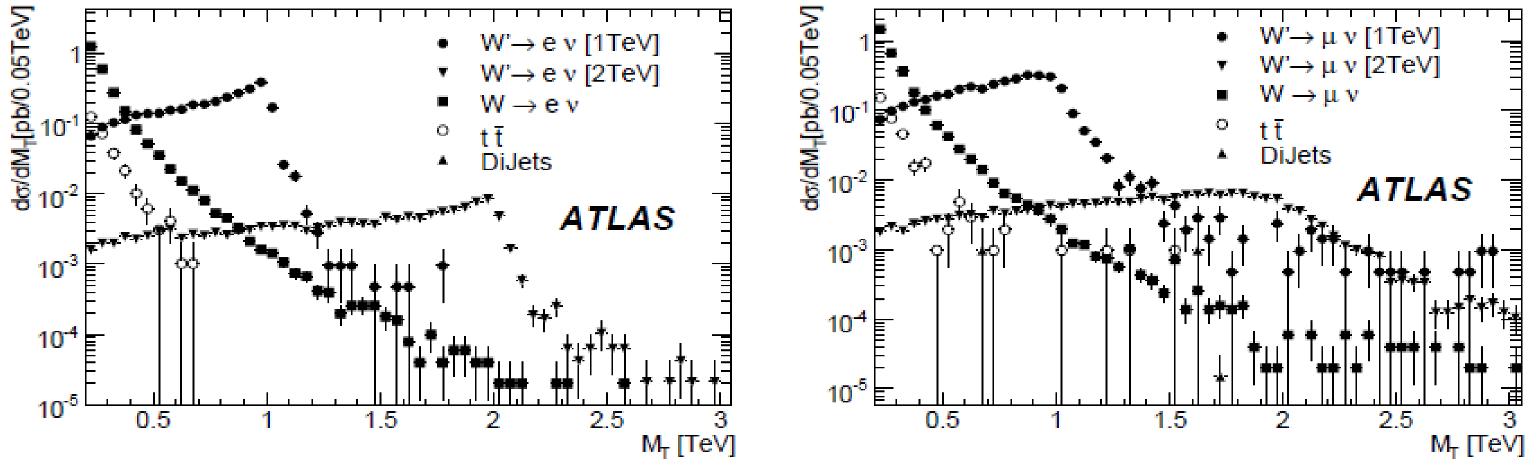
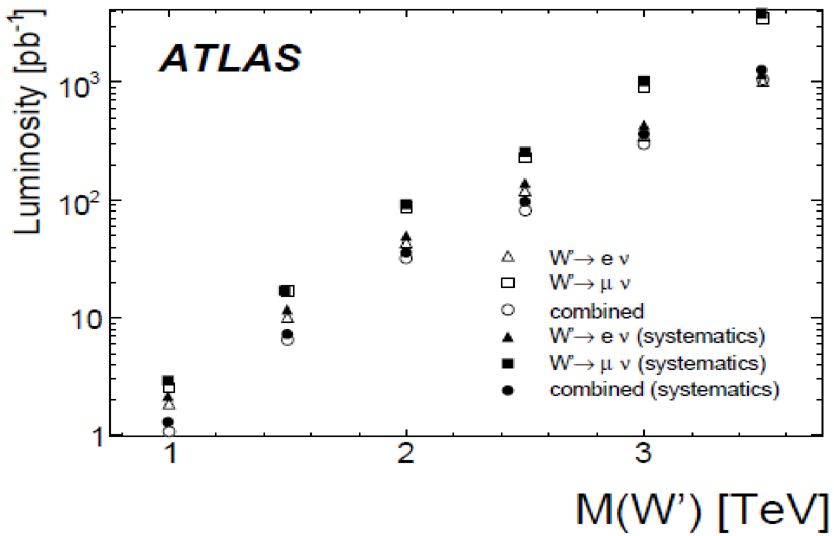


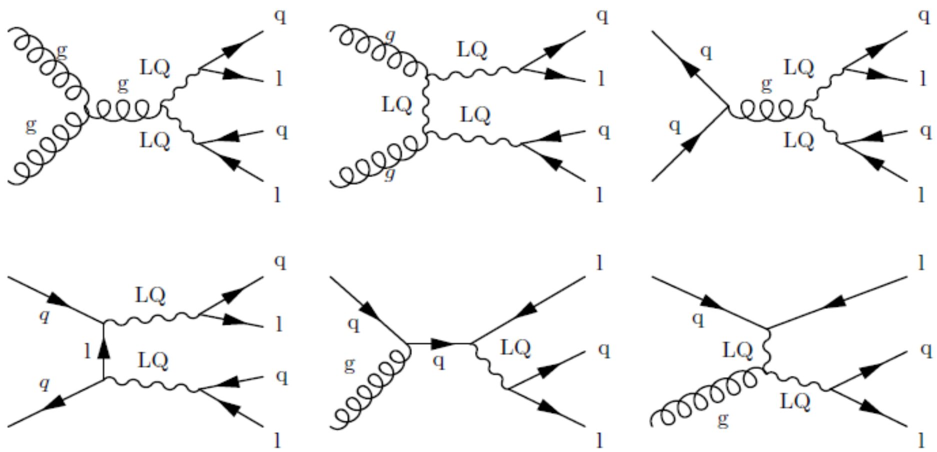
Figure 21: Expected transverse mass spectra after all requirements. Left: electron channel; right: muon channel.

- 5σ discovery potential
  - → systematics considered
    - generator (higher orders, pdf)
    - instrumental (energy scale and resolution of lepton and jet, impact on missing E_T)



Search for Leptoquarks

- boson with lepton and quark quantum numbers
  - → 3 generations of leptoquarks favored
  - → branching ratio β to lepton and quark
- Tevatron should be able to exclude up to 300-350 GeV



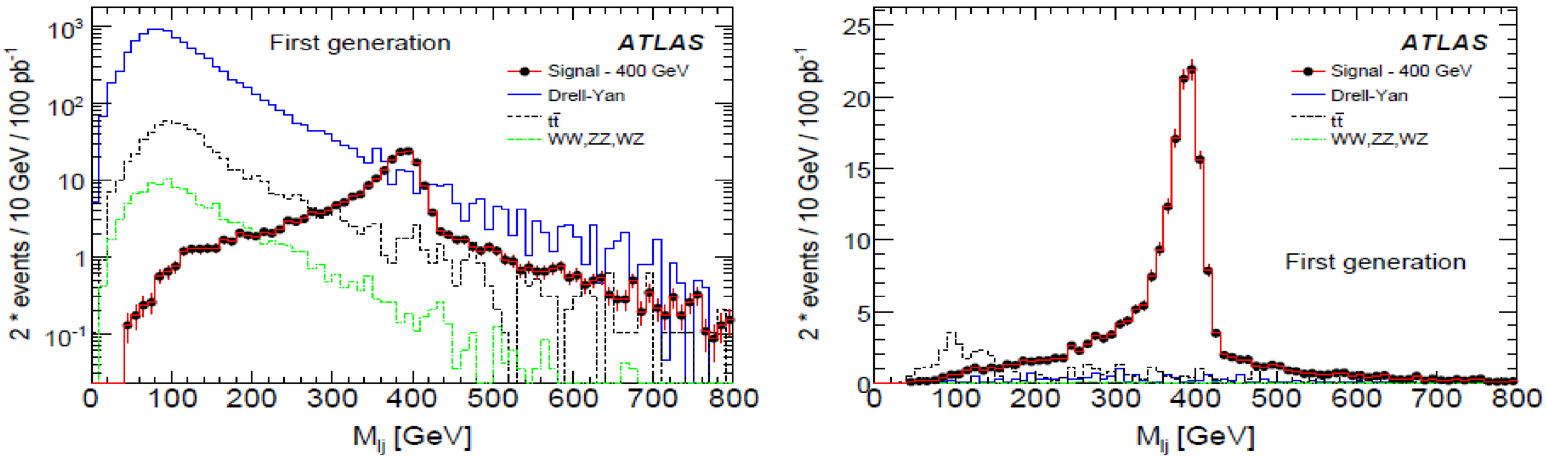


Figure 5: Reconstructed electron-jet invariant mass in the 1st generation leptoquark (m_{LQ}=400 GeV) analysis for signal and background MC events after baseline selection (left) and after all selection criteria (right). All distributions are given for 100 pb^{-1} of integrated luminosity.

Discovery potential for leptoquarks

- systematic uncertainties considered
  - → trigger, reconstruction and identification of lepton and jet
  - → higher orders, pdfs, background processes

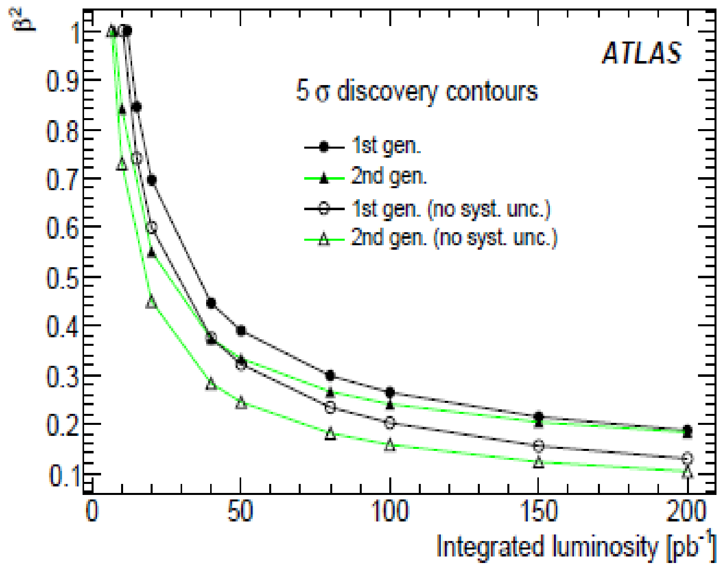


Figure 11: 5σ discovery potential for 1st and 2nd gen. m = 400 GeV scalar leptoquarks versus β^2 with and without background systematic uncertainty included.

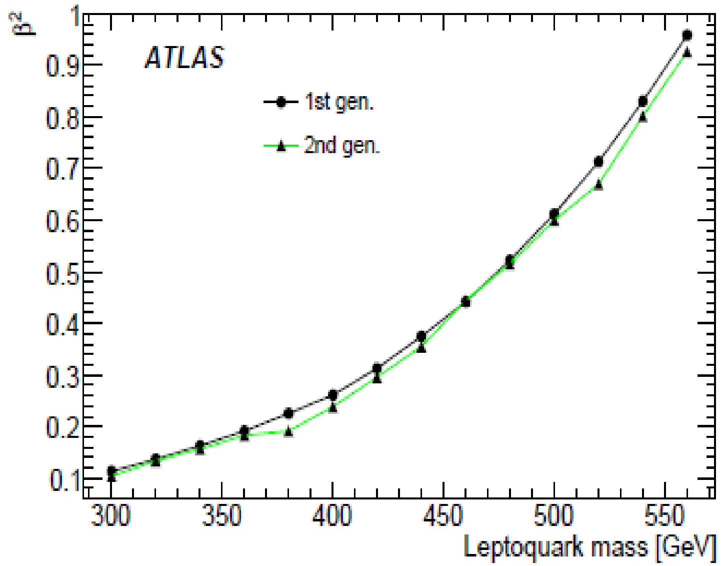
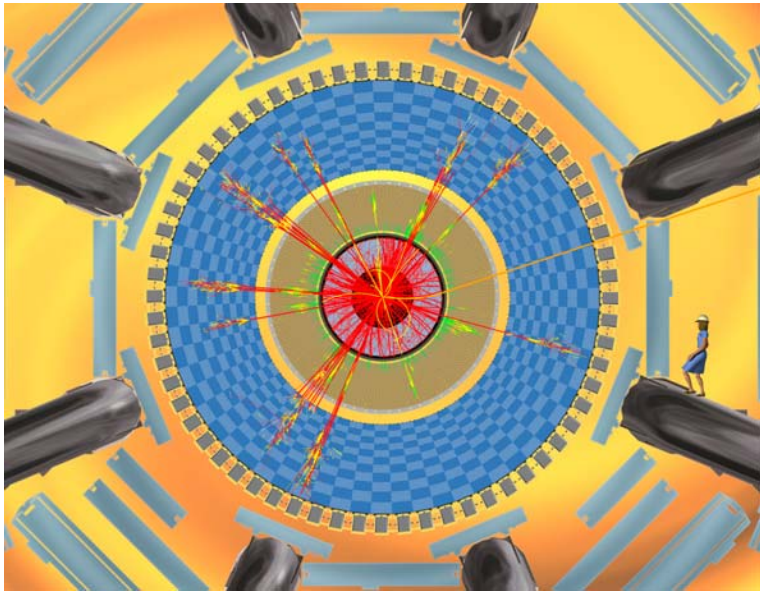
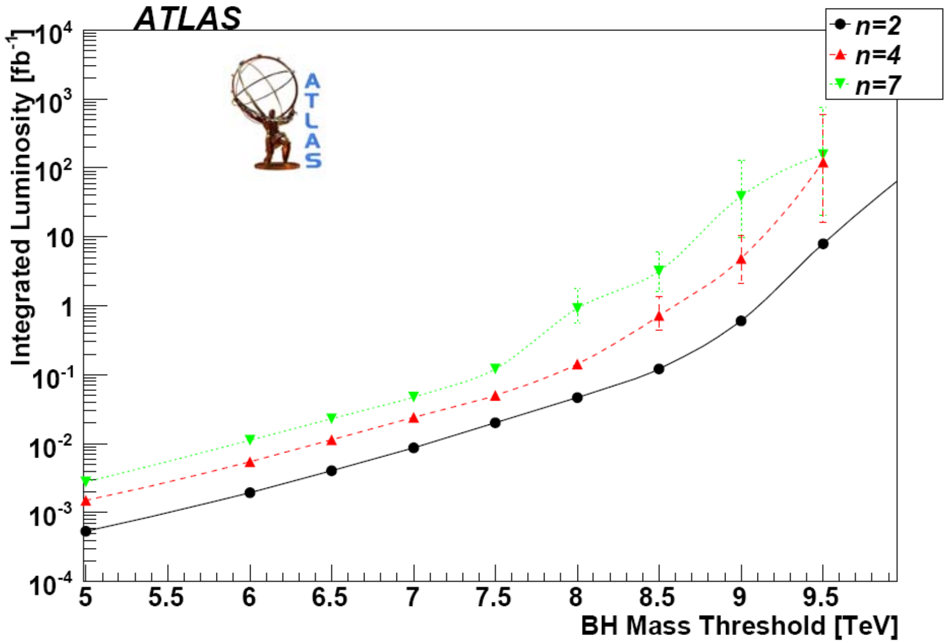


Figure 12: Minimum β^2 of scalar leptoquarks versus leptoquark mass for 100 pb^{-1} of integrated luminosity at 5σ (background systematic uncertainty included.)

Production of mini black holes



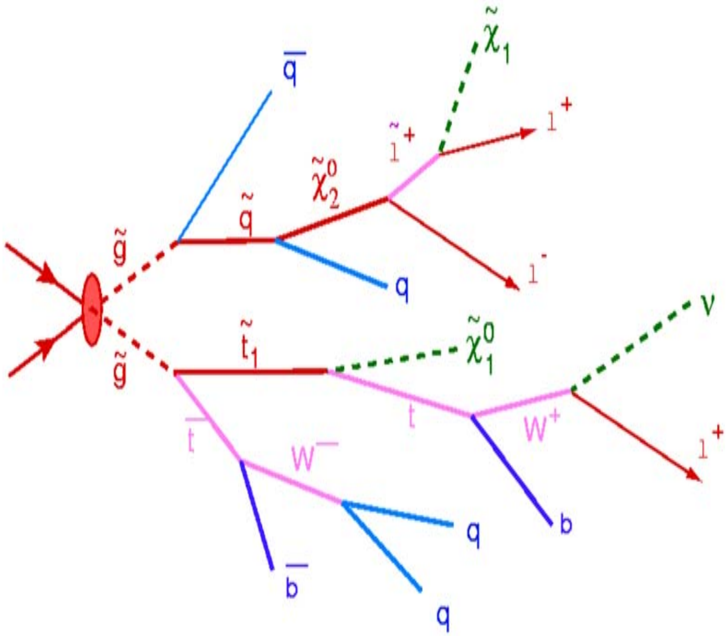
- spectacular signatures
  - → 5σ discovery potential

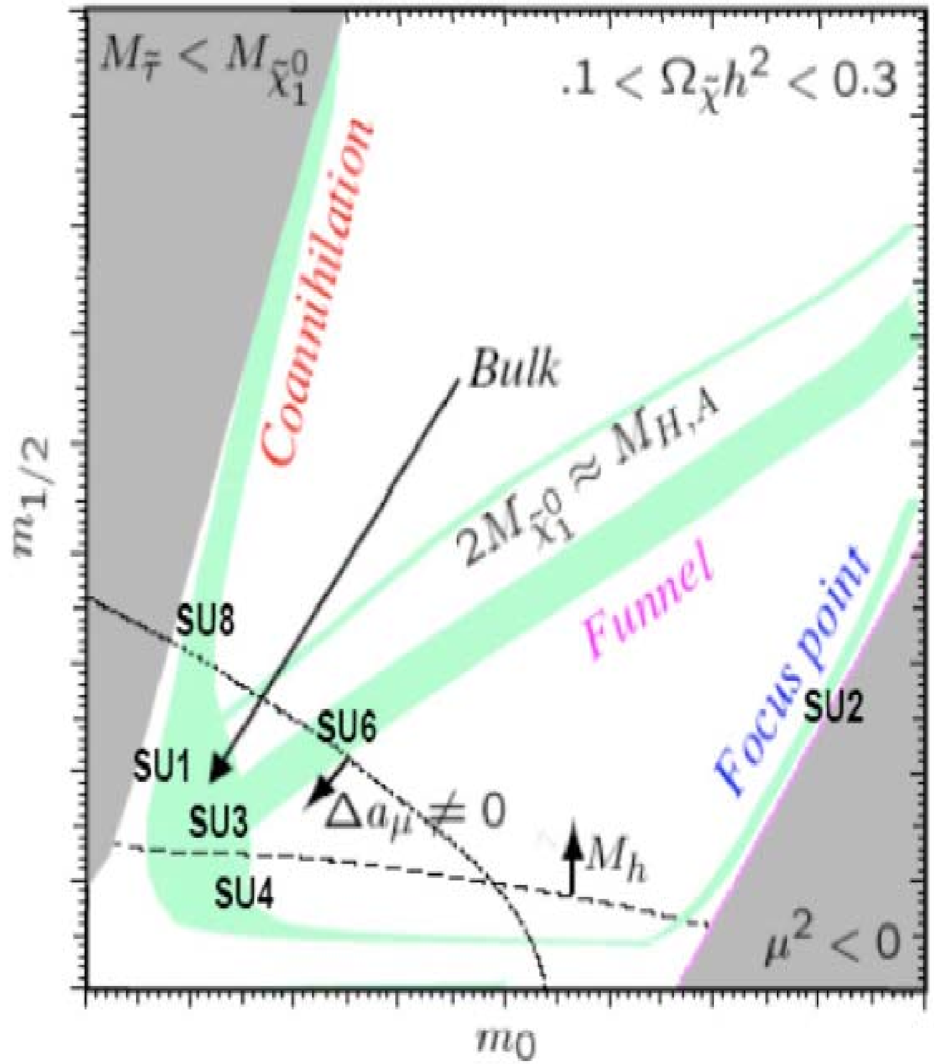


- selection
  - → $\Sigma|p_T| > 2.5$ TeV
  - → ≥ 1 lepton with $p_T > 50$ GeV

Supersymmetry

- mSUGRA
  - → one model for the symmetry breaking
  - → defines benchmark points

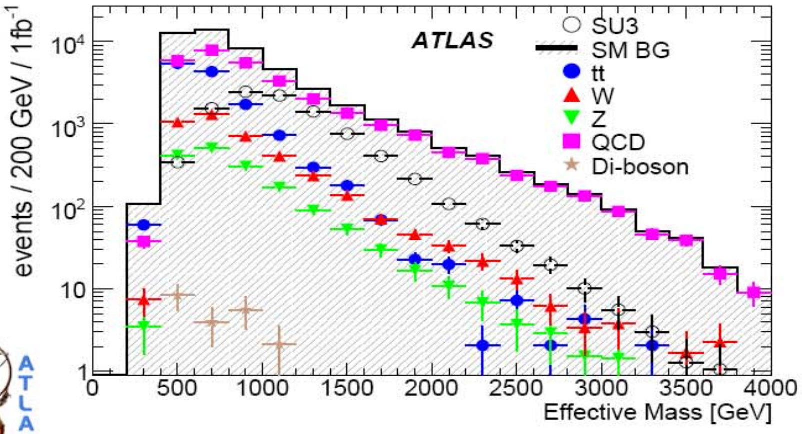


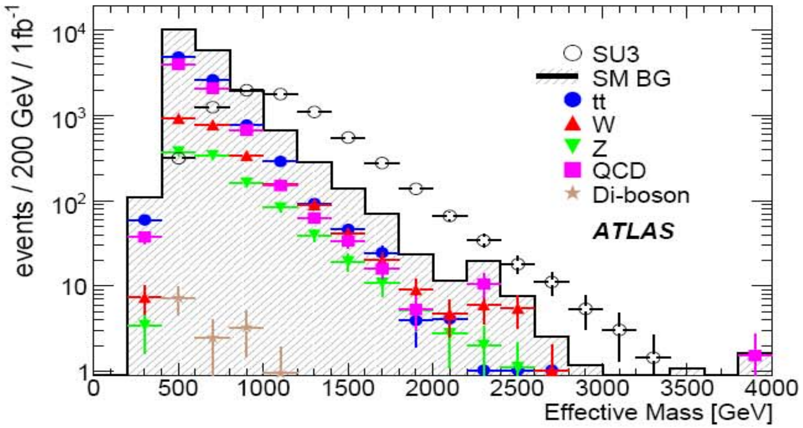


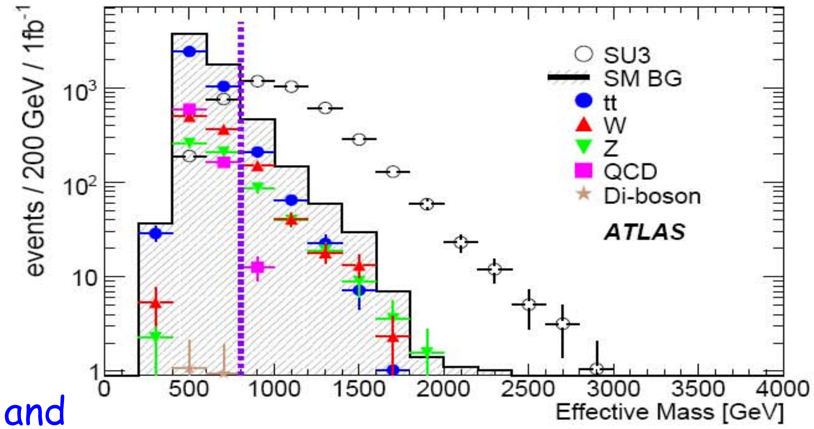
Inclusive search for supersymmetry

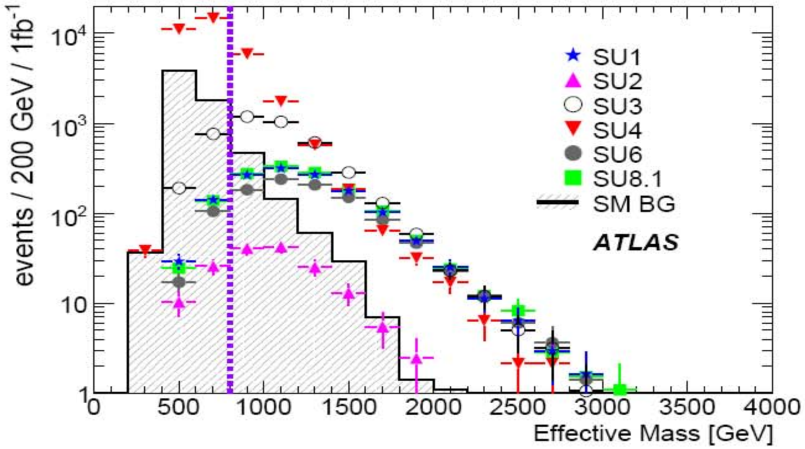
E_T^{miss}>100 GeV, ≥4 Jets E_T>100/50/50/50 GeV

… and $E_T^{miss} > 0{,}2 * M_{eff}$ $M_{\rm eff} \equiv \sum_{i=1}^{4} p_T^{{\rm jet},i} + \sum_i p_T^{{\rm lep},i} + E_T^{\rm miss}$









… and

3. Transverse sphericity, $S_T > 0.2$.

4. $\Delta\phi({\rm jet}_1 - E_{\rm T}^{\rm miss}) > 0.2$, $\Delta\phi({\rm jet}_2 - E_{\rm T}^{\rm miss}) > 0.2$, $\Delta\phi({\rm jet}_3 - E_{\rm T}^{\rm miss}) > 0.2$.

5. Reject events with an e or a μ.

6. $M_{\rm eff} > 800$ GeV.

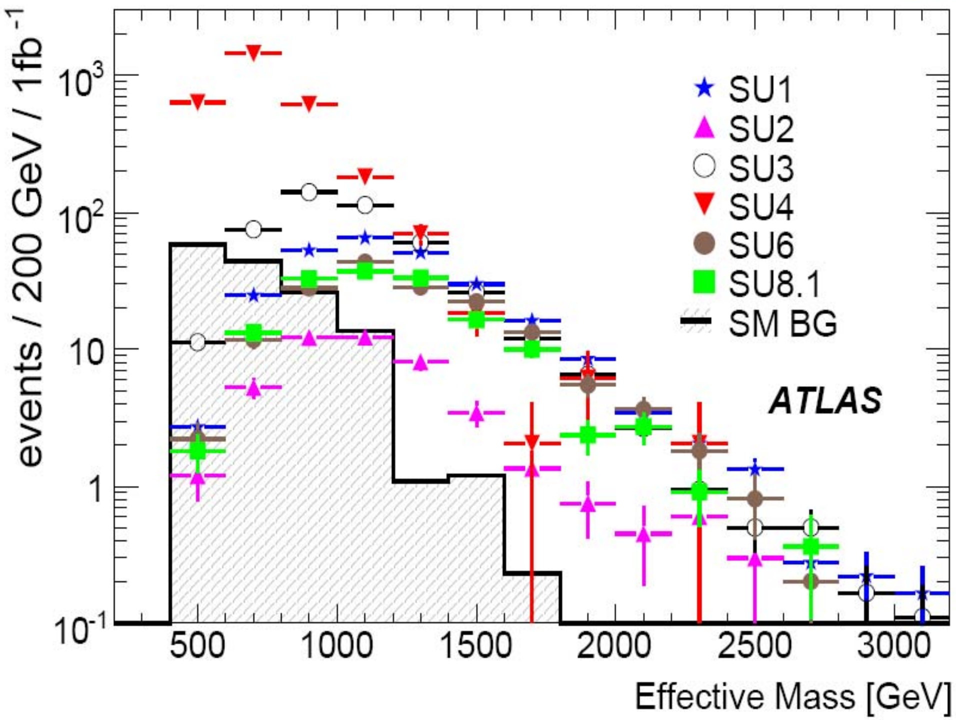
- sensitive to mismeasurements of QCD events!

Inclusive SUSY search (1 lepton channel)

1. Exactly one isolated lepton with $p_T > 20$ GeV satisfying the selection criteria described earlier.
2. No additional leptons with $p_T > 10$ GeV. This ensures no overlap with the 0-lepton, 2-lepton, and 3-lepton analyses.
3. At least four jets with $p_T > 50$ GeV at least one of which must have $p_T > 100$ GeV.
4. $E_T^{miss} > 100$ GeV and $E_T^{miss} > 0.2 M_{eff}$.
5. Transverse sphericity, $S_T > 0.2$.
6. Transverse mass, $M_T > 100$ GeV.

$$M_{eff} \equiv \sum_{i=1}^{4} p_T^{jet,i} + \sum_{i=1} p_T^{lep,i} + E_T^{miss}$$

- less sensitive to mis-measurements in QCD events



Discovery reach for SUSY

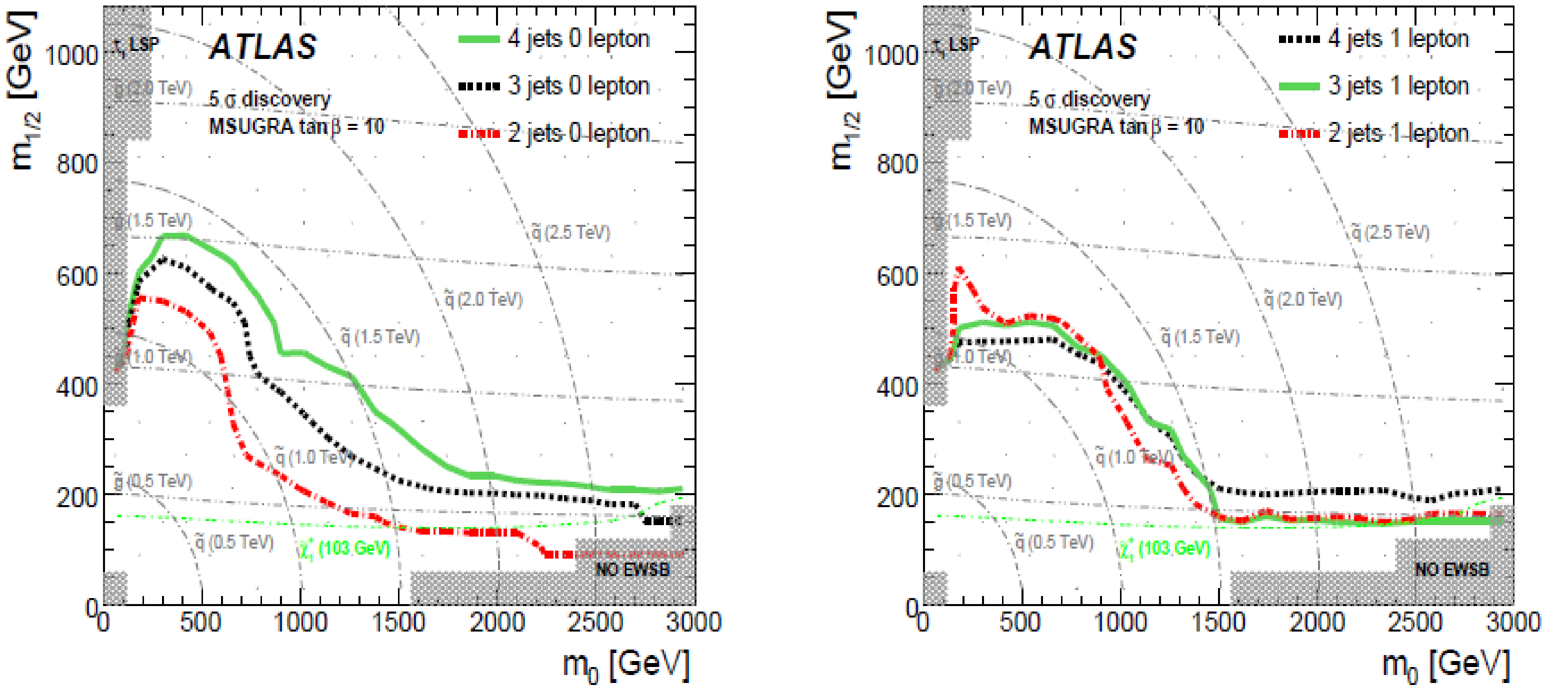
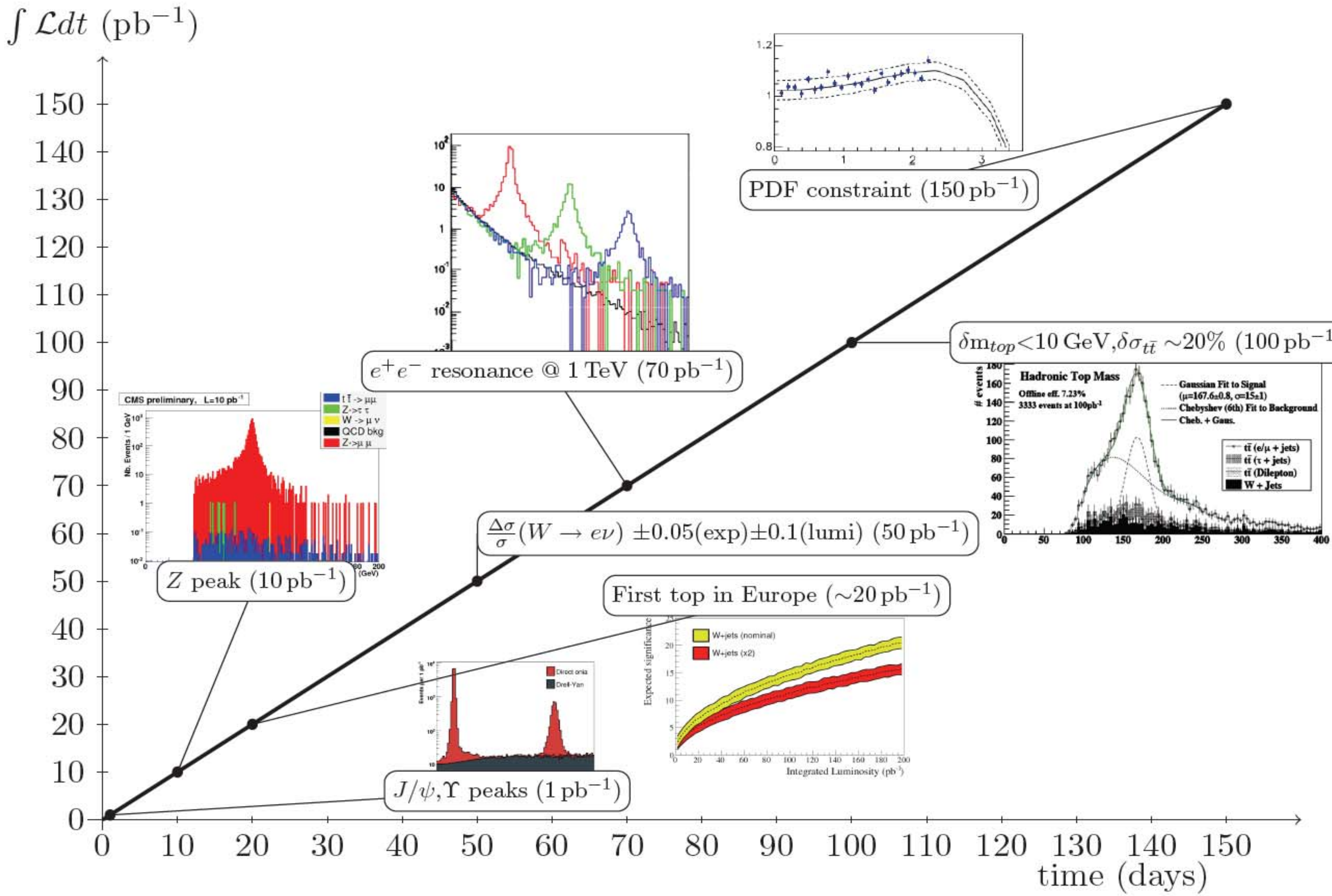


Figure 12: The 1 fb^{-1} 5σ reach contours for the 0-lepton and 1-lepton plus E_T^{miss} analyses with various jet requirements as a function of m_0 and $m_{1/2}$ for the $\tan\beta = 10$ mSUGRA scan. The horizontal and curved grey lines indicate the gluino and squark masses respectively in steps of 500 GeV.

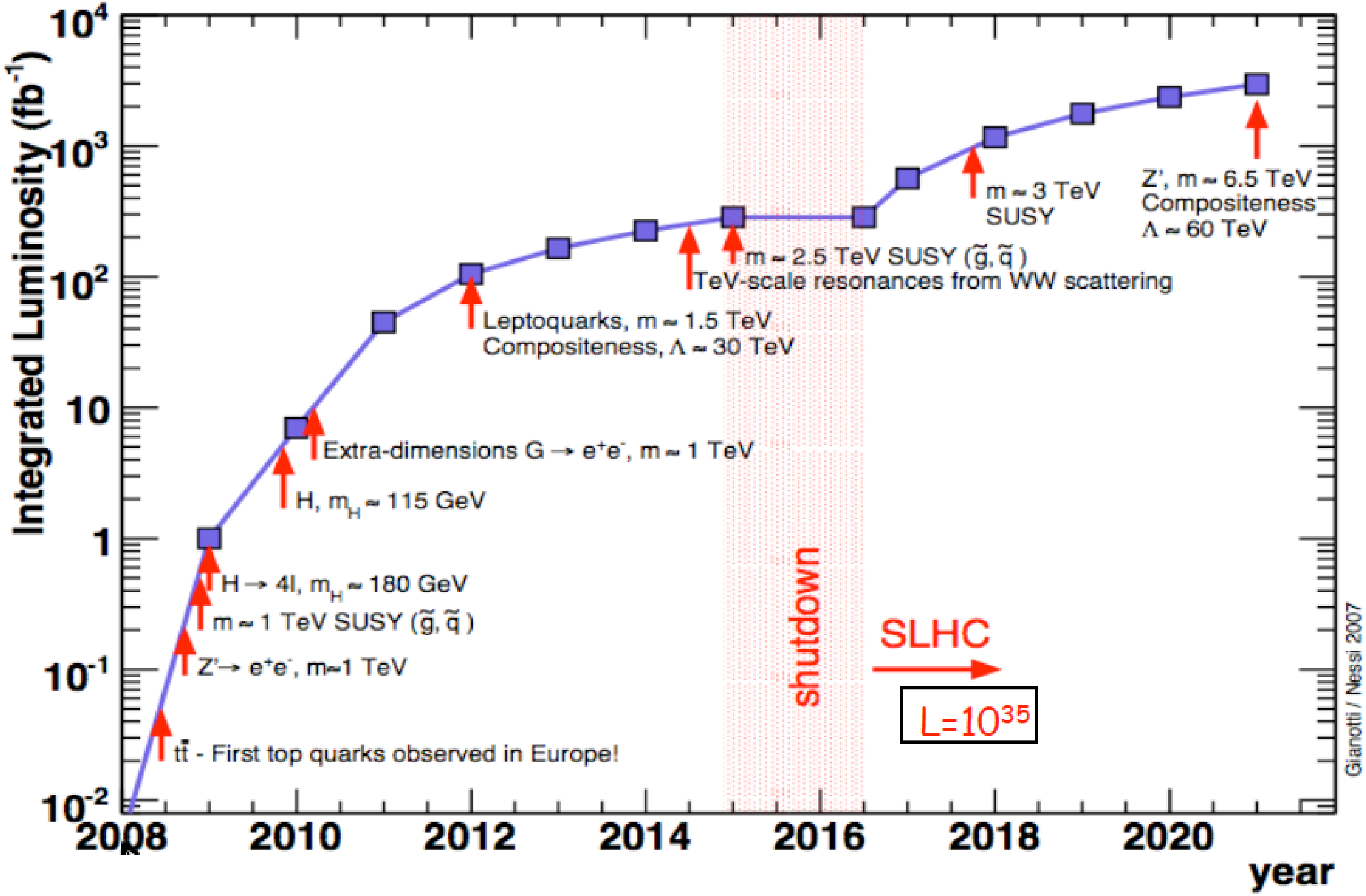
almost

done …

A vision towards initial results …



A long term (wild) guess (from 2007)



The very final slide

- hope that to be soon in a situation where we know that there are a lot of unknowns to be explored