Quarkonium and Higgs physics with ATLAS at LHC

Vakhtang Kartvelishvili
Lancaster University, United Kingdom

L'Aquila, Italy, 9-10 July 2014

Outline

Thanks for the invitation, glad to be here!

Request: give an overview of some measurements made by ATLAS collaboration at CERN, including various technical details of statistical methods used

11 am on Wed 9 July:

Quarkonium studies in ATLAS **-- selected topics covering recent measurements:**

- **Production of $\psi(2S)$ in its $J/\psi(\rightarrow\mu^+\mu^-)\pi^+\pi^-$ decay mode**
- **Production of χ_c in their radiative decay mode $J/\psi+\gamma$**
- **Discovery of the $\chi_b(3P)$**

11 am on Thu 10 July:

Higgs boson studies in ATLAS **–selected topics on its observation and properties**

- **Four-lepton decay mode ZZ^***
- **Di-photon decay mode**
- **Significance and mass determination**

Both topics are HUGE, each worth a series of lectures --
will not attempt to be comprehensive, just a few highlights in some detail...

About myself

A theorist by education (Tbilisi State University)

PhD in 1979 on heavy quark production and fragmentation (IHEP, Protvino)

Selected old publications --- those I am especially proud of:

- On the fragmentation function of heavy quarks... PLB78 (1978) 615
- Hadronic resonances from pion sum rules PLB287 (1992) 159
- SVD approach to data unfolding NIM A372 (1996) 469

In the 90s, slowly migrated towards experimental particle physics

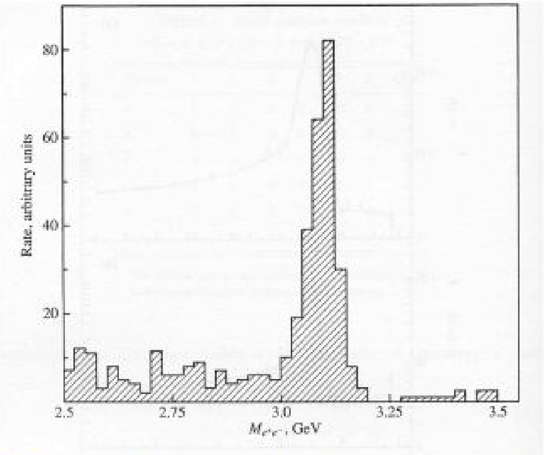
1995-2001: Member of OPAL collaboration at LEP (from Manchester Univ., UK)

2001- now: Member of ATLAS collaboration at LHC (from Lancaster Univ., UK)

Lead the Quarkonium physics subgroup in ATLAS since its inception in 2006

Lead or significantly contributed to the essence of ~30 publications in OPAL and ATLAS

The Beginning: J/ψ



$\Leftarrow$ **Discovery 1:** Ting's group

$$pN \to e^+e^-X$$

at $P_{\text{lab}} = 30$ GeV/c

[Aubert et al., PRL, 6/11/1974]

Found a peak in e^+e^- inv.mass at 3.1 GeV, called it J.

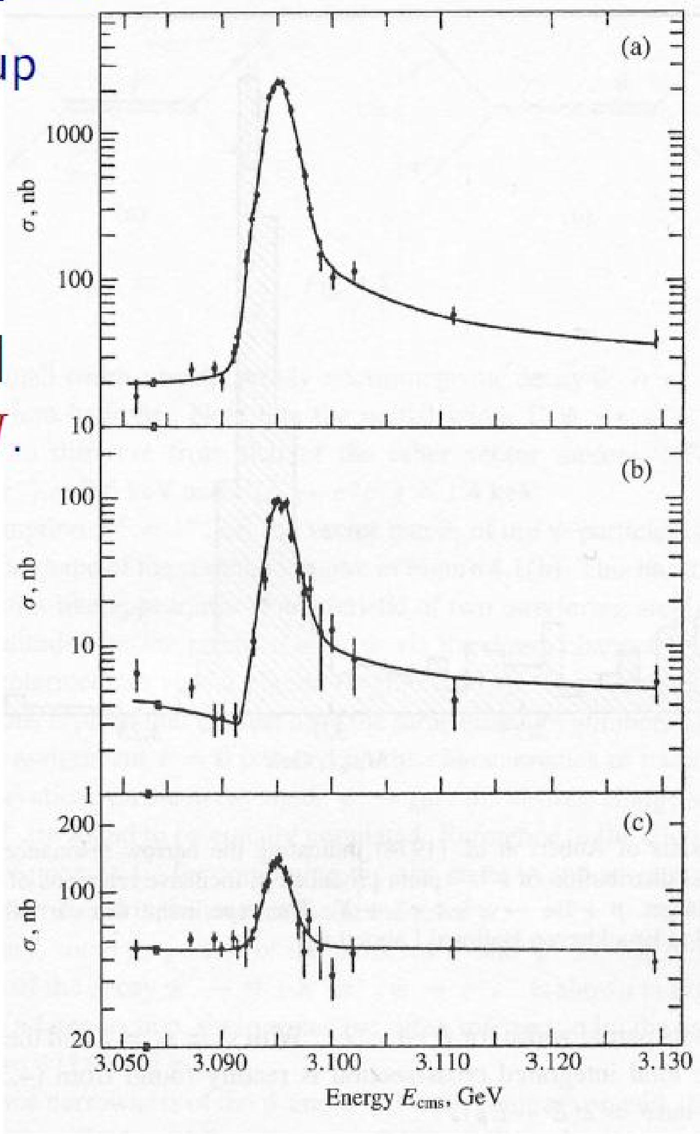
Discovery 2: Richter's group $\Rightarrow$

$$\begin{array}{llll} (a) & e^+e^- & \to & \text{hadrons} \\ (b) & e^+e^- & \to & \mu^+\mu^- \\ (c) & e^+e^- & \to & e^+e^- \end{array}$$

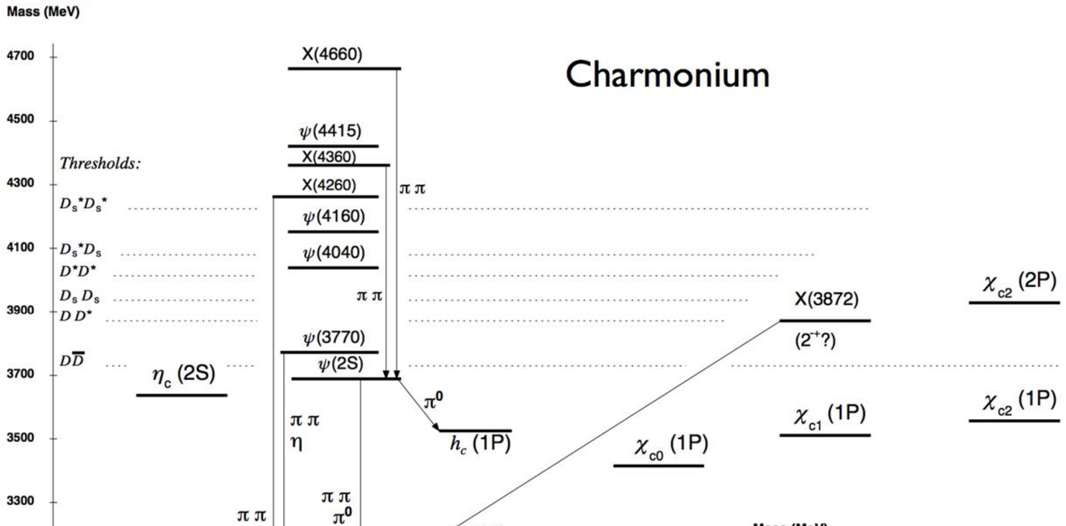
[Augustin et al., PRL, 7/11/1974]

Found a peak in all these three cross-sections,

at the c.m.s. energy 3.1 GeV; called it ψ.



The quarkonium family now

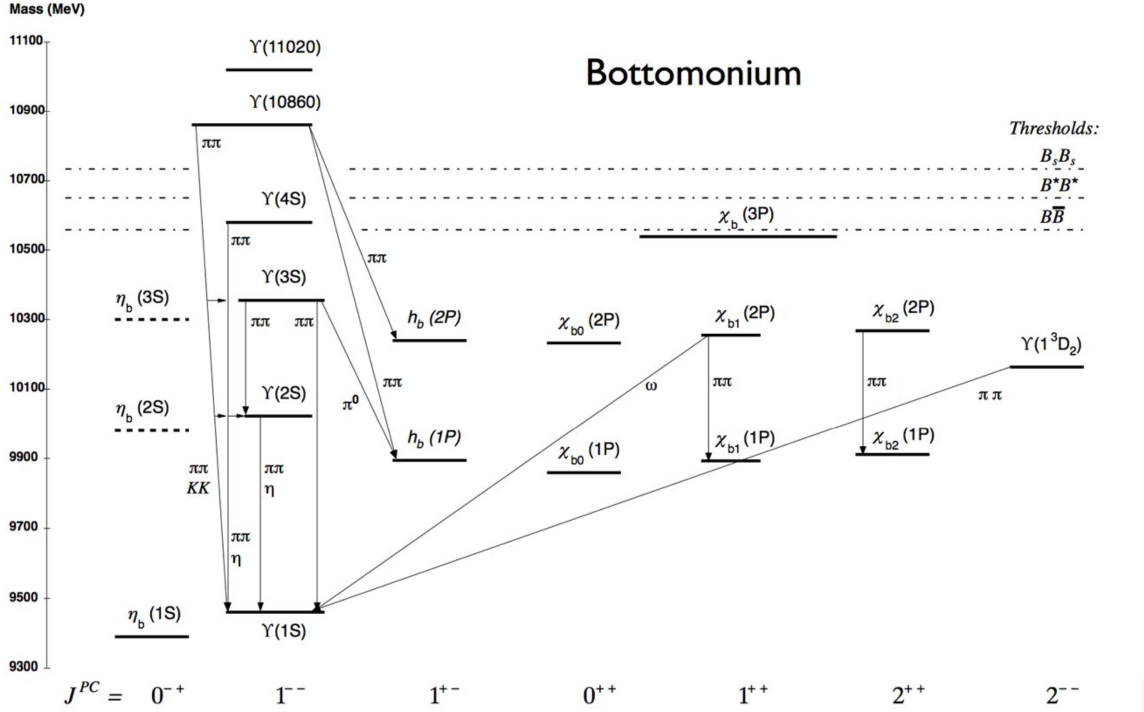


Quarkonium bound states produce a rich spectroscopy

Complex “ecosystem” – understanding quarkonium requires careful study of many transitions and decay channels

Several topics I cover today:

- $\psi(2S) \to J/\psi\ \pi^+\pi^-$
- $X_{c1,2} \to J/\psi\ \gamma$
- Discovery of $\chi_b(3P)$
- Search for X_b
  (if approved on time)



Quarkonium production

Seemingly a ‘simple’ system: quark and anti-quark of same flavour in a bound state

Two dominant approaches:

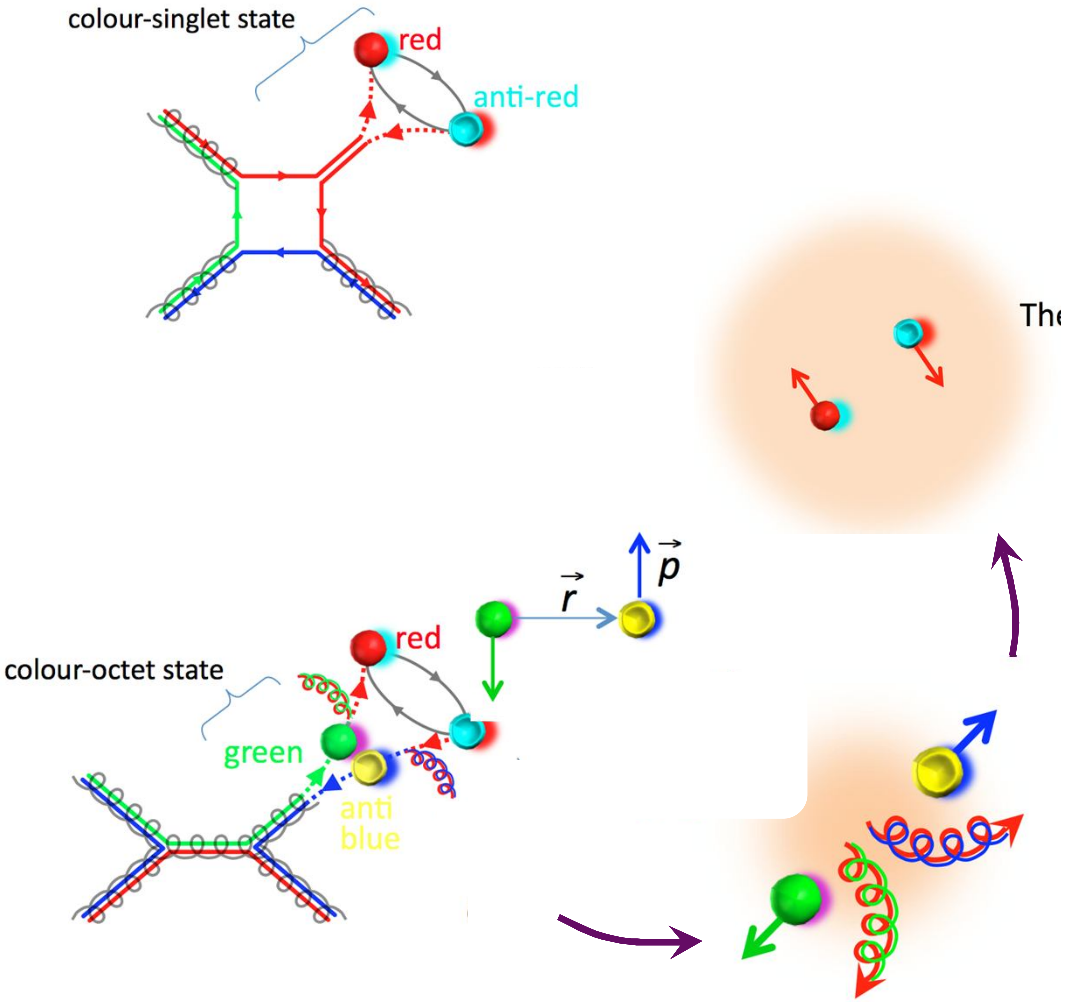
Colour Singlet Mechanism:

-- no free parameters
apart from usual QCD scales
-- C-even states enhanced

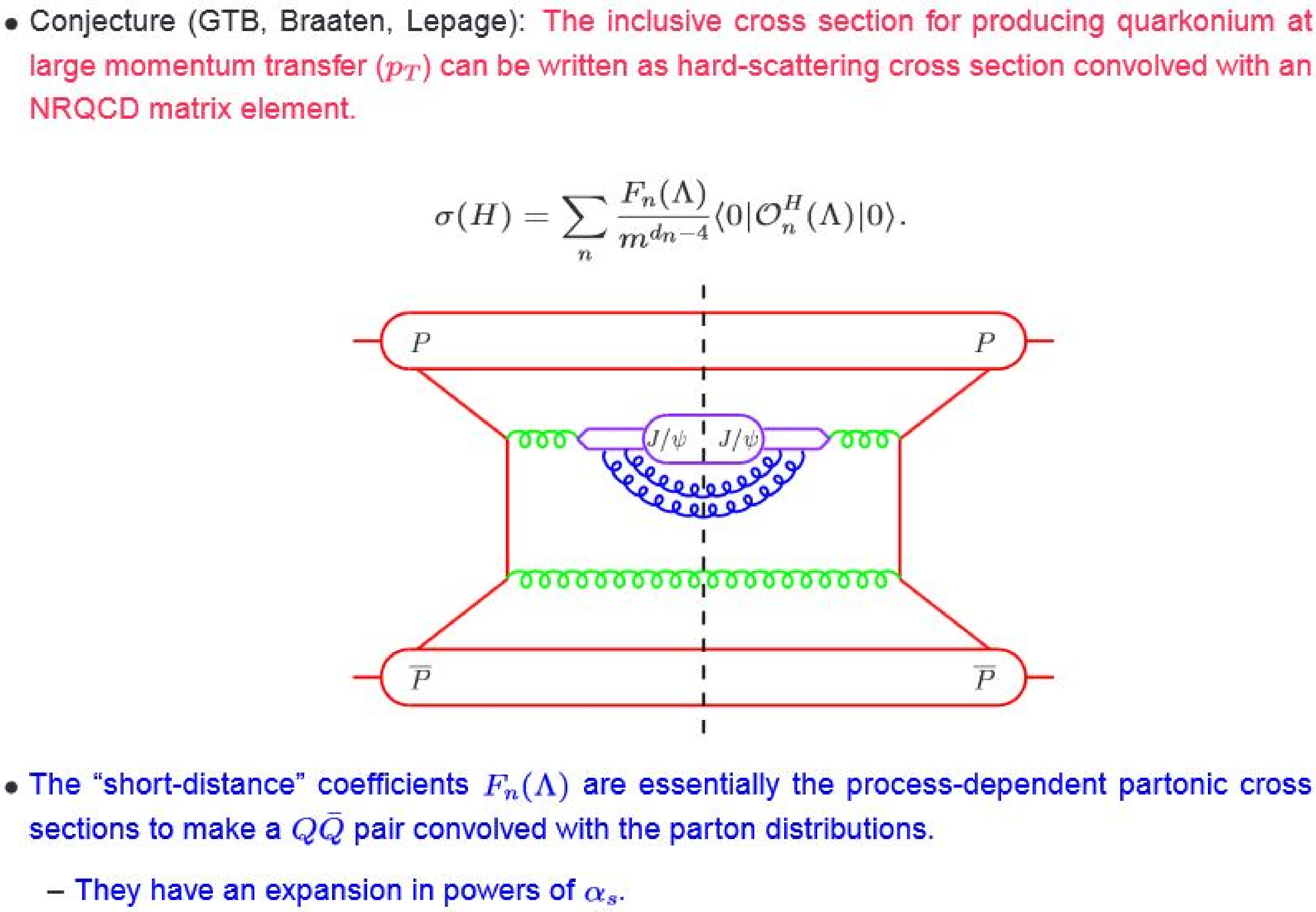
Non-Relativistic QCD (NRQCD)

‘Colour Octet’ calculations:

-- double-expansion in α_s and v
-- many free parameters (LDME)
-- extracted from data



A slide from G. Bodwin's talk:



- Conjecture (GTB, Braaten, Lepage): The inclusive cross section for producing quarkonium at large momentum transfer (p_T) can be written as hard-scattering cross section convolved with an NRQCD matrix element.

$$\sigma(H) = \sum_n \frac{F_n(\Lambda)}{m^{d_n-4}} \langle 0|\mathcal{O}_n^H(\Lambda)|0\rangle .$$

- The "short-distance" coefficients $F_n(\Lambda)$ are essentially the process-dependent partonic cross sections to make a $Q\bar{Q}$ pair convolved with the parton distributions.
  - They have an expansion in powers of α_s.

Quarkonium production studies

So why do we want to study quarkonia at LHC?

Plenty of reasons, in no particular order:

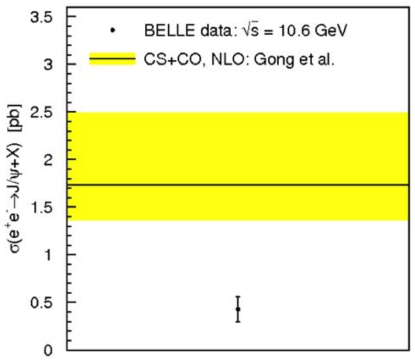
- **Tests of QCD calculations at the perturbative/non-perturbative boundary**
- **New inputs – new constraints on theories**
- **Exceptionally useful for detector performance studies**
- **Standard candles for Heavy Ion physics, B-hadron production**
- **Backgrounds to many SM/BSM processes**
- **Test double-parton scattering effects, parton density functions**
- **Search for rare decays and probes of new physics**
- **Because it’s interesting?**

Quarkonium production

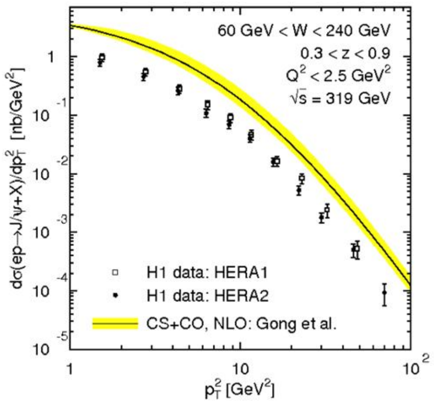
Ever since the November Revolution – discovery of J/ψ in 1974 – quarkonium provides valuable insights into QCD dynamics, as well as endless new puzzles

One would think that by now theory describes the experiment perfectly well, right?

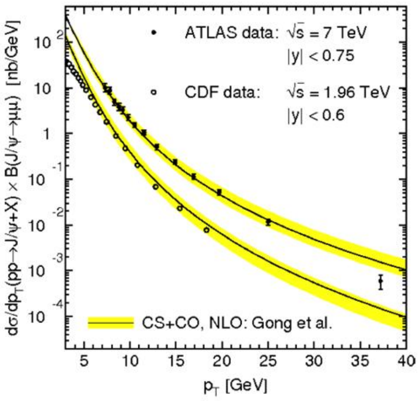
e+e- yields



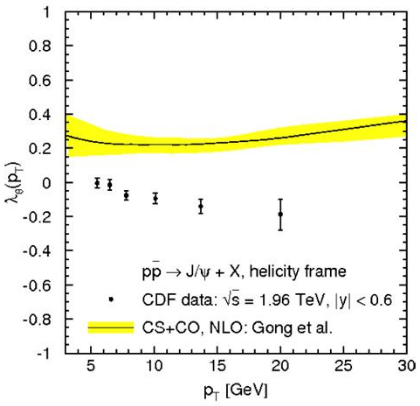
γ-p yields



pp yields



Polarisation



Clearly, more precision data on more observables are needed

Taken from slides by Mathias Butenschön, CHARM2013

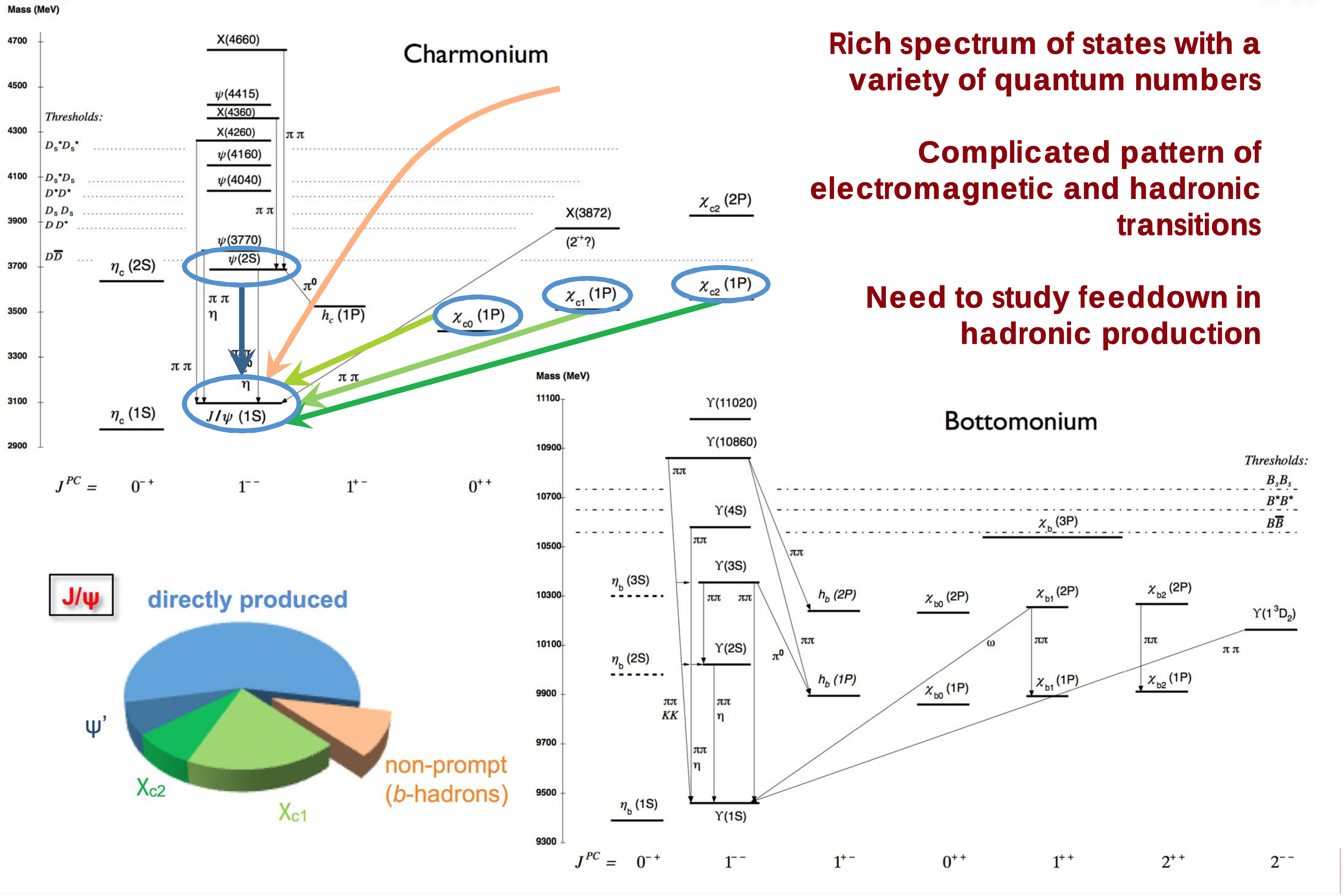
Trying to provide just that, but it takes a lot of time – so far, the huge sample collected in 2012 is virtually untapped for quarkonium studies, only published analyses using 2011 data so far…

Quarkonium spectroscopy and feeddown

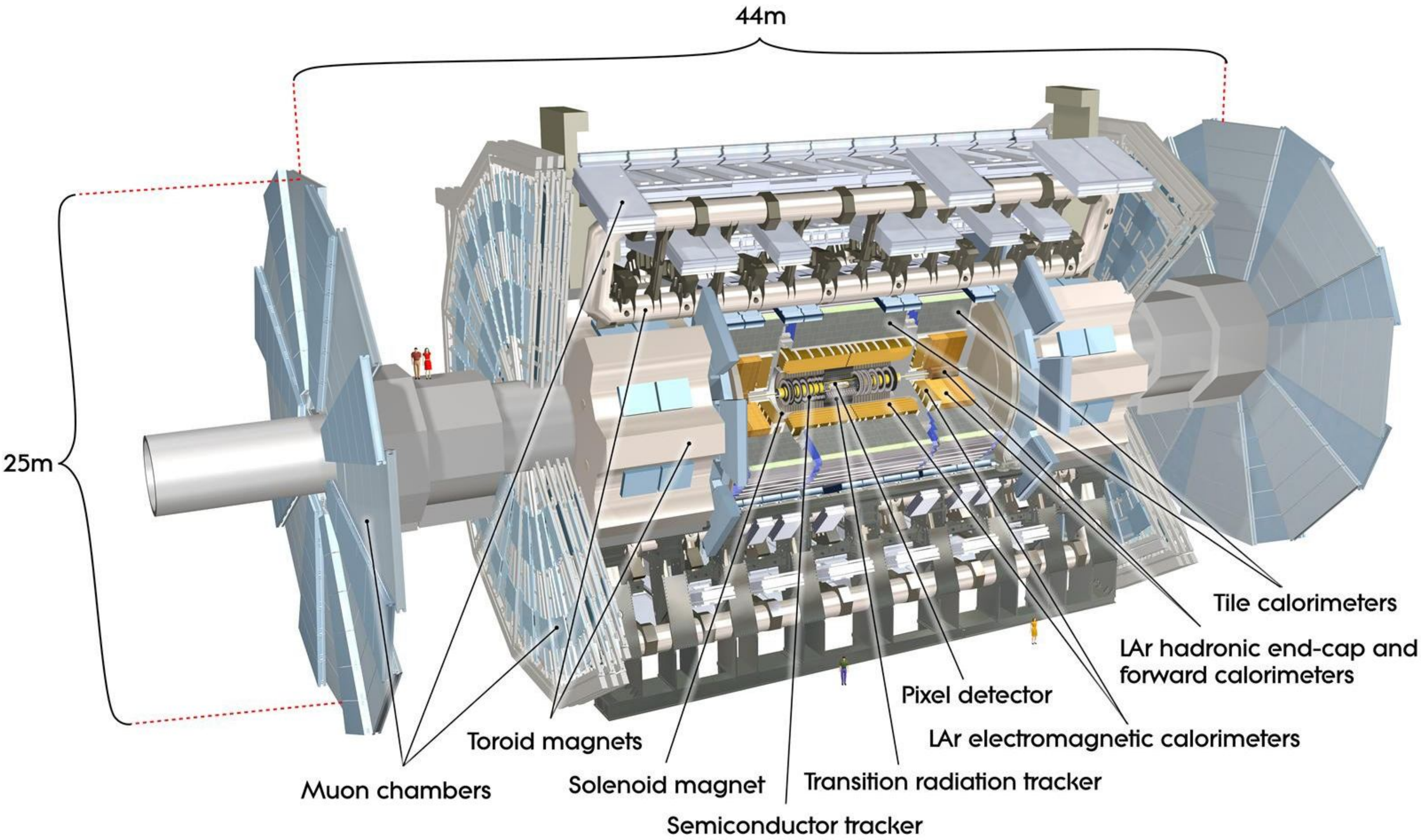
Rich spectrum of states with a variety of quantum numbers

Complicated pattern of electromagnetic and hadronic transitions

Need to study feeddown in hadronic production



The ATLAS detector at LHC



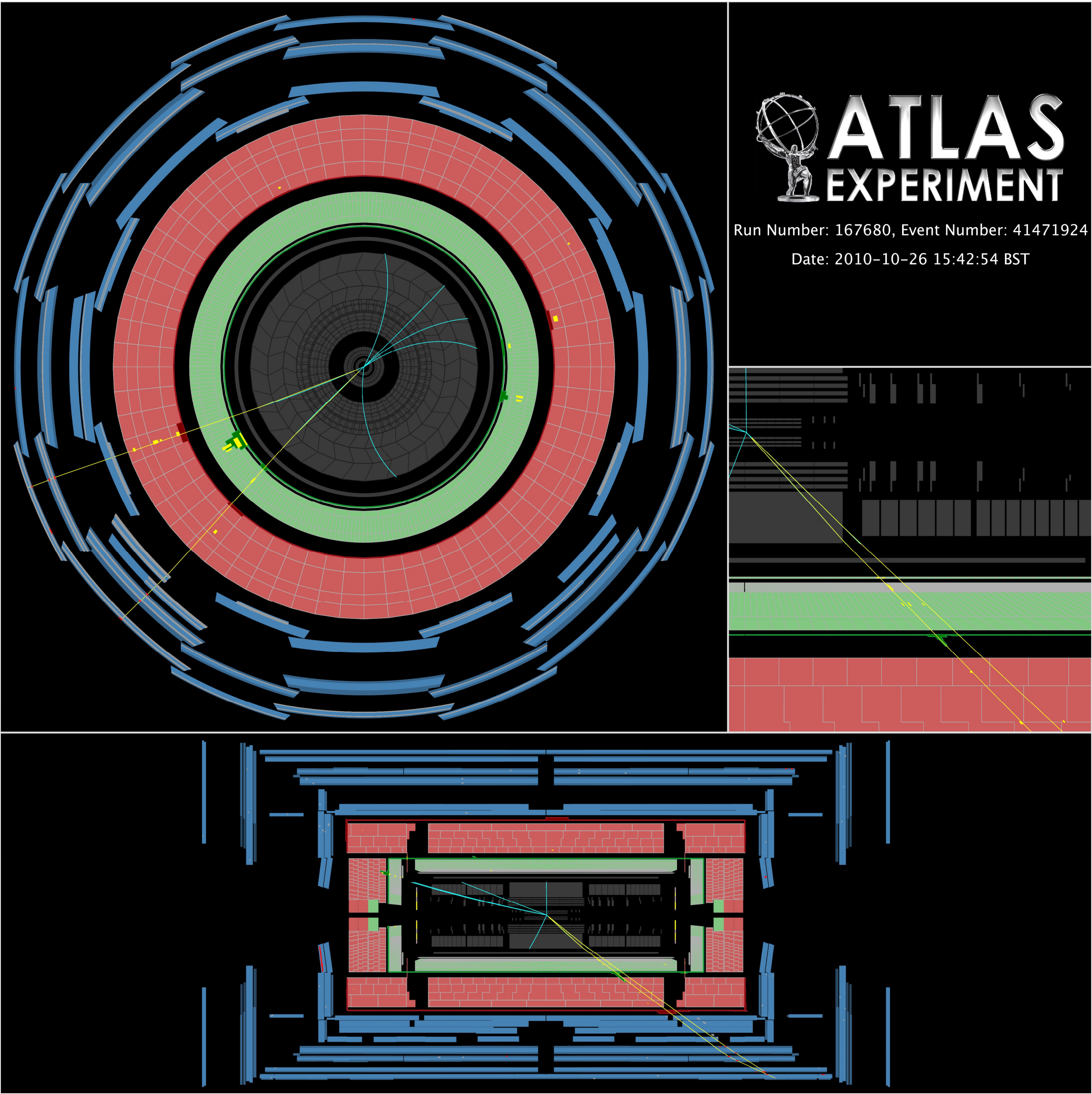
ATLAS event display: $\chi_c \rightarrow J/\psi(\mu^+\mu^-)\,\gamma$ candidate

Cross section views perpendicular and parallel to the beam line

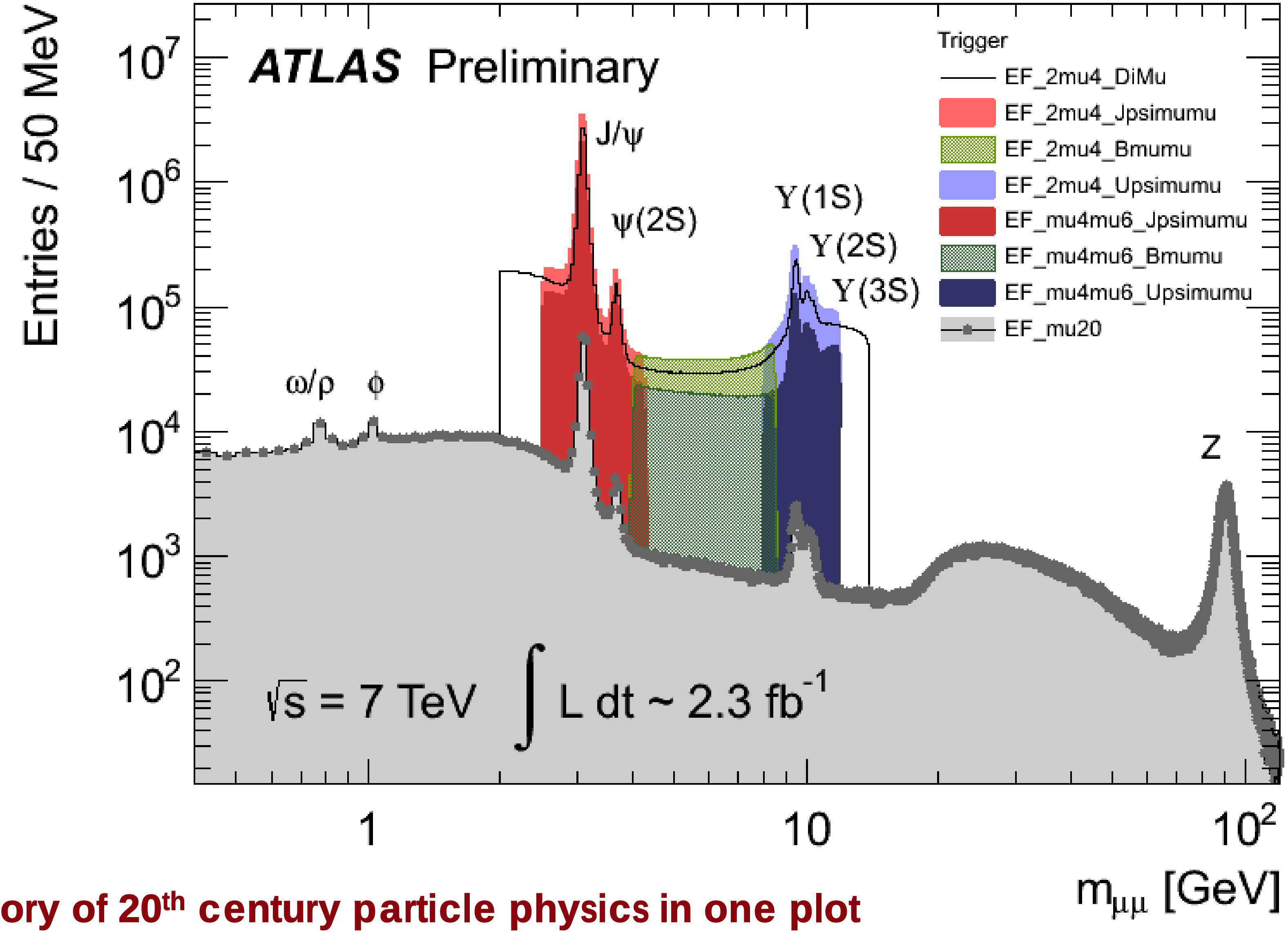
Two muon tracks spanning the Inner Detector and the Muon System

A photon tower in Eclectromagnetic Calorimeter

Invariant mass in the χ_c region



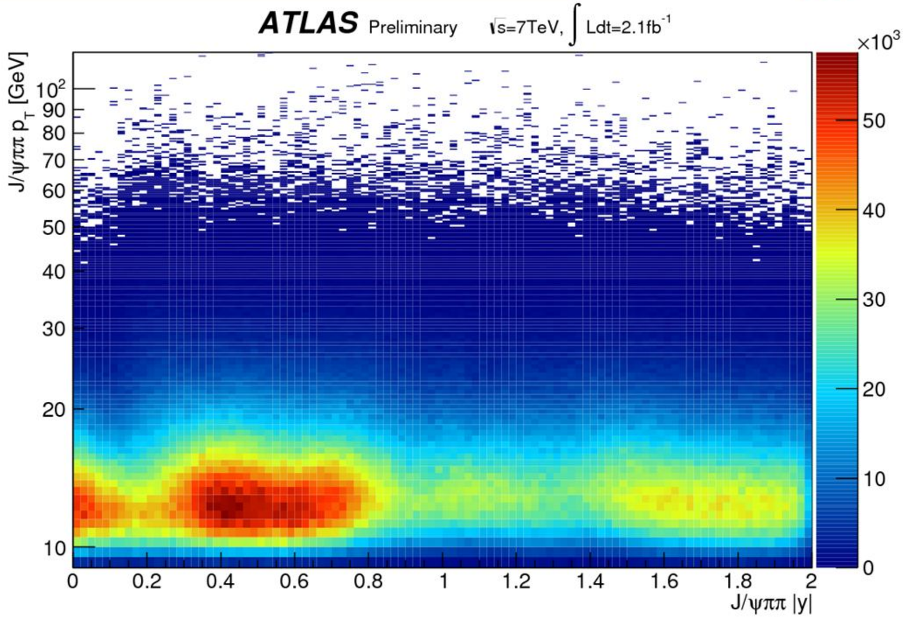
Muon and dimuon triggers in ATLAS



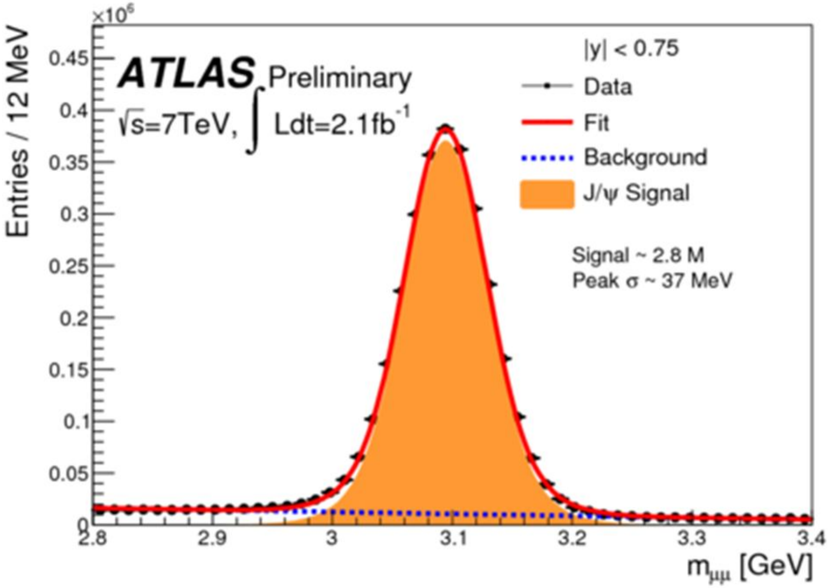
History of 20th century particle physics in one plot

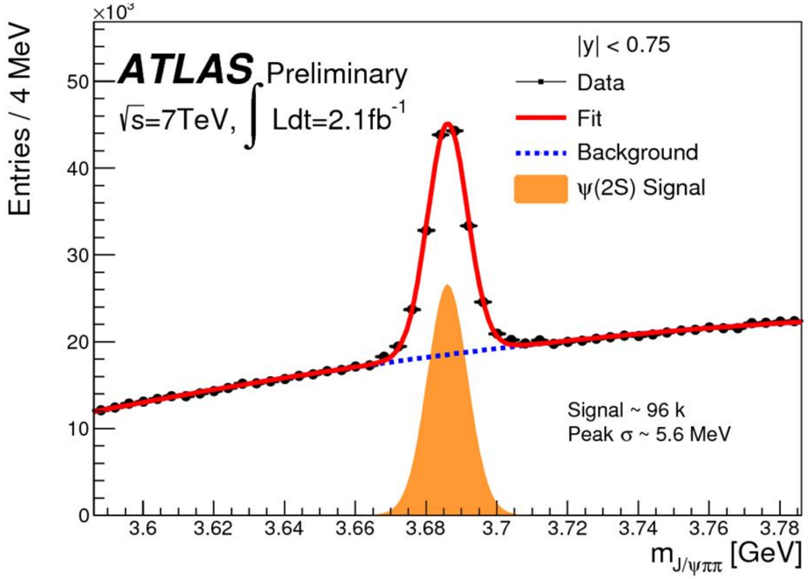
$J/\psi(\to\mu^+\mu^-)\pi^+\pi^-$ candidates

Scatter plot in p_T - rapidity space of $J/\psi(\to\mu^+\mu^-)\pi^+\pi^-$ candidates in the vicinity of $\psi(2S)$ mass



Resolution in $\mu^+\mu^-\pi^+\pi^-$ mass is greatly improved by a kinematic fit constraining $\mu^+\mu^-$ to J/ψ mass and all four tracks to the same vertex





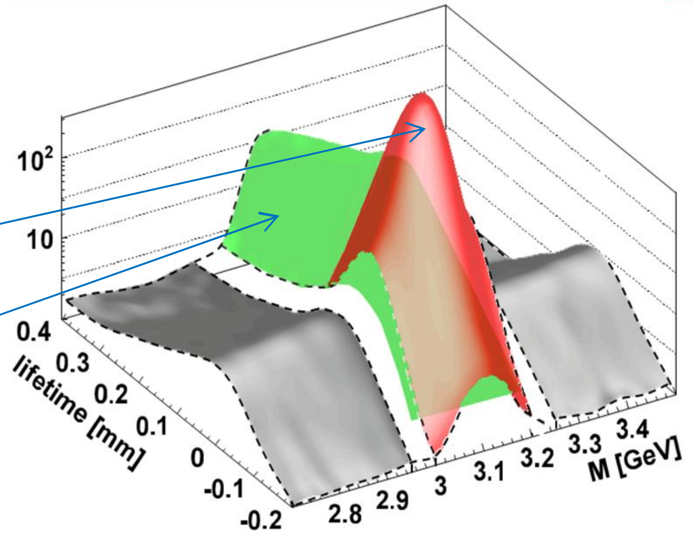
Prompt and Non-Prompt contributions

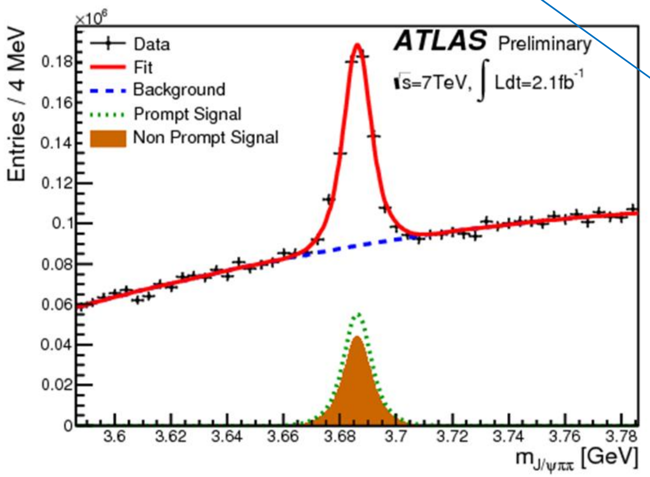
Use transverse distance (lifetime)

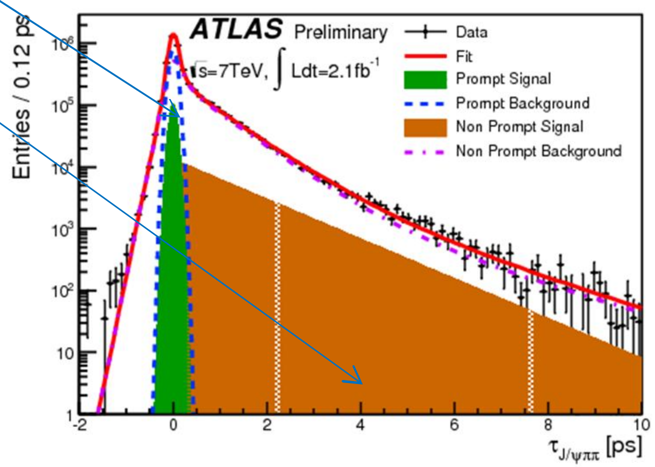
$$l_{J/\psi} = L_{xy} \cdot \frac{m_{J/\psi}}{p_T}$$

of the J/ψ vertex relative to the primary vertex to separate:

1. ***Prompt*** production -- from QCD (or short-lived) sources, with lifetimes consistent with resolution
2. ***Non-prompt*** production -- from long-lived sources such as b-hadron decays







2D mass vs lifetime unbinned maximum-likelihood fit is done to extract *Prompt* and *Non-prompt* yields in each p_T – rapidity bin

Two projections shown for a sample bin

Likelihood, PDF and fit quality

These days, more often than not, unbinned maximum-likelihood fit is used:

A probability density function PDF (of 1,2 or more variables) is defined, which contains as many parameters as needed

$$\mathrm{PDF}(m,\tau) = \sum_{i=1}^{5} \kappa_i f_i(m) \cdot h_i(\tau) \otimes G(\tau)$$

Say, in ψ(2S) → J/ψ(→$\mu^+\mu^-$)$\pi^+\pi^-$ analysis:
$\mu^+\mu^-\pi^+\pi^-$ mass m and "vertex lifetime" τ

i	Type	Source	$f_i(m)$	$h_i(\tau)$
1	S	P	$\omega G_1(m) + (1-\omega) G_2(m)$	$\delta(\tau)$
2	S	NP	$\omega G_1(m) + (1-\omega) G_2(m)$	$E_1(\tau)$
3	B	P	$C_1(m)$	$\delta(\tau)$
4	B	NP	$C_2(m)$	$\rho E_2(\tau) + (1-\rho) E_3(\tau)$
5	B	NP	$C_3(m)$	$E_4(\lvert\tau\rvert)$

a combination of Gaussian G, exponential E and polynomial C

for Prompt and Non-prompt signal (S) and background (B)

Likelihood L is ***the product of the PDF for all selected $\mu^+\mu^-\pi^+\pi$ candidates***
(each with its observed values of m and τ plugged in)

For best fit, maximize Likelihood L (or minimize -2 log L) with respect to fit parameters

X^2 roughly equivalent to -2 log L, one-sigma error contour corresponds to $(-2 \log L)_{min}+1$
Fit quality hard to establish: make binned projections of the fits with their pull distributions

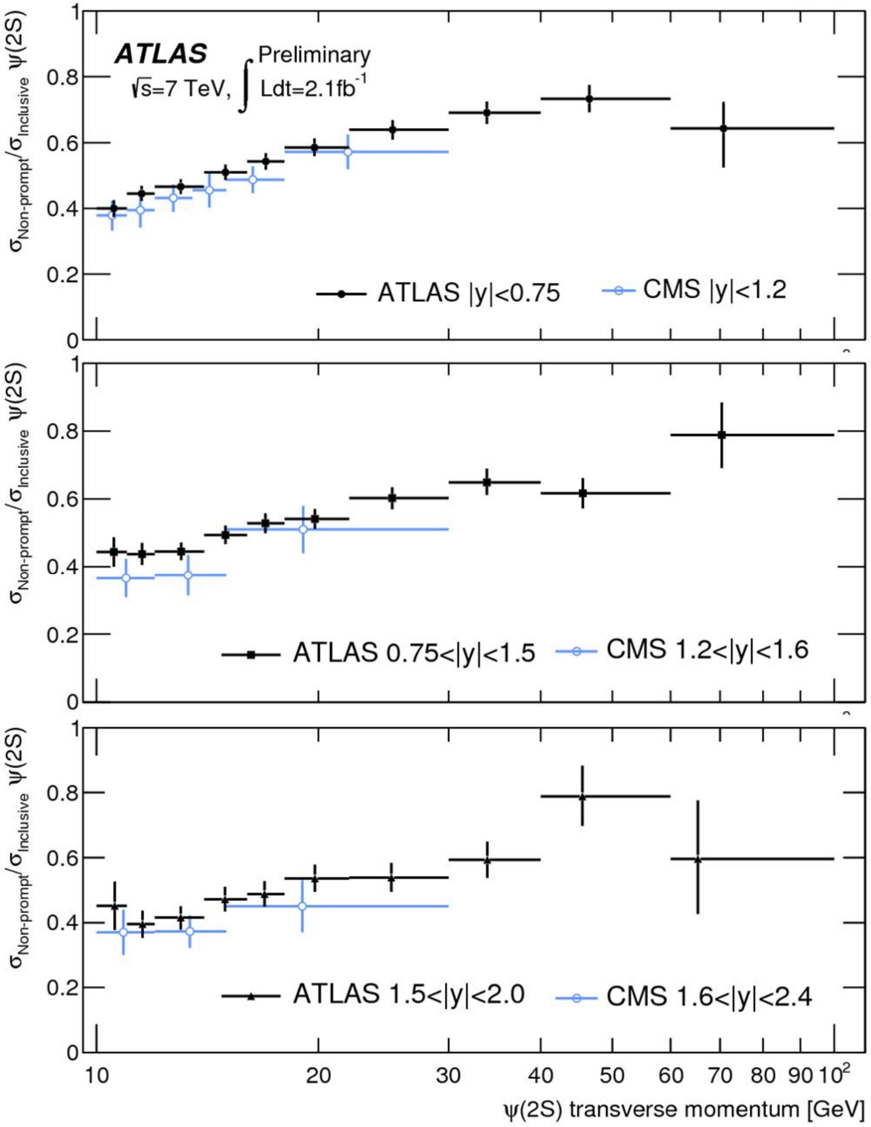
Non-prompt fraction of ψ(2S)

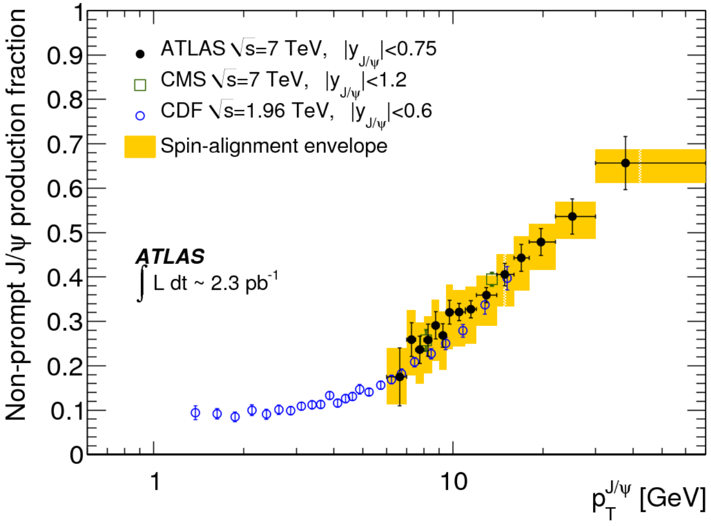
One of the fit parameters is the fraction of “long-lived” ψ(2S)

I.e. the fraction of ψ(2S) produced from b-hadron decays

Can be measured with good precision as many systematic effects largely cancel out

Fraction increases with transverse momentum, but to a lesser extent than J/ψ



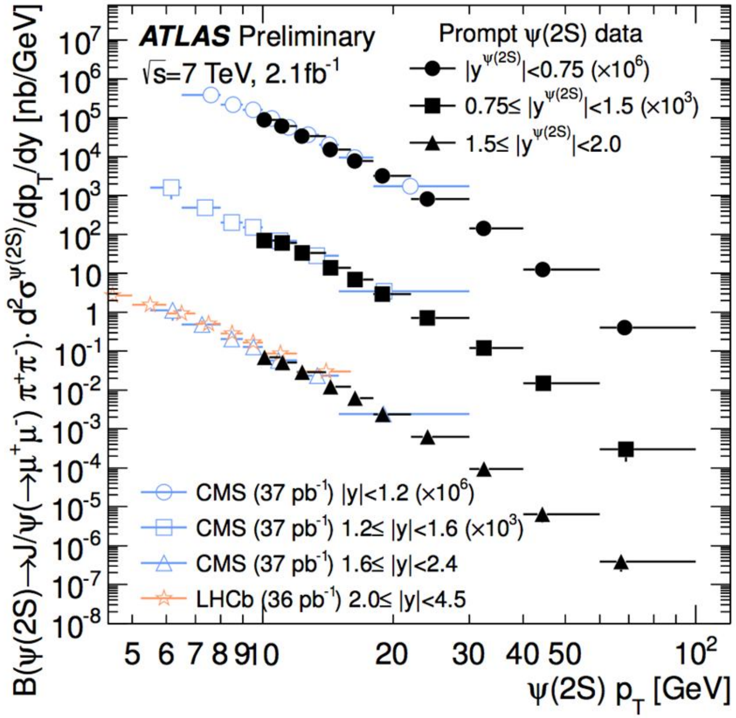


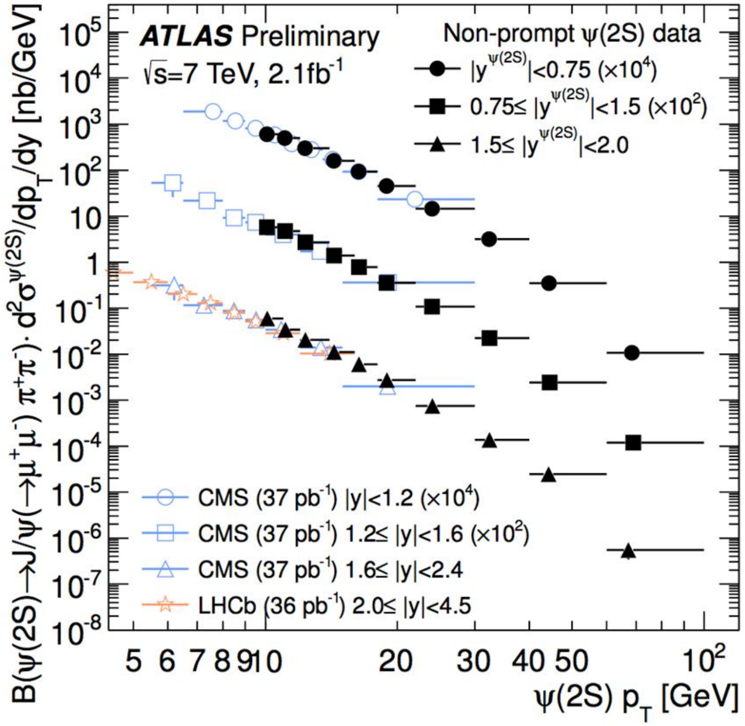
$\psi(2S) \to J/\psi(\to\mu^+\mu^-)\pi^+\pi^-$ production

Measurement with 2.1 fb^{-1} of pp data at 7 TeV

Muon p_T > 4 GeV, pion candidate tracks p_T> 0.5 GeV

- **Use unbinned mass-lifetime maximum likelihood fit to separate prompt and non-prompt production sources**
- **Baseline channel for study of X(3872), Extend p_T range probed to 100 GeV**

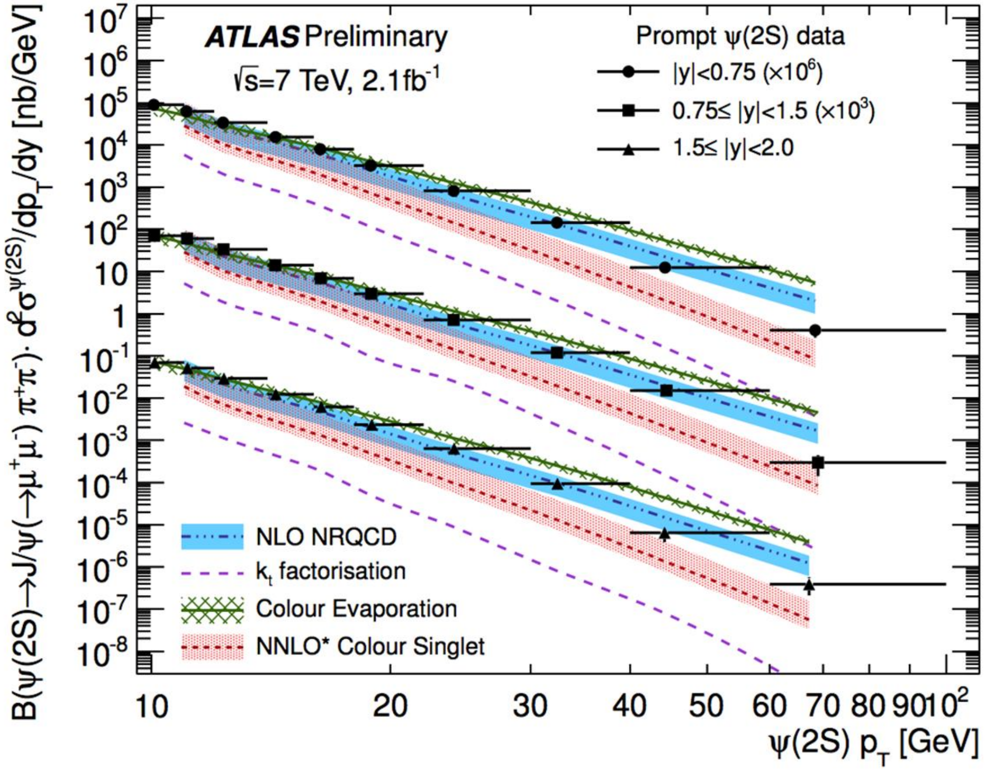


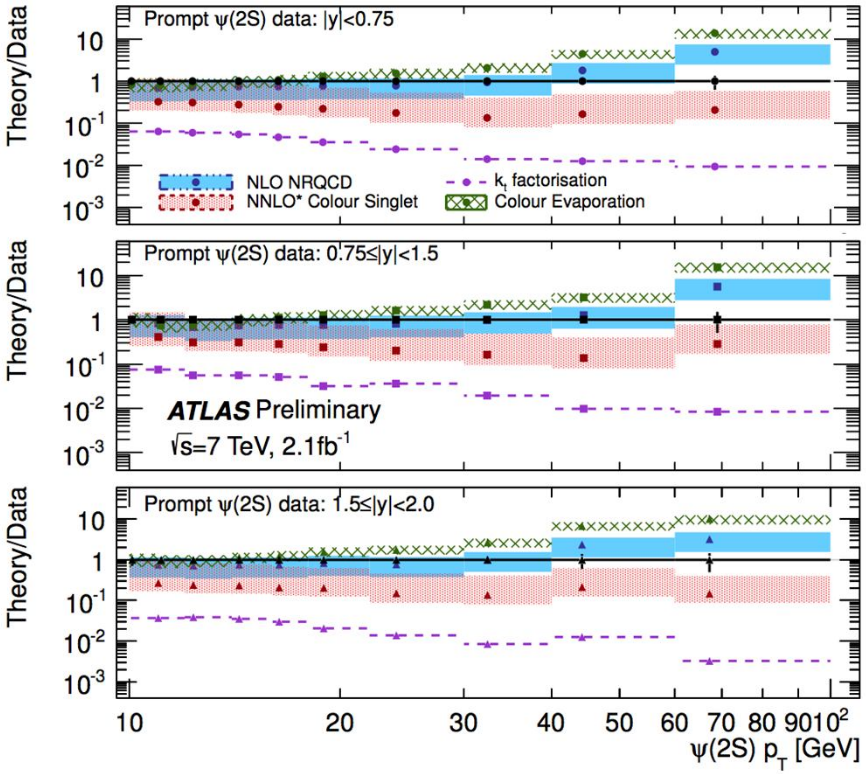


Prompt ψ(2S) → J/ψ π π production

High precision wide reach prompt production cross-section in ψ(2S)→J/ψππ.

- **Agreement with NRQCD, possible slight overestimate at highest p_T**
- **k_T-factorisation model does not describe data well**
- **Colour Singlet NNLO* predictions undershoot at highest scales**

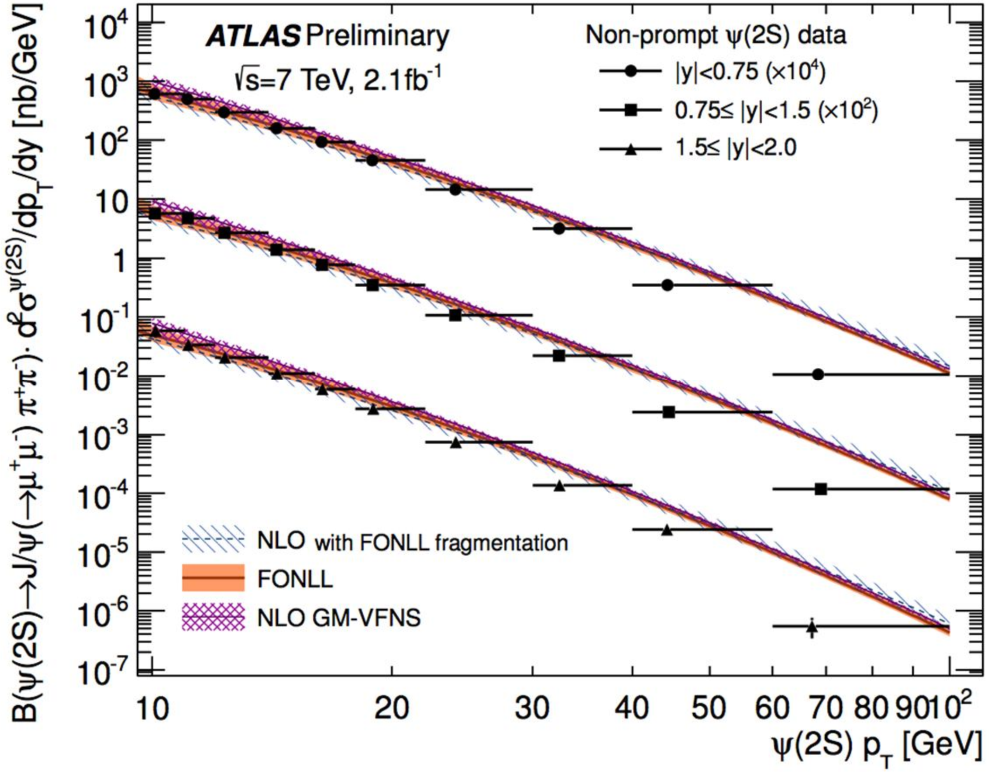


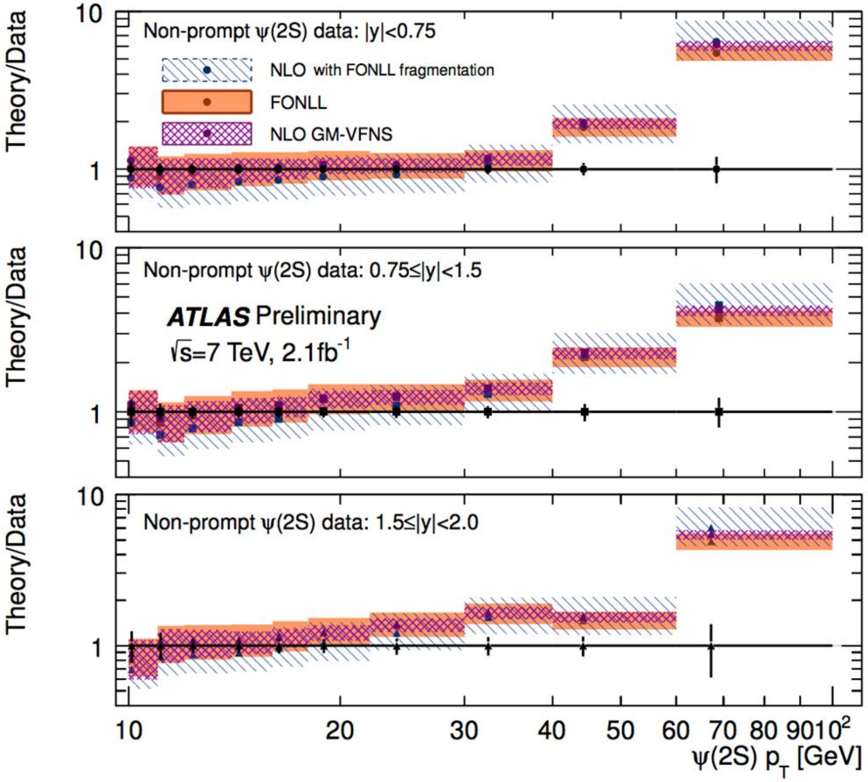


Non-prompt ψ(2S) → J/ψ π π production

Decent agreement with NLO and FONLL predictions at low p_T, but some deviations observed in both at larger p_T (more prevalent for NLO, without resummation)

- **Highest p_T sensitive to minor details. Possible modelling issues in high p_T B-meson decays – but let’s wait until final publication from ATLAS.**





$\chi_c \rightarrow J/\psi(\rightarrow\mu\mu)\gamma$

P-wave charmonium production theoretically and experimentally tricky to handle

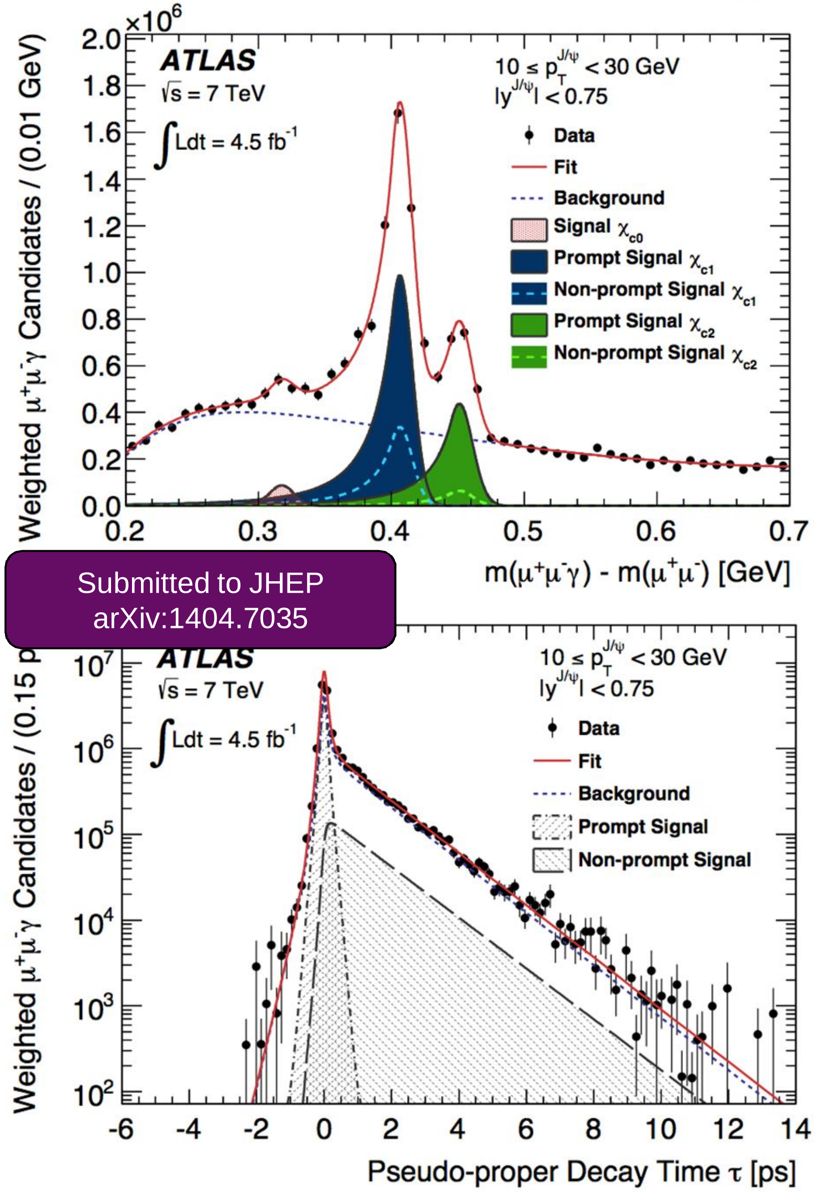
Important to understand this production channel to get a complete picture of quarkonium production.

Experimentally challenging:

- **low p_T muons**
- **precise reconstruction of soft (p_T>1 GeV) photon through conversions**
  - **– low efficiencies**

Perform unbinned maximum likelihood fit on acceptance- and efficiency-corrected mass and lifetime.

Extract prompt and non-prompt production of various χ_c states

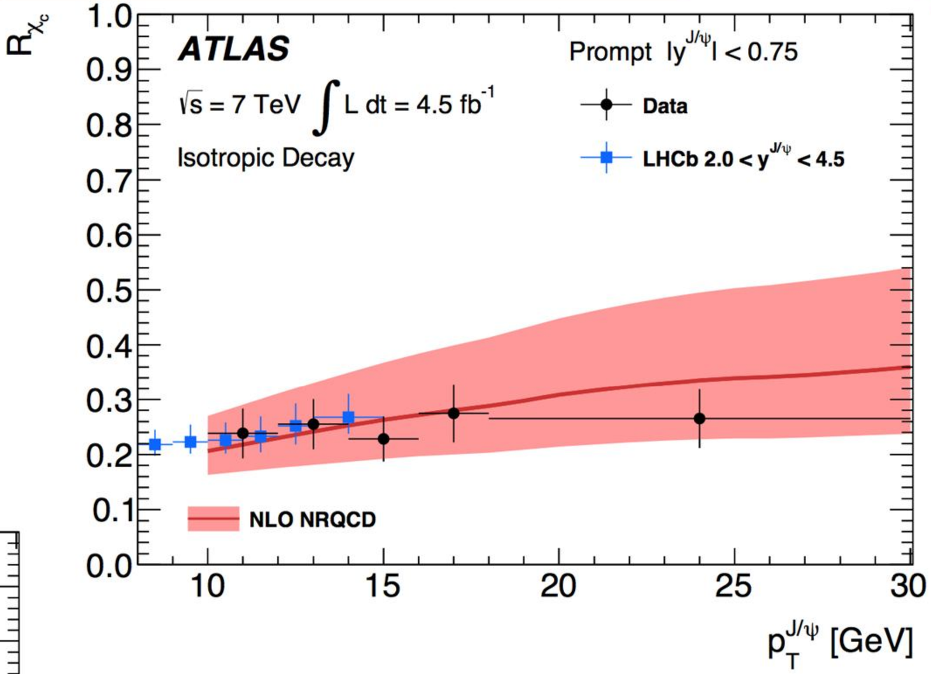


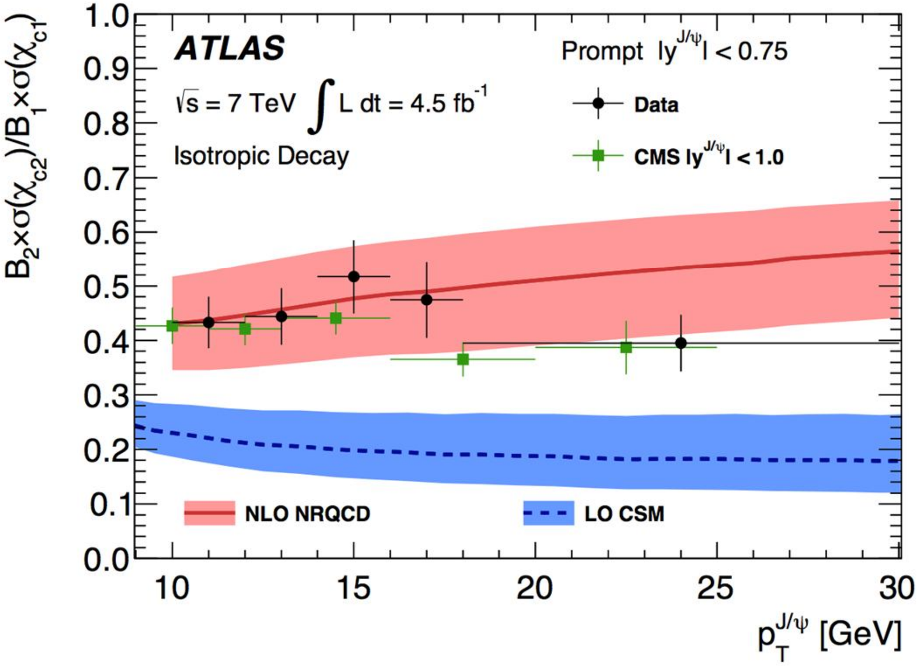
Submitted to JHEP
arXiv:1404.7035

Prompt $\chi_c \to J/\psi\gamma$ and $\sigma(\chi_{c2})/\sigma(\chi_{c1})$ ratio

Fraction of prompt J/ψ produced in χ_c feed-down (right)→

Data show that between 20–30% of prompt J/ψ are produced in χ_c decays



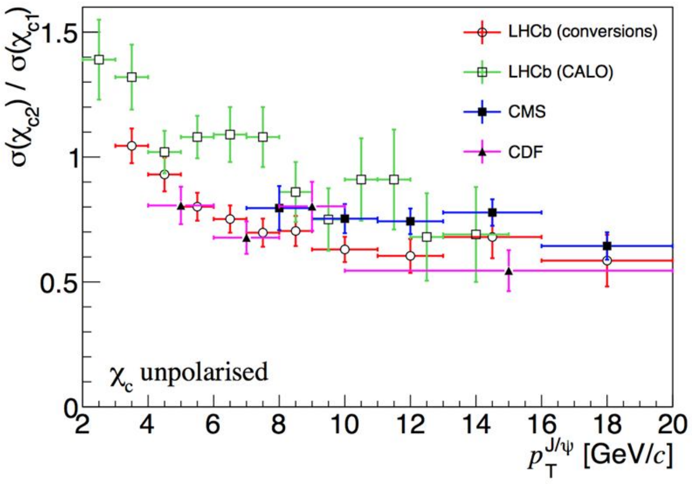


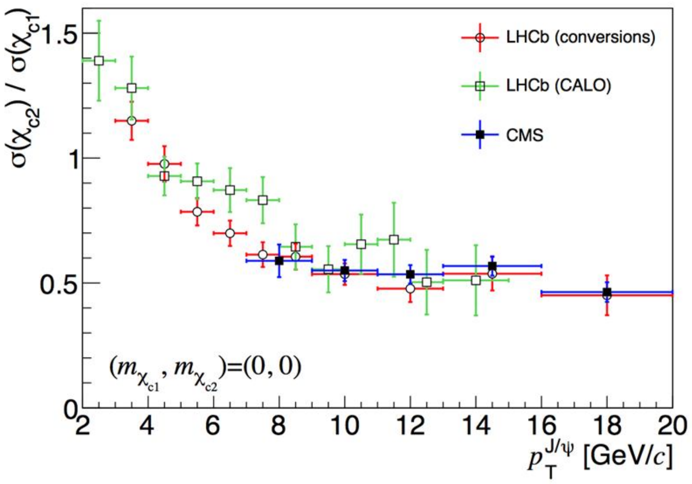
Prompt χ_c cross-section ratio ← (left)

Data show more χ_{c1} than χ_{c2}

Ratio sensitive to possible presence of colour octet contributions in NRQCD

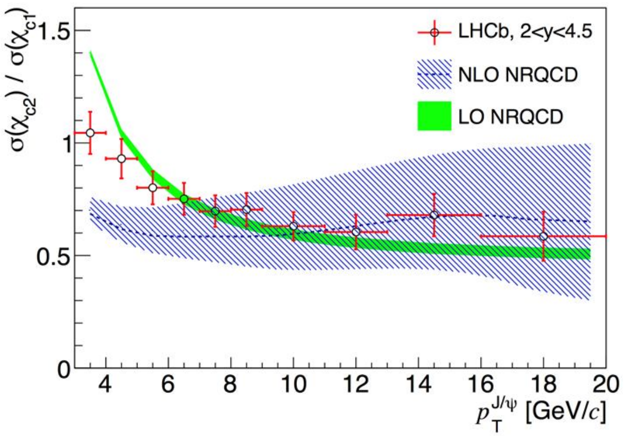
Comparison of relative χ_c rates

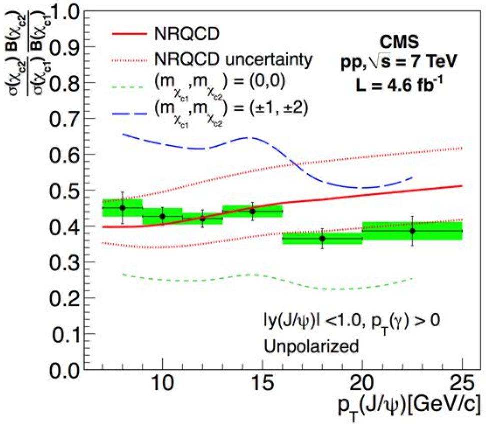


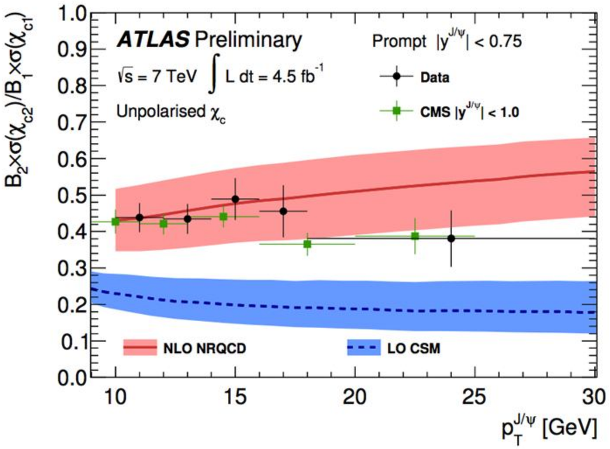


Data reasonably consistent with each other, NRQCD yields mixed results

Naively χ_{c2} should be enhanced at low p_T, as seen in LHCb data



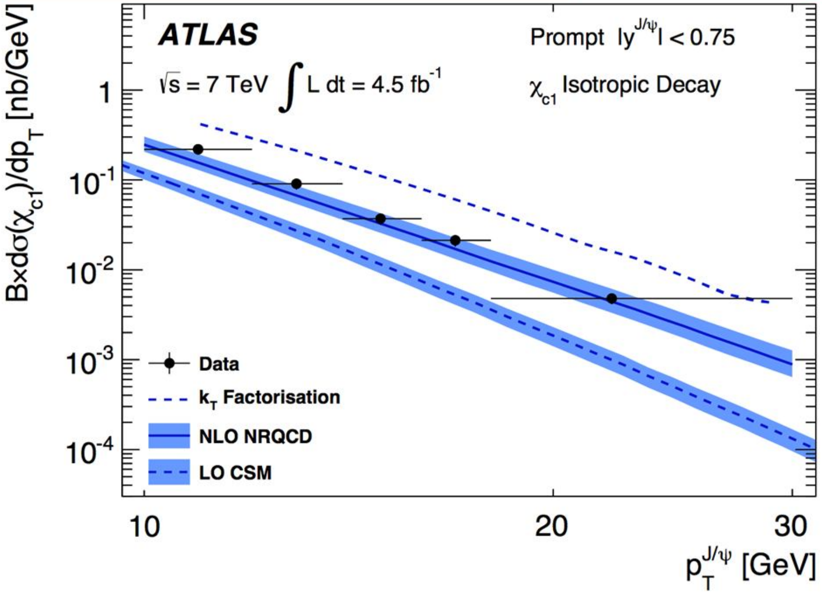


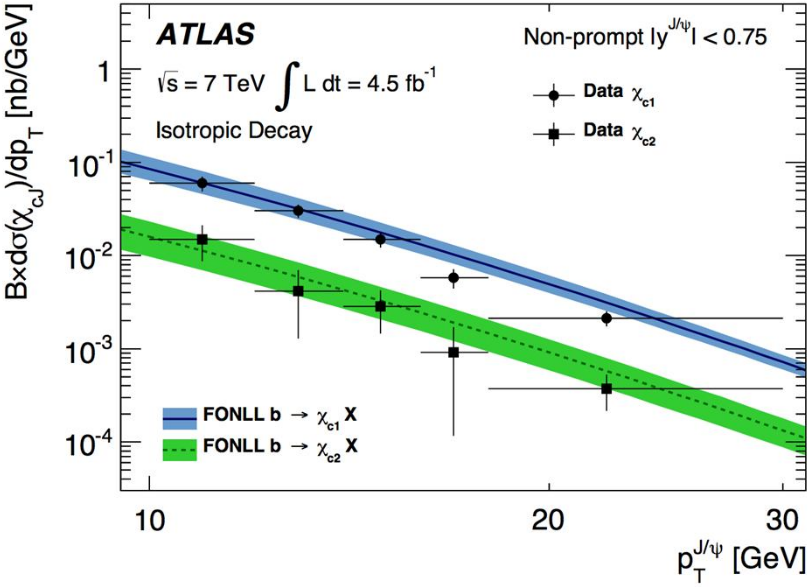


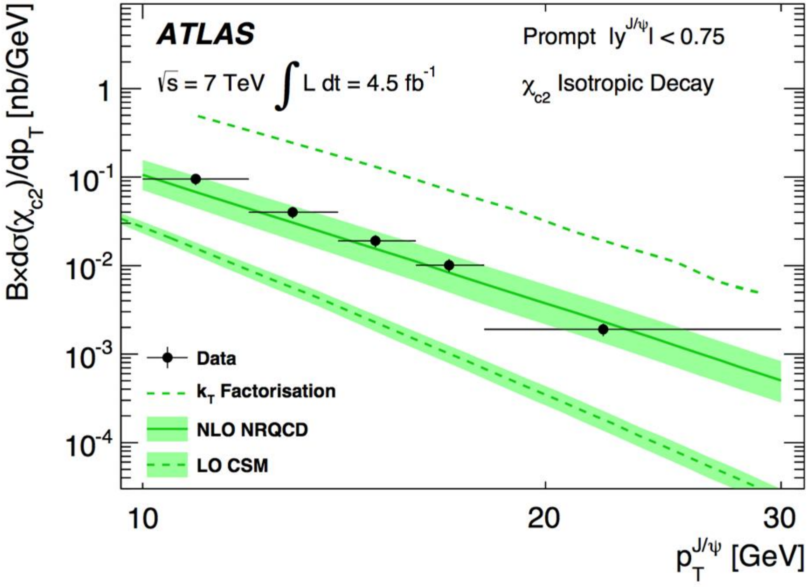
Absolute χ_c production rates

First absolute prompt (right) and non-prompt (below) χ_{c1} and χ_{c2} differential cross sections, compared to predictions

NRQCD / FONLL able to describe the data, but some hints at high-p_T excess in the latter?





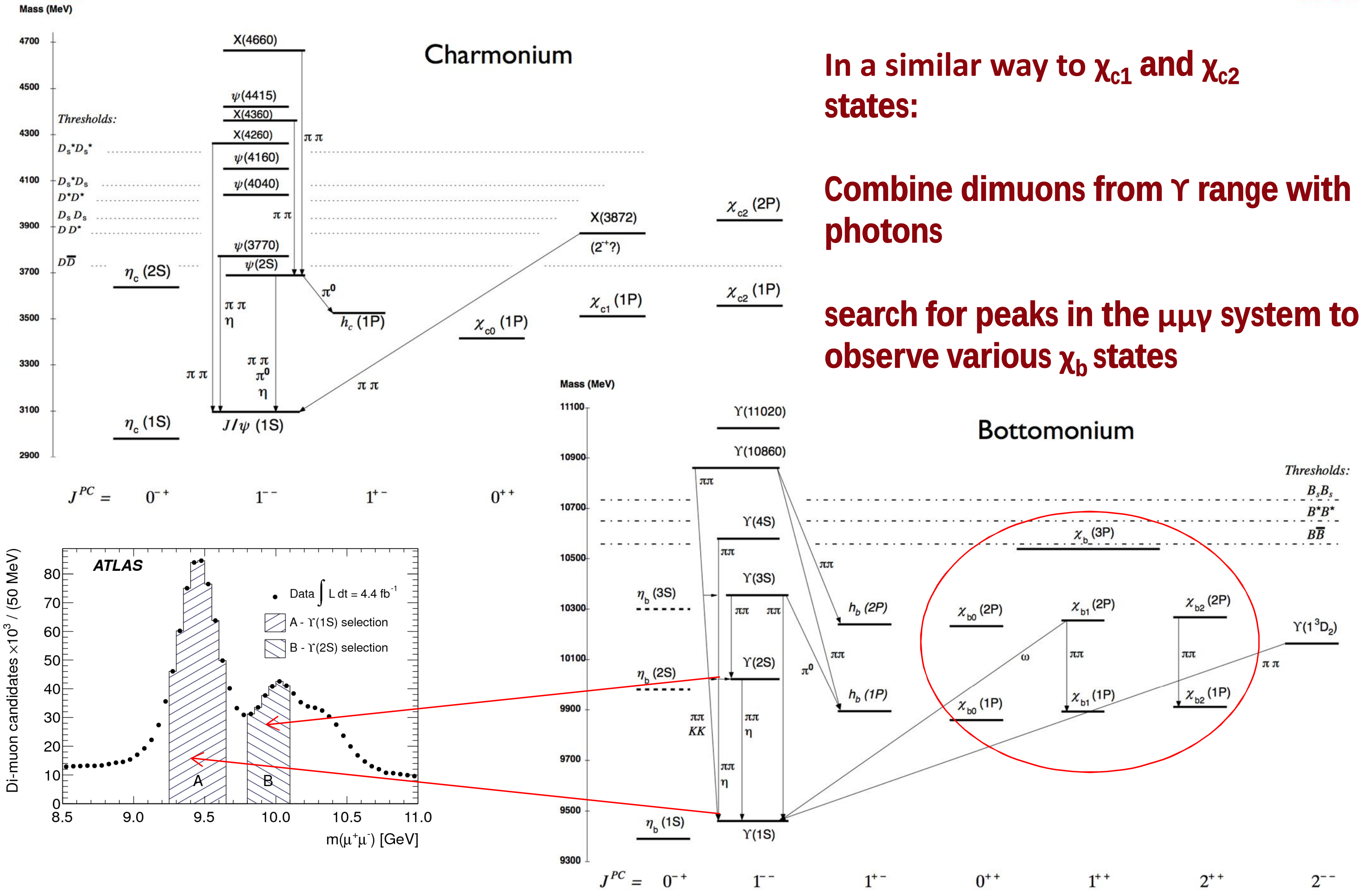


Observation of the χ_b states

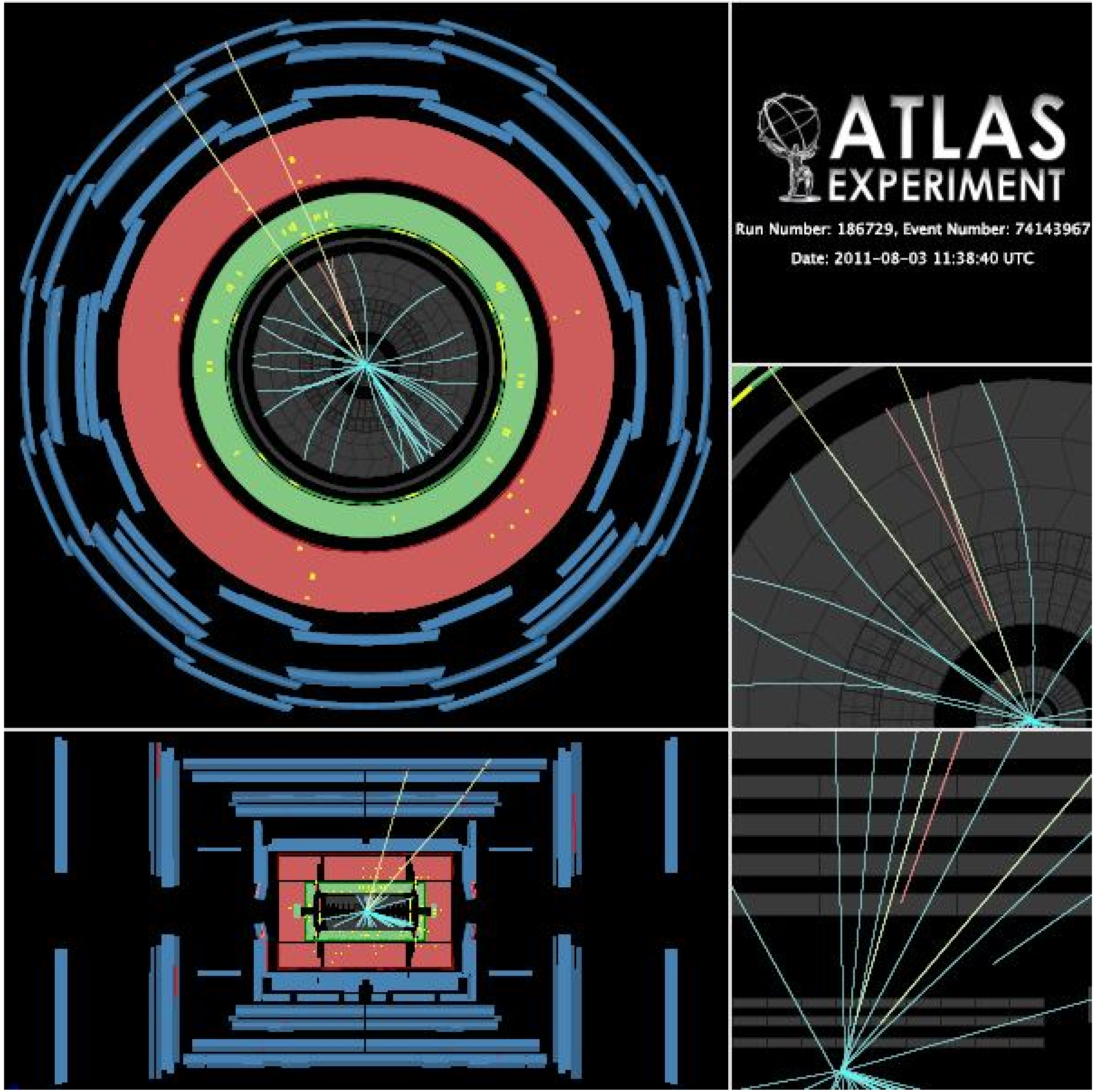
In a similar way to χ_{c1} and χ_{c2} states:

Combine dimuons from ϒ range with photons

search for peaks in the μμγ system to observe various χ_b states



Event with $\chi_b(3P)$ candidate



First observation of the χ_{bJ}(3P) state

Significance of the new peak calculated through the difference of log-likelihoods with and without the peak in the fit: $D = \log(L_{with} / L_{without})$

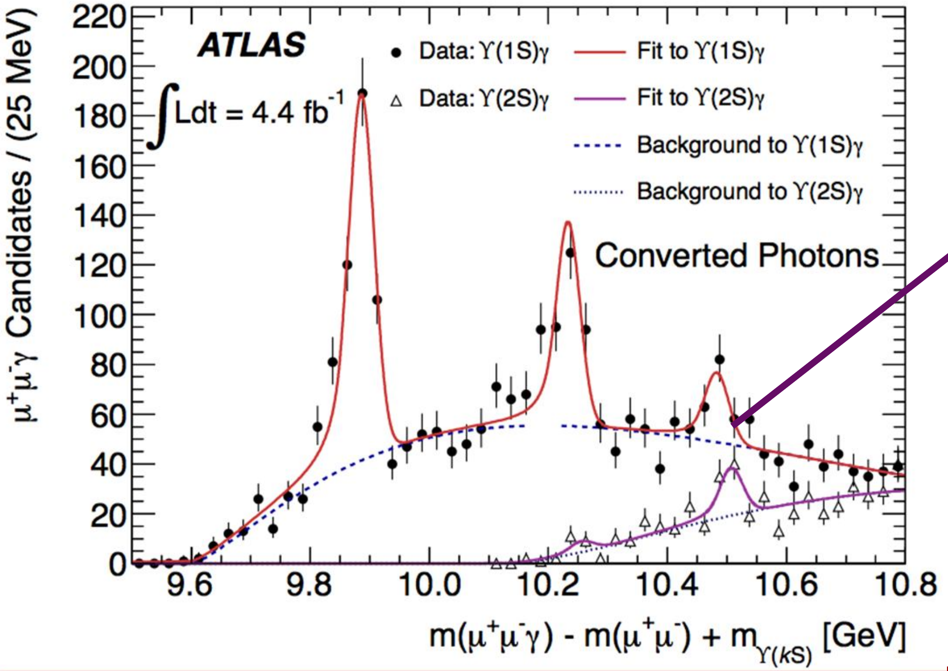
With moderately large numbers involved, -2D is distributed as $\Delta\chi^2$

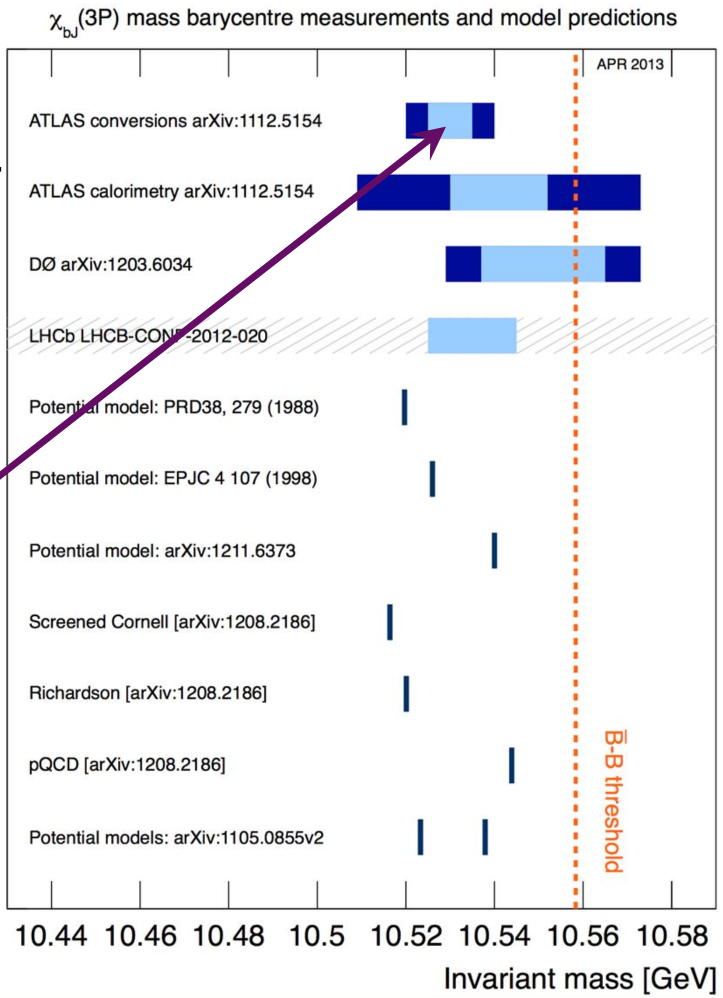
The “with” hypothesis won, with significance in excess of 6σ

Since then, confirmed by DØ and LHCb,

light blue: statistical,
dark blue statistical+systematic
[No quoted systematic for LHCb observation]

PRL 108 (2012) 152001





Phys.Rev.Lett. 108 (2012) 152001

Observation of the χ_{bJ}(3P) state (media)

22 December 2011 Last updated at 10:59

LHC reports discovery of its first new particle

By Jonathan Amos
Science correspondent, BBC News

The Large Hadron Collider (LHC) on the Franco-Swiss border has made its first clear observation of a new particle since opening in 2009.

It is called Chi_b (3P) and will help scientists understand better the forces that hold matter together.

Large Hadron Collider has first confirmed sighting of new particle (but it's not the Higgs)

Large Hadron Collider discovers a new particle: the Chi-b(3P)

By Mark Brown | 22 December 11

Outline (again)

Thanks for the invitation, glad to be here!

Request: give an overview of some measurements made by ATLAS collaboration at CERN, including various technical details of statistical methods used

11 am on Wed 9 July:

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- **Production of $\psi(2S)$ in its $J/\psi(\rightarrow\mu^+\mu^-)\pi^+\pi^-$ decay mode**
- **Production of χ_c in their radiative decay mode $J/\psi+\gamma$**
- **Discovery of the $\chi_b(3P)$**

11 am on Thu 10 July:

Higgs boson studies in ATLAS **–selected topics on its observation and properties**

- **Four-lepton decay mode ZZ^***
- **Di-photon decay mode**
- **Significance and mass determination**

Both topics are HUGE, each worth a series of lectures --

will not attempt to be comprehensive, just a few highlights in some detail...

Introduction to Higgs

Does not really need much introduction...

The good news: the wait is over

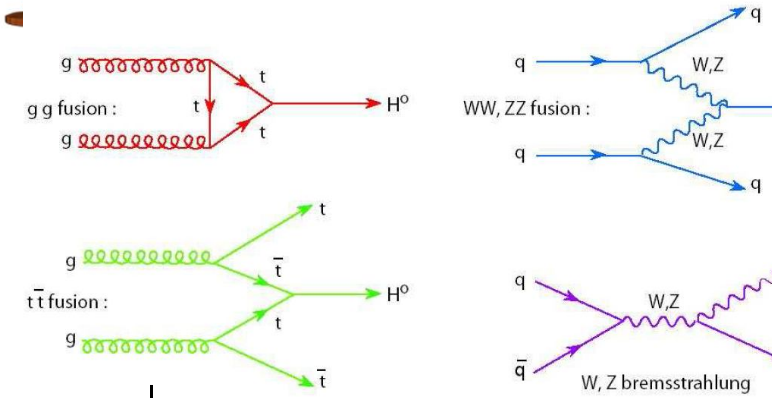
We now have something which very much looks like a Higgs boson

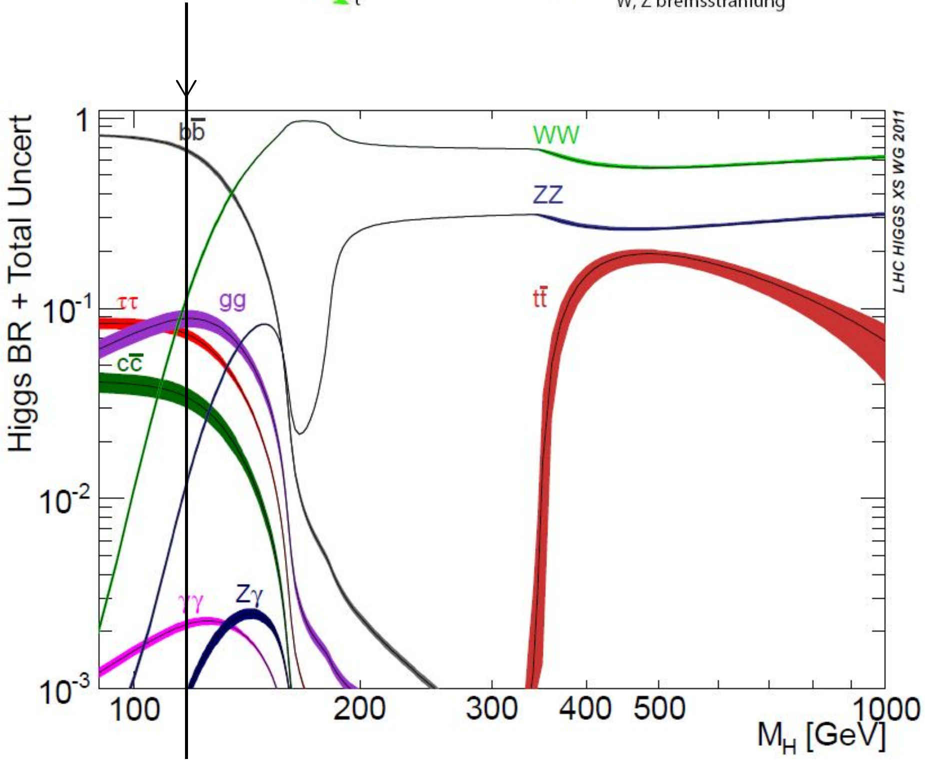
So far, no indication that it is not THE Standard Model Higgs boson

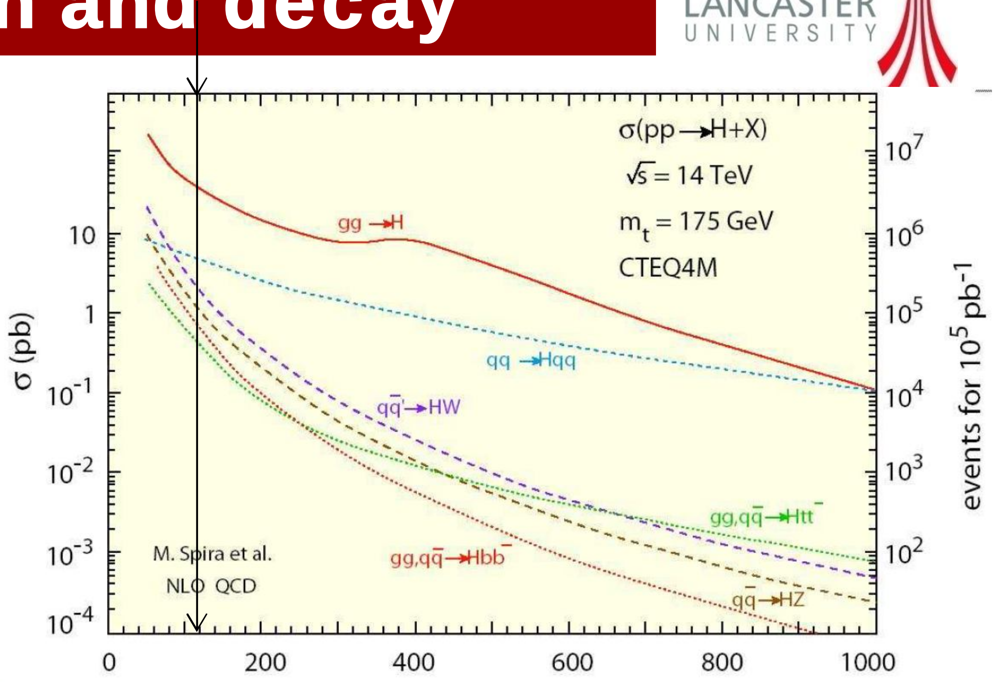
We had almost 50 years to calculate everything there is to calculate about the SM Higgs:

- **Decay BR**
- **Production cross sections**
- **Radiative corrections**

SM Higgs – production and decay







We knew everything about the SM Higgs – except one thing: whether it existed or not

It was found at the mass where up to 8 decay modes can be accessible, allowing us to study various couplings in some detail

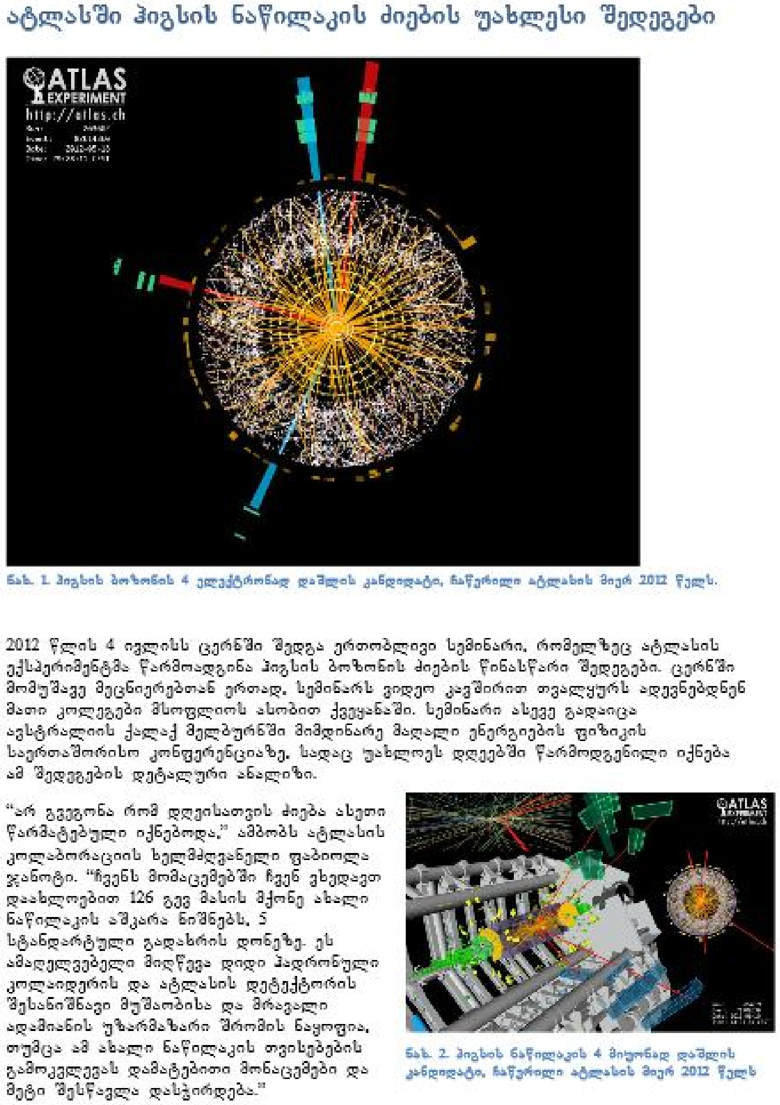
Higgs boson announcement

On the eve of the announcement I (foolishly) volunteered to translate official ATLAS press release into Georgian

Did not know it was 5 pages long

Spent all night translating – and happily overslept through the announcement seminar…

On the bright side: the Georgian version went on-line simultaneously with all others on the 4th of July 2012



ატლასში ჰიგსის ნაწილაკის ძიების უახლესი შედეგები

ნახ. 1. ჰიგსის ბოზონის 4 ელექტრონად დაშლის კანდიდატი, ჩაწერილი ატლასის მიერ 2012 წელს.

2012 წლის 4 ივლისს ცერნში შედგა ერთობლივი სემინარი, რომელზეც ატლასის ექსპერიმენტმა წარმოადგინა ჰიგსის ბოზონის ძიების წინასწარი შედეგები. ცერნში მომუშავე მეცნიერებთან ერთად, სემინარს ვიდეო კავშირით თვალყურს ადევნებდნენ მათი კოლეგები მსოფლიოს ასობით ქვეყანაში. სემინარი ასევე გადაიცა ავსტრალიის ქალაქ მელბურნში მიმდინარე მაღალი ენერგიების ფიზიკის საერთაშორისო კონფერენციაზე, სადაც უახლოეს დღეებში წარმოდგენილი იქნება ამ შედეგების დეტალური ანალიზი.

“არ გვეგონა რომ დღეისათვის ძიება ასეთი წარმატებული იქნებოდა,” ამბობს ატლასის კოლაბორაციის ხელმძღვანელი ფაბიოლა ჯანოტი. “ჩვენს მონაცემებში ჩვენ ვხედავთ დაახლოებით 126 გევ მასის მქონე ახალი ნაწილაკის აშკარა ნიშნებს, 5 სტანდარტული გადახრის დონეზე. ეს ამაღელვებელი მიღწევა დიდი ჰადრონული კოლაიდერის და ატლასის დეტექტორის შესანიშნავი მუშაობისა და მრავალი ადამიანის უზარმაზარი შრომის ნაყოფია, თუმცა ამ ახალი ნაწილაკის თვისებების გამოკვლევას დამატებითი მონაცემები და მეტი შესწავლა დასჭირდება.”

ნახ. 2. ჰიგსის ნაწილაკის 4 მიუონად დაშლის კანდიდატი, ჩაწერილი ატლასის მიერ 2012 წელს

http://www.atlas.ch/news/2012/latest-results-from-higgs-search.html

Short history of the Higgs signal - ZZ^*

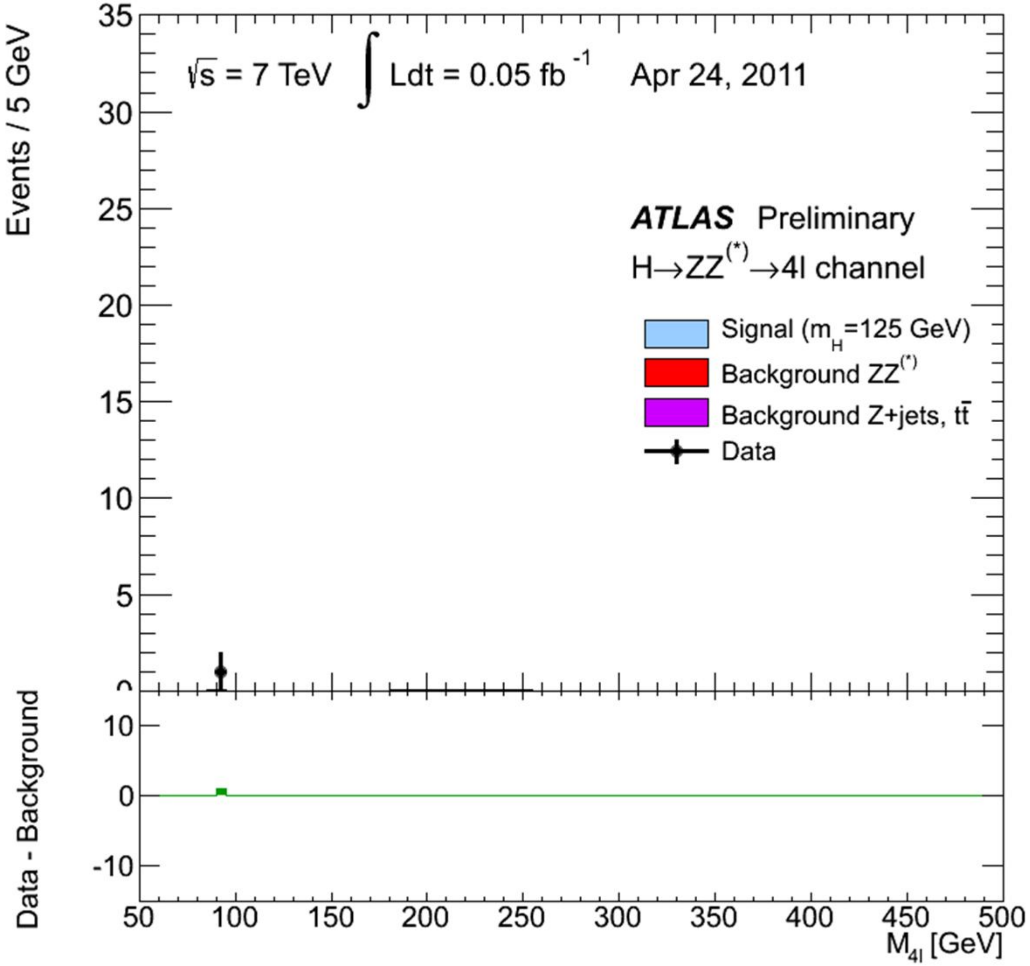
Higgs to ZZ^* to 4 leptons

Video goes through 2011 and 2012 data-taking

Some peaks are xpected

The one around 126 GeV is new…

Signal significance increases with increasing statistics

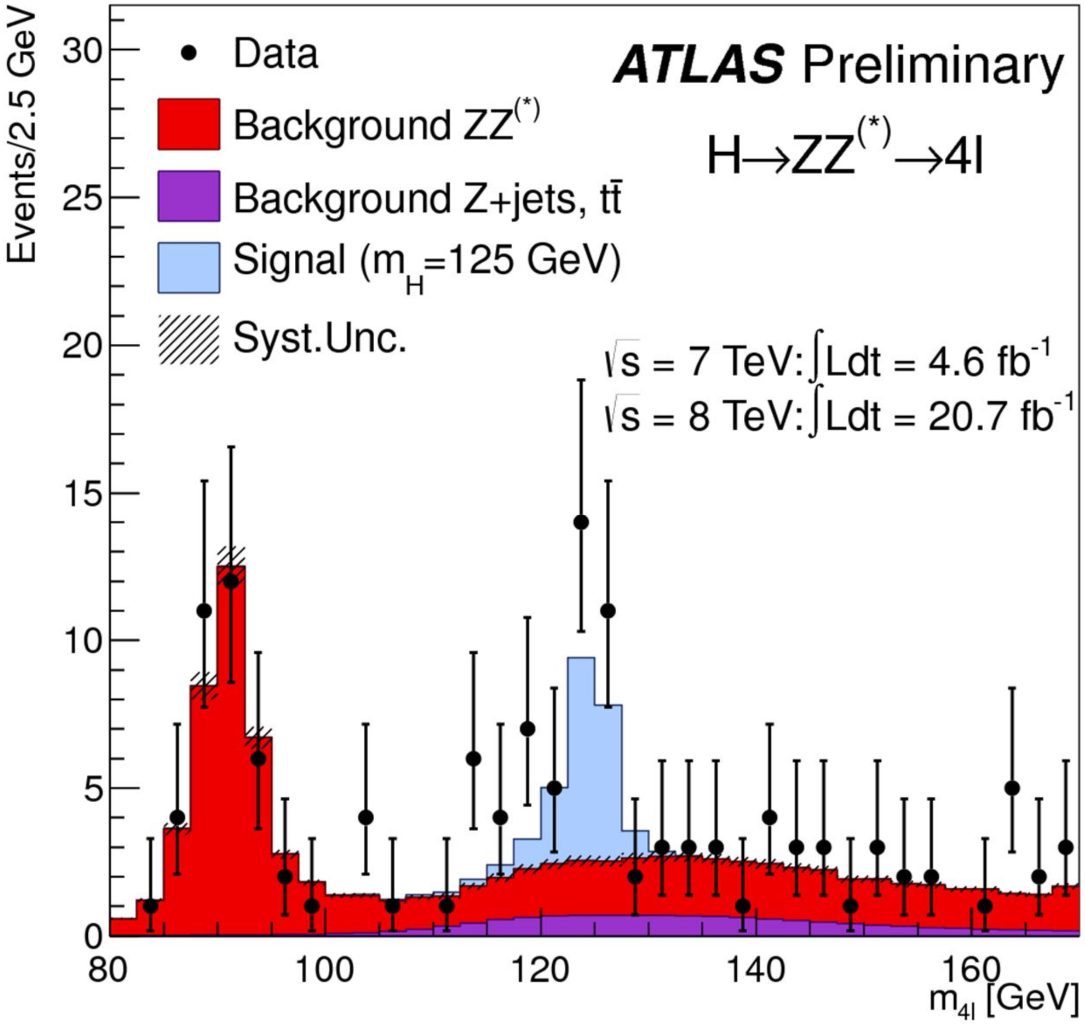


Higgs signal - ZZ*

Higgs to ZZ* to 4 leptons

2011 and 2012 data combined

Latest static plot



http://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2013-013

Short history of the Higgs signal - γγ

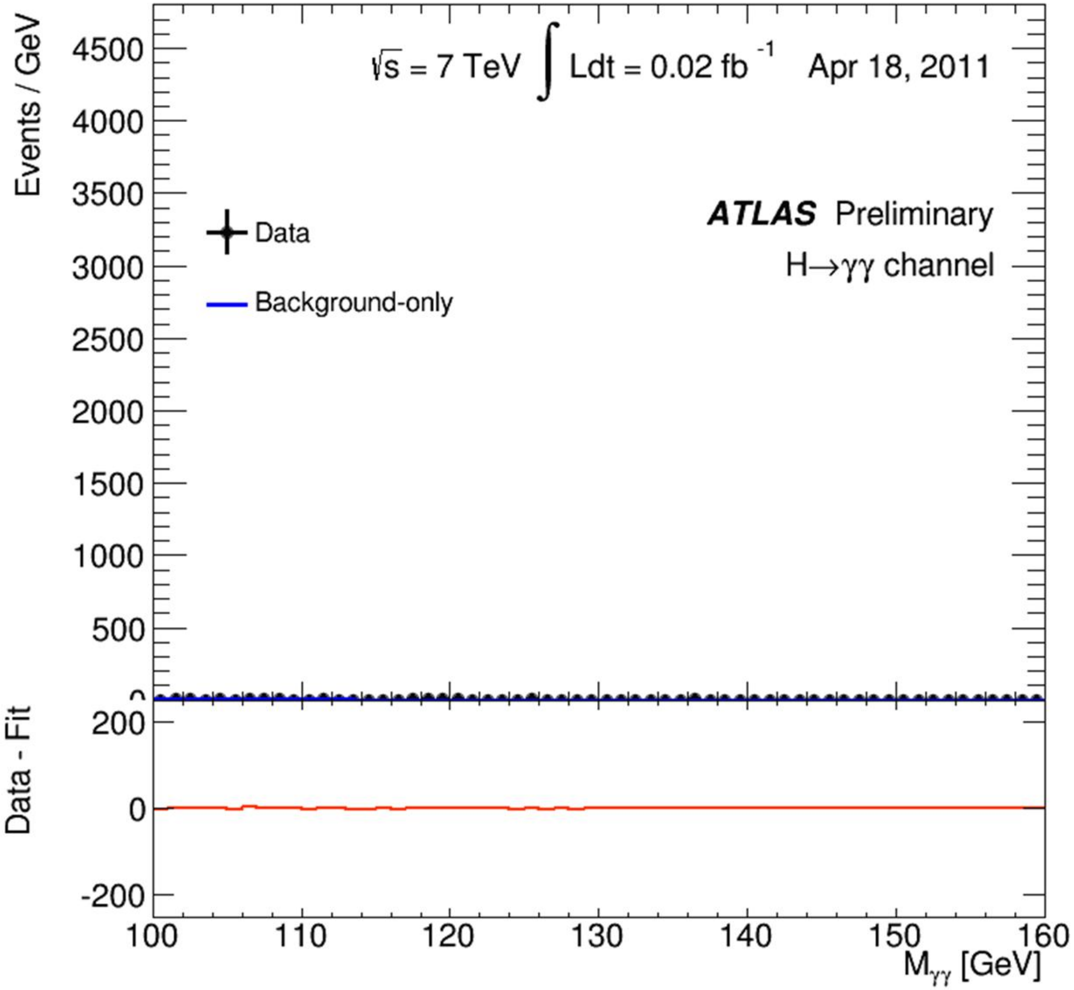
Higgs to gamma-gamma

Video goes through 2011 and 2012 data-taking

Blue line: Background-only fit

Red line: Signal+background fit

Signal significance increases with increasing statistics



https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HiggsPublicResults#Animations

Higgs signal - γγ

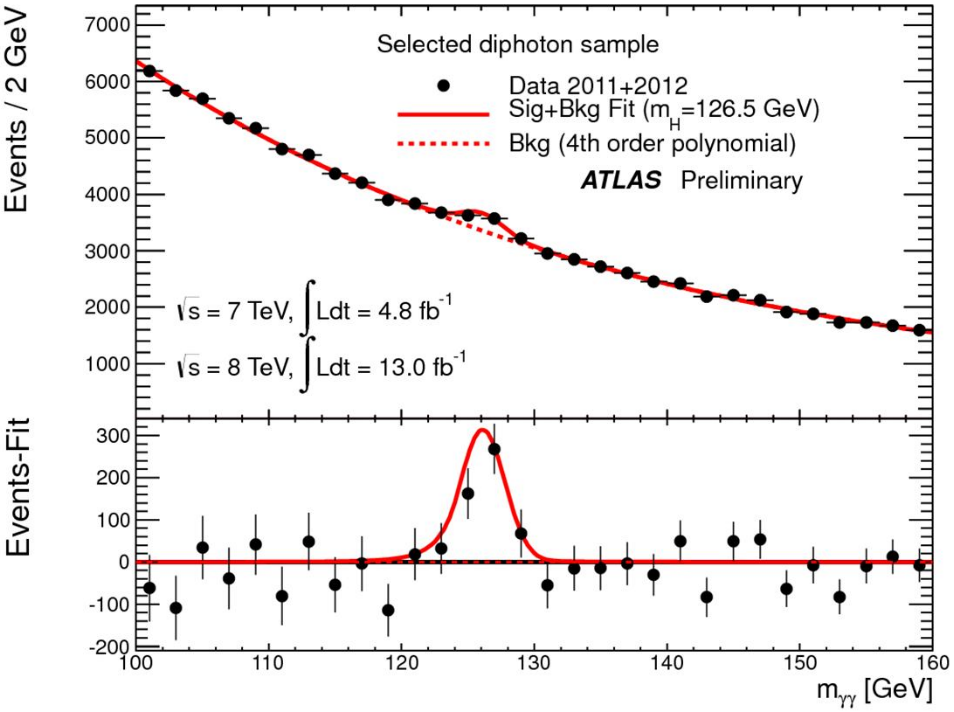
Higgs to γγ

2011 and 2012 data-taking combined

Static plot in case video did not work

Somebody might have tried to fit this with a smooth background and a Gaussian peak, and if the fitted peak height comes up as, say, 60 ± 10, would claim a 6-sigma signal!

Right?



http://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2012-168/

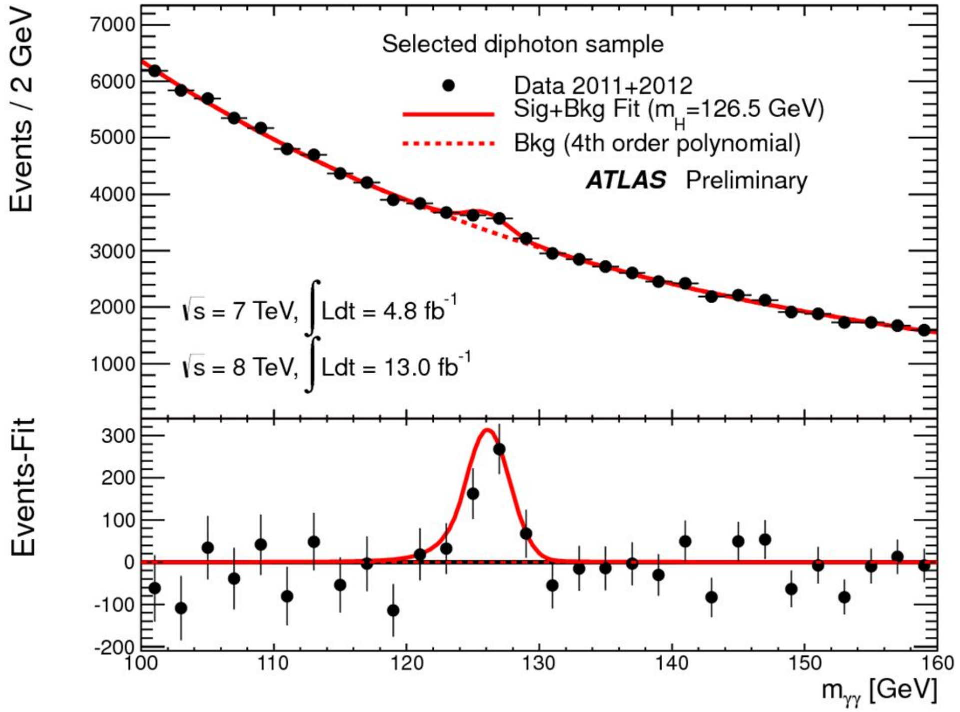
Higgs signal - γγ

Higgs to γγ

2011 and 2012 data-taking combined

Static plot in case video did not work

Somebody might have tried to fit this with a smooth background and a Gaussian peak, and if the fitted peak height comes up as, say, 60 ± 10, would claim a 6-sigma signal!



Right? ***WRONG!!!***

Certainly wrong if you are an ATLAS physicist trying to discover the Higgs Boson…

http://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2012-168/

Disclaimer (almost serious)

There are quite a few experts in statistical methods, at CERN in general and in ATLAS in particular

They often come up with quite sophisticated statistical tools and methods for all kinds of things people do in particle physics, even when well-tested, simple and familiar tools exist

Why? Well, maybe they need to justify their existence?
More likely: when you spend billions to satisfy your curiosity, you better make sure your output is rock-solid!

In any case, I am *NOT* one of those experts. My explanations below are based on my understanding of these methods, through my own background and experience.

However, these things are notoriously prone to misinterpretations, misunderstandings and misleading wordings. Although I tried hard to avoid these, *believe me at your own risk!*

Or, better still, look into the "Statistics" chapter in the PDG book (if you have not done so already), and let me know if you find anything wrong with my explanations!

http://pdg.lbl.gov/2013/reviews/rpp2013-rev-statistics.pdf

Background and Signal fits

Background fit has as many parameters as needed, but it has to be smooth

- **Example: for diphoton invariant mass -- fourth order polynomial**

Signal peak fit may have three parameters

- **Width (resolution) – determine in advance**
- **Mass (peak position) – scan in small steps**
- **Height (peak intensity) – the only parameter for signal, μ**

With resolution pre-determined, *<u>for each value of hypothesized signal mass m</u>*, do:

1) **background-only fit -- returns likelihood $L(\mu=0, m)$**
2) **background + signal -- returns likelihood $L(\mu=\hat{\mu}, m)$**

Null hypothesis and signal hypothesis

Let μ be a scale factor on the number of events predicted by SM for the Higgs signal

- $\mu=0$ corresponds to the background-only hypothesis
- $\mu=1$ corresponds to the SM Higgs boson signal in addition to the background (assuming that the SM prediction can be calculated precisely and reliably)

So, for each hypothesized mass of Higgs, m, a Maximum Likelihood fit is done (on, say, diphoton mass) and a value $\mu=\hat{\mu}$ is found corresponding to that maximum

- Profile likelihood ratio: $\lambda(\mu) = L(\mu=0, m) / L(\mu=\hat{\mu}, m)$
- Possibly more convenient to consider $-2 \log \lambda(\mu)$ which has a minimum of 0 at $\mu=\hat{\mu}$ and looks roughly like a parabola (similar to χ^2)

Based on the profile for $-2 \log \lambda(\mu)$, one can calculate

- Probability of null-hypothesis (background-only)
- Probability of signal + background hypothesis

Null hypothesis and its p-value p_0

Null hypothesis:

There is no signal, just the background

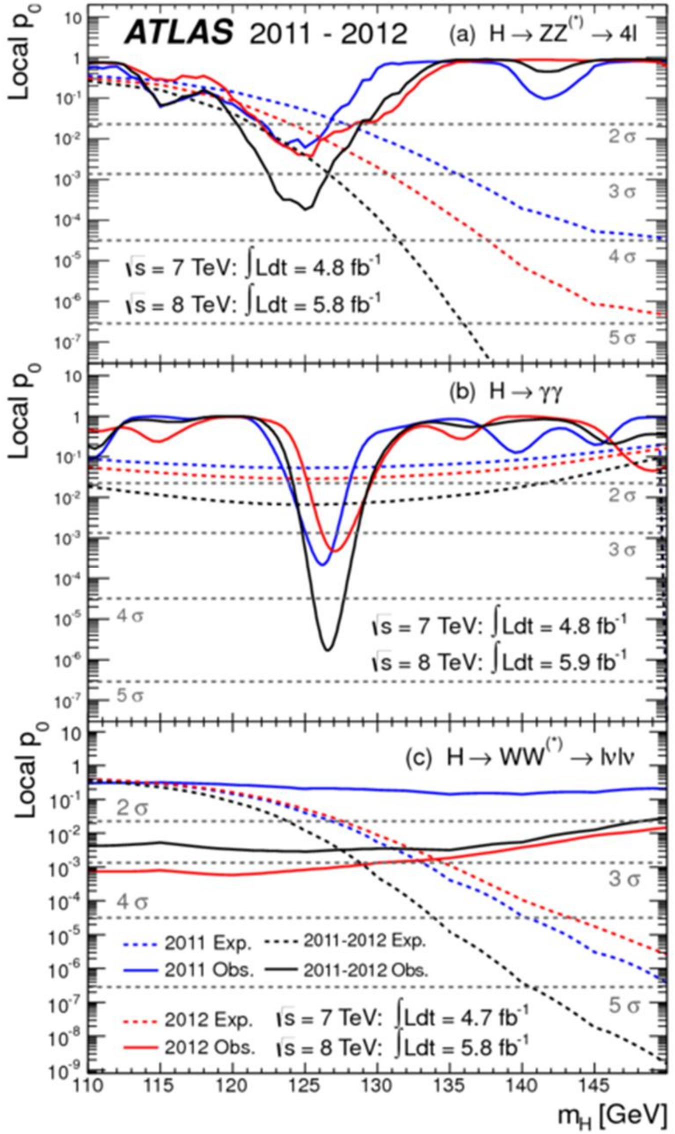
Type-1 error: rejecting null-hypothesis, when it is in fact true

- **Null hypothesis: the man is innocent.**
  Type-1 error: send him to prison!
- **Null hypothesis: there is no Higgs,**
  just a background fluctuation.
  Type-1 error: claim discovery anyway!

Nobody wants to make a type-1 error!

p-value p_0: probability of observing data at least as extreme as that observed, *given that the null hypothesis is true*

Null hypothesis has a problem if – for some mass region – p-value is "small enough": smaller than a pre-determined Significance Level (usually 5%)



Signal strength μ and its p-value p_μ

In general, null-hypothesis being in trouble does NOT necessarily mean the presence of the right kind of signal (or any signal at all!)

For each hypothesized value of μ one can compute p_μ – probability of observing data corresponding to this value of μ

Those μ for which p_μ is smaller than some pre-determined value α (say, 5%) are ***rejected***.
Those μ which *are not rejected* constitute a confidence interval with confidence level $1-\alpha$

Low sensitivity: signal model almost indistinguishable from background-only model

You do NOT want to exclude a signal model simply because you are not sensitive to it…

Introduce $CL_S = p_\mu / (1-p_0)$ Exclude the model if $CL_S < \alpha$

This is more stringent than simply rejecting a model if $p_\mu < \alpha$,
hence avoids rejecting signal models in areas of low sensitivity

Null-hypothesis -- combined

Now, if there *IS* a signal at a particular mass, with strength as predicted by the SM,

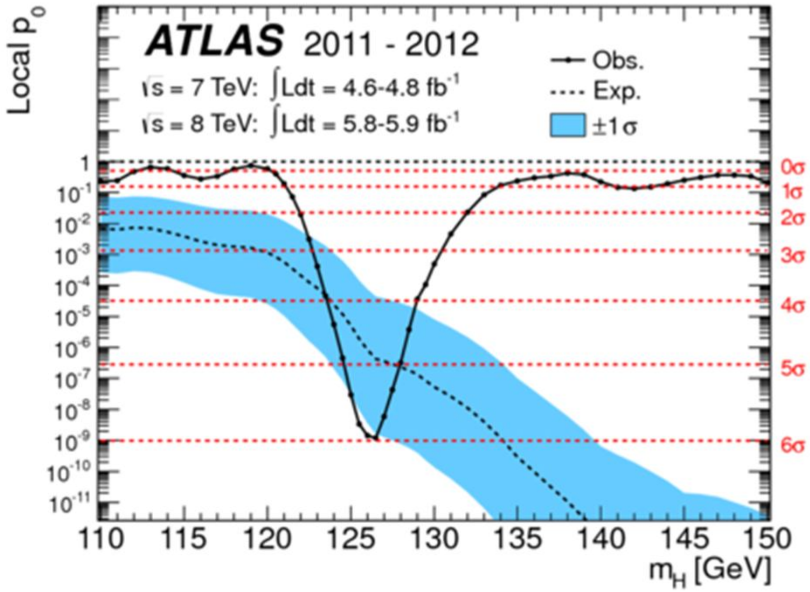
AND **if the experiment is sensitive to that signal at that mass**

then the *null-hypothesis will be in trouble at that mass* – local p_0 will be small

Here is the null-hypothesis p_0 plot for all three decay channels ZZ^*, $\gamma\gamma$, WW^* combined

Null-hypothesis (background-only) clearly has a problem around 126 GeV

The "Expected" blue band shows the ± 1σ range of these expected p_0 values, if the SM strength signal is present at that mass, so the sensitivity is there



The further down the blue band goes, the bigger is the potential trouble for the null-hypothesis, hence the higher is the sensitivity to the signal at that mass

Higgs signal significance plots

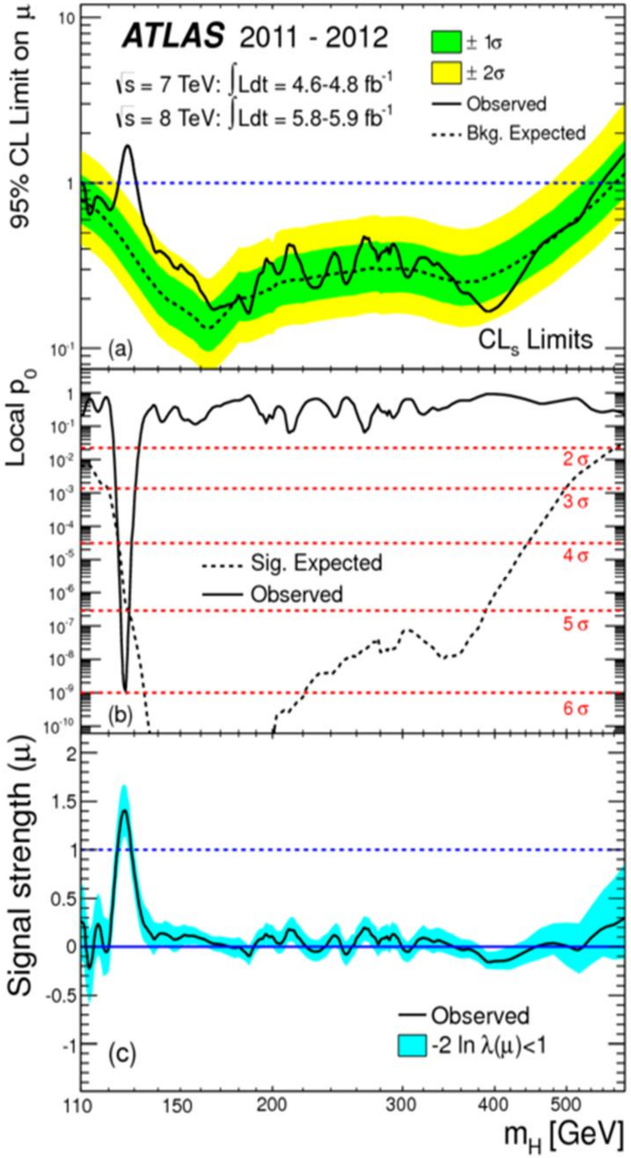
Middle plot is a combination of the null-hypothesis p_0 plots, for all three decay channels together – just as before but for a wider mass range

Bottom plot is the signal strength, obtained by fitting the data for μ, in all three decay channels combined, for different hypothesized Higgs masses.
For most m_H values the signal strength μ is consistent with 0, but deviates significantly away from 0 around 126 GeV

Top plot shows CL_S limits for signal strength in this mass range

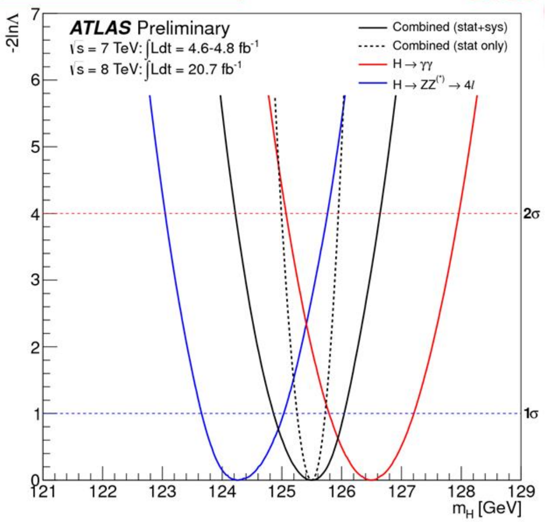
- a value of μ is excluded at 95% CL when CL_s is less than 5%
- m_H is excluded at 95% CL when μ=1 is excluded at that mass

The dashed line with colour bands shows the expected limits on μ if there is no signal, just the background. The observed limits remain within the colour bands for most masses, apart from the narrow range around 126 GeV.

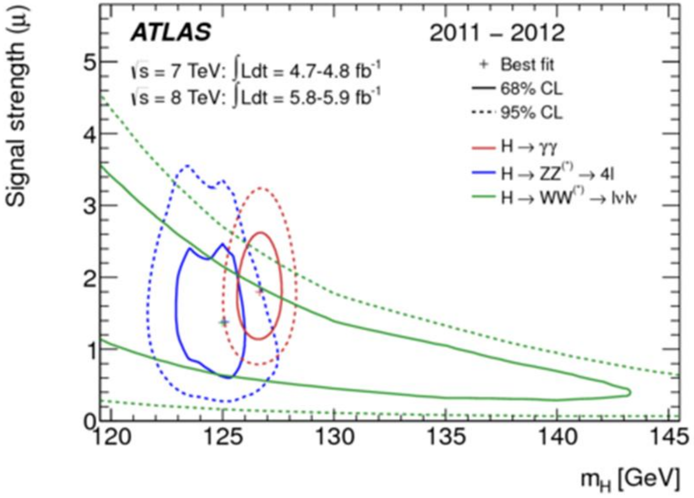


More Higgs combination plots

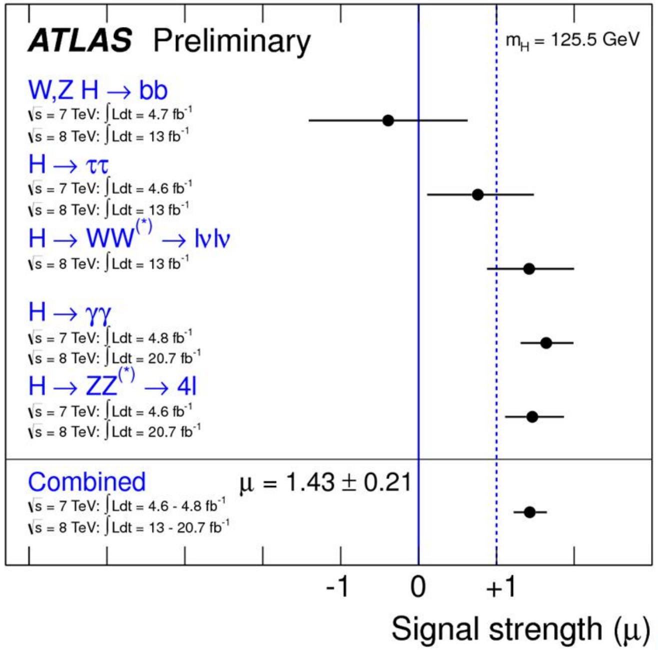
Combining likelihood profiles for the Higgs mass extracted from ZZ* and γγ final states



One- and two-sigma contours for the two channels in signal strength vs m_H plane



Signal strength in separate channels together with overall combination



Fermionic couplings start to show up
Looks like we are seeing a bit stronger signal than expected by SM, that "SM prediction" is not stone-clad either…

Higgs decay to muon pair

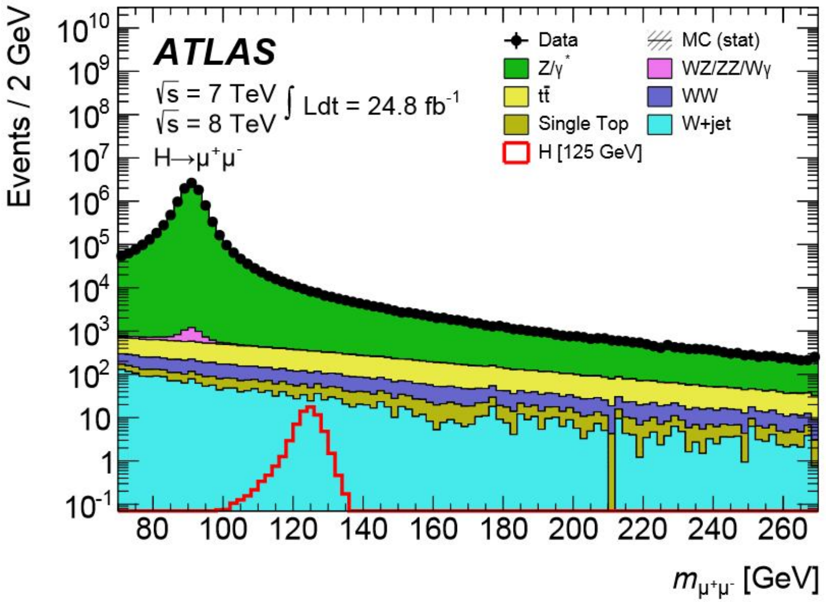
ATLAS search for the Higgs decaying into $\mu^+\mu^-$

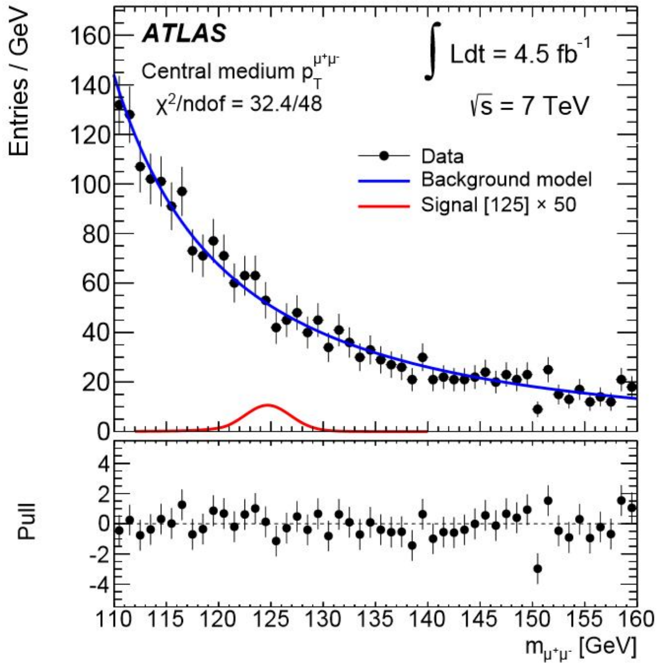
For Higgs mass at 125.5 GeV, 95% CL:

Observed upper limit on signal strength is $\mu_S = 7.0$
Expected upper limit on signal strength is $\mu_S = 7.2$

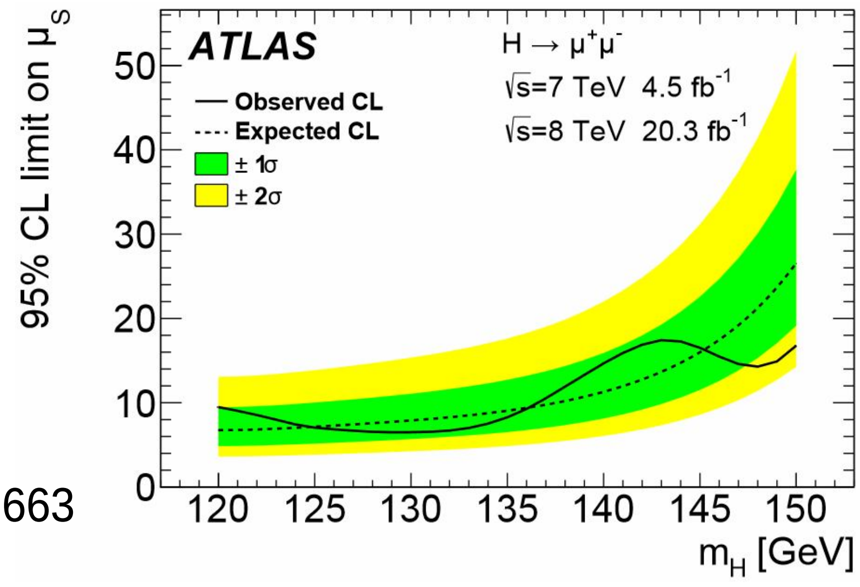
i.e. "not seen at level ~7 times the SM prediction"

SM at this mass predicts BR($\mu^+\mu^-$) just below 10^{-5}

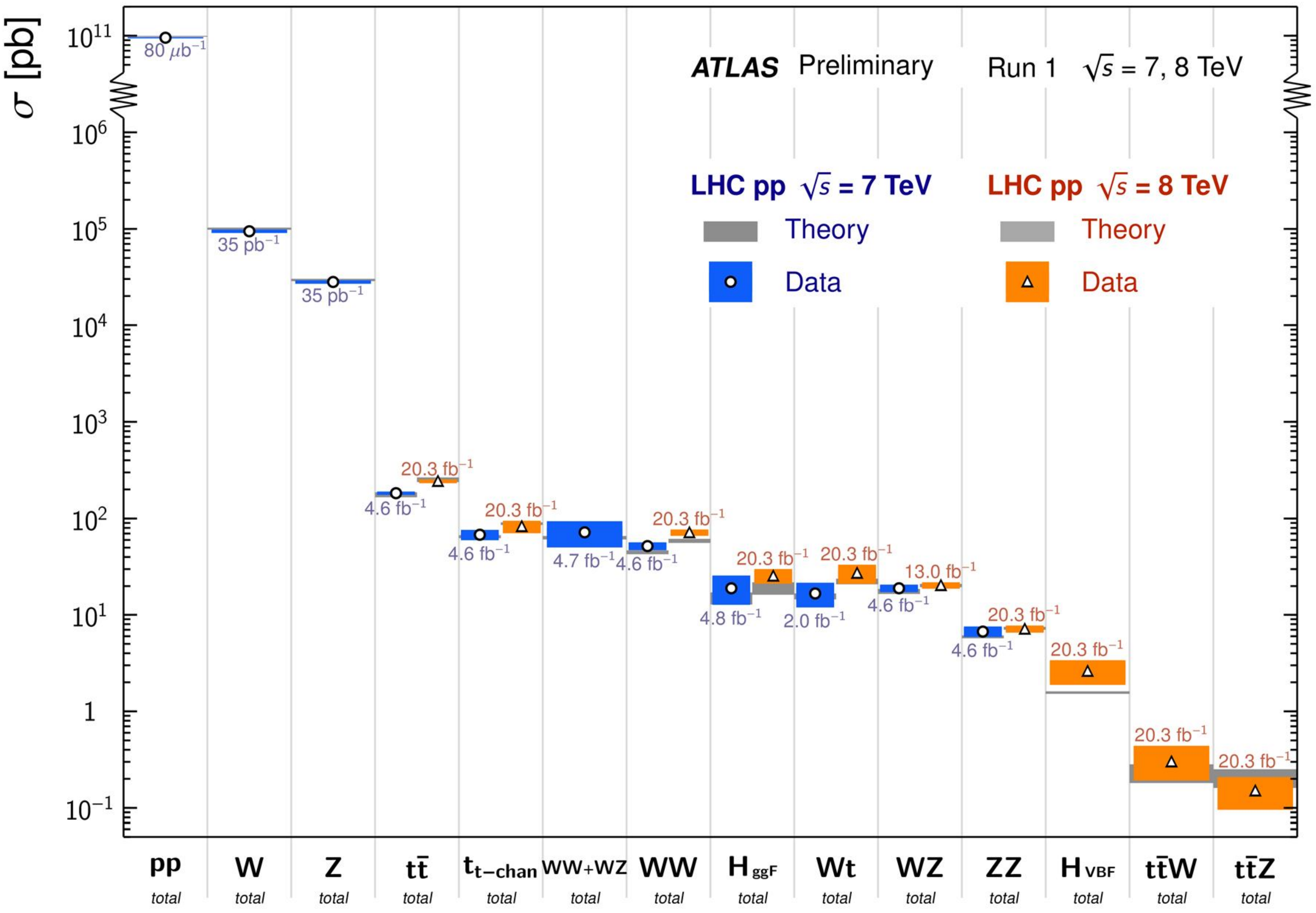




arXiv:1406.7663



Other SM processes

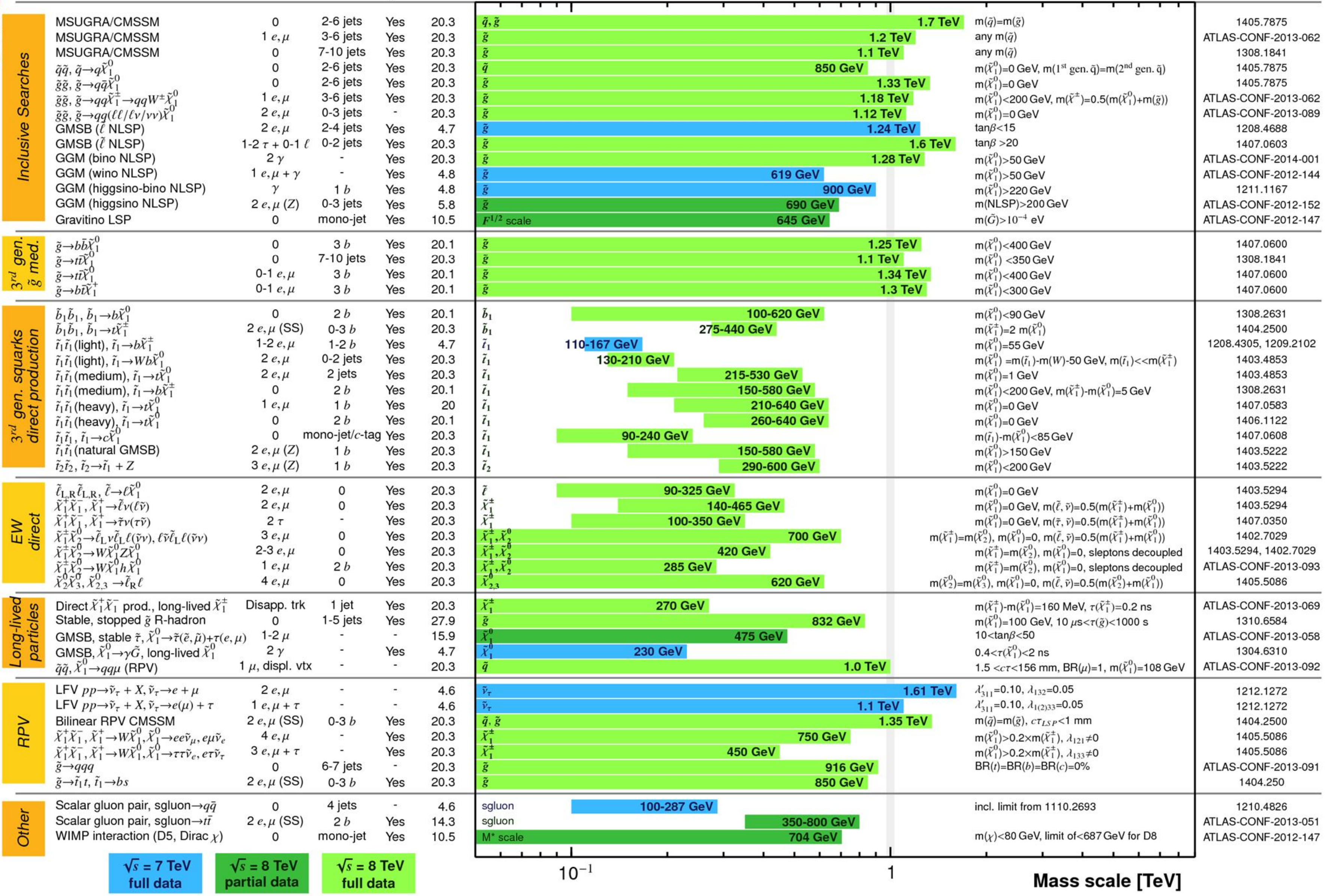

Standard Model Total Production Cross Section Measurements Status: July 2014

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: ICHEP 2014

ATLAS Preliminary

$\sqrt{s}$ = 7, 8 TeV



	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\,dt[\mathrm{fb}^{-1}]$	Mass limit			Reference
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q}, \tilde{g}$	1.7 TeV	m($\tilde{q}$)=m($\tilde{g}$)	1405.7875
	MSUGRA/CMSSM	1 e, μ	3-6 jets	Yes	20.3	$\tilde{g}$	1.2 TeV	any m($\tilde{q}$)	ATLAS-CONF-2013-062
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	any m($\tilde{q}$)	1308.1841
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$	850 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m(1^{st} gen. $\tilde{q}$)=m(2^{nd} gen. $\tilde{q}$)	1405.7875
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$	1.33 TeV	m($\tilde{\chi}_1^0$)=0 GeV	1405.7875
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}_1^\pm\to qqW^\pm\tilde{\chi}_1^0$	1 e, μ	3-6 jets	Yes	20.3	$\tilde{g}$	1.18 TeV	m($\tilde{\chi}_1^0$)<200 GeV, m($\tilde{\chi}^\pm$)=0.5(m($\tilde{\chi}_1^0$)+m($\tilde{g}$))	ATLAS-CONF-2013-062
	$\tilde{g}\tilde{g}, \tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e, μ	0-3 jets	-	20.3	$\tilde{g}$	1.12 TeV	m($\tilde{\chi}_1^0$)=0 GeV	ATLAS-CONF-2013-089
	GMSB ($\tilde{\ell}$ NLSP)	2 e, μ	2-4 jets	Yes	4.7	$\tilde{g}$	1.24 TeV	tanβ<15	1208.4688
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets	Yes	20.3	$\tilde{g}$	1.6 TeV	tanβ >20	1407.0603
	GGM (bino NLSP)	2 γ	-	Yes	20.3	$\tilde{g}$	1.28 TeV	m($\tilde{\chi}_1^0$)>50 GeV	ATLAS-CONF-2014-001
	GGM (wino NLSP)	1 $e, \mu + \gamma$	-	Yes	4.8	$\tilde{g}$	619 GeV	m($\tilde{\chi}_1^0$)>50 GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$	900 GeV	m($\tilde{\chi}_1^0$)>220 GeV	1211.1167
	GGM (higgsino NLSP)	2 e, μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$	690 GeV	m(NLSP)>200 GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	10.5	$F^{1/2}$ scale	645 GeV	m($\tilde{G}$)>10^{-4} eV	ATLAS-CONF-2012-147
3^{rd} gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$	1.25 TeV	m($\tilde{\chi}_1^0$)<400 GeV	1407.0600
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	m($\tilde{\chi}_1^0$) <350 GeV	1308.1841
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$	1.34 TeV	m($\tilde{\chi}_1^0$)<400 GeV	1407.0600
	$\tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$	1.3 TeV	m($\tilde{\chi}_1^0$)<300 GeV	1407.0600
3^{rd} gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$	100-620 GeV	m($\tilde{\chi}_1^0$)<90 GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to t\tilde{\chi}_1^\pm$	2 e, μ (SS)	0-3 b	Yes	20.3	$\tilde{b}_1$	275-440 GeV	m($\tilde{\chi}_1^\pm$)=2 m($\tilde{\chi}_1^0$)	1404.2500
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	1-2 e, μ	1-2 b	Yes	4.7	$\tilde{t}_1$	110-167 GeV	m($\tilde{\chi}_1^0$)=55 GeV	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to Wb\tilde{\chi}_1^0$	2 e, μ	0-2 jets	Yes	20.3	$\tilde{t}_1$	130-210 GeV	m($\tilde{\chi}_1^0$) =m($\tilde{t}_1$)-m(W)-50 GeV, m($\tilde{t}_1$)<<m($\tilde{\chi}_1^\pm$)	1403.4853
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to t\tilde{\chi}_1^0$	2 e, μ	2 jets	Yes	20.3	$\tilde{t}_1$	215-530 GeV	m($\tilde{\chi}_1^0$)=1 GeV	1403.4853
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	0	2 b	Yes	20.1	$\tilde{t}_1$	150-580 GeV	m($\tilde{\chi}_1^0$)<200 GeV, m($\tilde{\chi}_1^\pm$)-m($\tilde{\chi}_1^0$)=5 GeV	1308.2631
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	1 e, μ	1 b	Yes	20	$\tilde{t}_1$	210-640 GeV	m($\tilde{\chi}_1^0$)=0 GeV	1407.0583
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{t}_1$	260-640 GeV	m($\tilde{\chi}_1^0$)=0 GeV	1406.1122
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$	90-240 GeV	m($\tilde{t}_1$)-m($\tilde{\chi}_1^0$)<85 GeV	1407.0608
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	2 e, μ (Z)	1 b	Yes	20.3	$\tilde{t}_1$	150-580 GeV	m($\tilde{\chi}_1^0$)>150 GeV	1403.5222
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1 + Z$	3 e, μ (Z)	1 b	Yes	20.3	$\tilde{t}_2$	290-600 GeV	m($\tilde{\chi}_1^0$)<200 GeV	1403.5222
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell}\to\ell\tilde{\chi}_1^0$	2 e, μ	0	Yes	20.3	$\tilde{\ell}$	90-325 GeV	m($\tilde{\chi}_1^0$)=0 GeV	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e, μ	0	Yes	20.3	$\tilde{\chi}_1^\pm$	140-465 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m($\tilde{\ell}, \tilde{\nu}$)=0.5(m($\tilde{\chi}_1^\pm$)+m($\tilde{\chi}_1^0$))	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.3	$\tilde{\chi}_1^\pm$	100-350 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m($\tilde{\tau}, \tilde{\nu}$)=0.5(m($\tilde{\chi}_1^\pm$)+m($\tilde{\chi}_1^0$))	1407.0350
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e, μ	0	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	700 GeV	m($\tilde{\chi}_1^\pm$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, m($\tilde{\ell}, \tilde{\nu}$)=0.5(m($\tilde{\chi}_1^\pm$)+m($\tilde{\chi}_1^0$))	1402.7029
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$	2-3 e, μ	0	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	420 GeV	m($\tilde{\chi}_1^\pm$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, sleptons decoupled	1403.5294, 1402.7029
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 h\tilde{\chi}_1^0$	1 e, μ	2 b	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	285 GeV	m($\tilde{\chi}_1^\pm$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, sleptons decoupled	ATLAS-CONF-2013-093
	$\tilde{\chi}_2^0\tilde{\chi}_3^0, \tilde{\chi}_{2,3}^0\to\tilde{\ell}_R\ell$	4 e, μ	0	Yes	20.3	$\tilde{\chi}_{2,3}^0$	620 GeV	m($\tilde{\chi}_2^0$)=m($\tilde{\chi}_3^0$), m($\tilde{\chi}_1^0$)=0, m($\tilde{\ell}, \tilde{\nu}$)=0.5(m($\tilde{\chi}_2^0$)+m($\tilde{\chi}_1^0$))	1405.5086
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^\pm$	270 GeV	m($\tilde{\chi}_1^\pm$)-m($\tilde{\chi}_1^0$)=160 MeV, τ($\tilde{\chi}_1^\pm$)=0.2 ns	ATLAS-CONF-2013-069
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	27.9	$\tilde{g}$	832 GeV	m($\tilde{\chi}_1^0$)=100 GeV, 10 μs<τ($\tilde{g}$)<1000 s	1310.6584
	GMSB, stable $\tilde{\tau}, \tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e}, \tilde{\mu})+\tau(e, \mu)$	1-2 μ	-	-	15.9	$\tilde{\chi}_1^0$	475 GeV	10<tanβ<50	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	4.7	$\tilde{\chi}_1^0$	230 GeV	0.4<τ($\tilde{\chi}_1^0$)<2 ns	1304.6310
	$\tilde{q}\tilde{q}, \tilde{\chi}_1^0\to qq\mu$ (RPV)	1 μ, displ. vtx	-	-	20.3	$\tilde{q}$	1.0 TeV	1.5 <$c\tau$<156 mm, BR(μ)=1, m($\tilde{\chi}_1^0$)=108 GeV	ATLAS-CONF-2013-092
RPV	LFV $pp\to\tilde{\nu}_\tau + X, \tilde{\nu}_\tau\to e + \mu$	2 e, μ	-	-	4.6	$\tilde{\nu}_\tau$	1.61 TeV	λ'_{311}=0.10, λ_{132}=0.05	1212.1272
	LFV $pp\to\tilde{\nu}_\tau + X, \tilde{\nu}_\tau\to e(\mu) + \tau$	1 $e, \mu + \tau$	-	-	4.6	$\tilde{\nu}_\tau$	1.1 TeV	λ'_{311}=0.10, $\lambda_{1(2)33}$=0.05	1212.1272
	Bilinear RPV CMSSM	2 e, μ (SS)	0-3 b	Yes	20.3	$\tilde{q}, \tilde{g}$	1.35 TeV	m($\tilde{q}$)=m($\tilde{g}$), $c\tau_{LSP}$<1 mm	1404.2500
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$	4 e, μ	-	Yes	20.3	$\tilde{\chi}_1^\pm$	750 GeV	m($\tilde{\chi}_1^0$)>0.2×m($\tilde{\chi}_1^\pm$), $\lambda_{121}\neq 0$	1405.5086
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to\tau\tau\tilde{\nu}_e, e\tau\tilde{\nu}_\tau$	3 $e, \mu + \tau$	-	Yes	20.3	$\tilde{\chi}_1^\pm$	450 GeV	m($\tilde{\chi}_1^0$)>0.2×m($\tilde{\chi}_1^\pm$), $\lambda_{133}\neq 0$	1405.5086
	$\tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$	916 GeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2013-091
	$\tilde{g}\to\tilde{t}_1 t, \tilde{t}_1\to bs$	2 e, μ (SS)	0-3 b	Yes	20.3	$\tilde{g}$	850 GeV		1404.250
Other	Scalar gluon pair, sgluon$\to q\bar{q}$	0	4 jets	-	4.6	sgluon	100-287 GeV	incl. limit from 1110.2693	1210.4826
	Scalar gluon pair, sgluon$\to t\bar{t}$	2 e, μ (SS)	2 b	Yes	14.3	sgluon	350-800 GeV		ATLAS-CONF-2013-051
	WIMP interaction (D5, Dirac χ)	0	mono-jet	Yes	10.5	M* scale	704 GeV	m(χ)<80 GeV, limit of<687 GeV for D8	ATLAS-CONF-2012-147

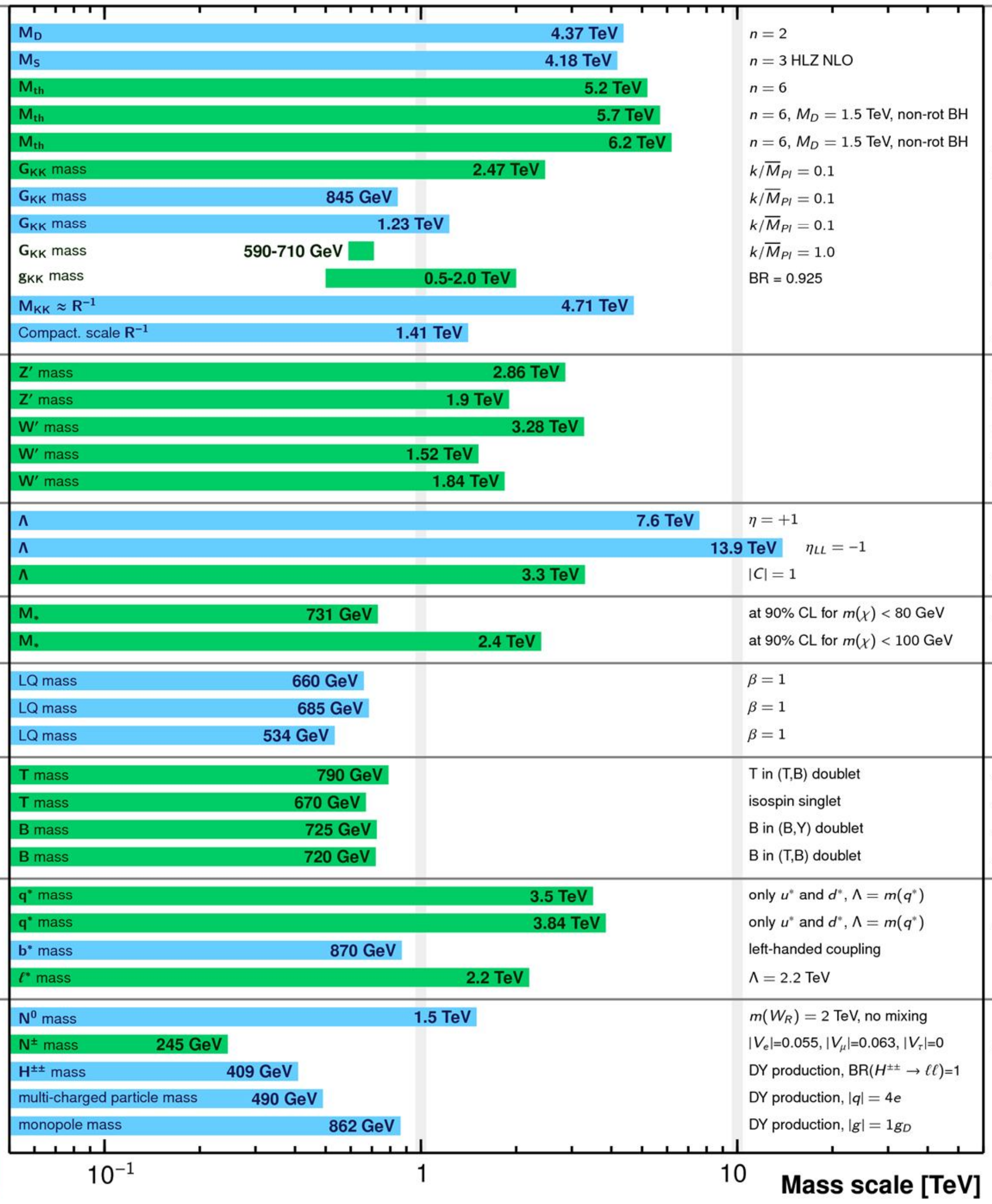
**Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.*

ATLAS Exotics Searches* - 95% CL Exclusion

Status: April 2014

ATLAS Preliminary

$\int \mathcal{L}\, dt = (1.0 - 20.3)$ fb^{-1} $\sqrt{s} = 7, 8$ TeV



	Model	ℓ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt [fb^{-1}]$	Mass limit		Reference
Extra dimensions	ADD $G_{KK} + g/q$	–	1-2 j	Yes	4.7	🟦 M_D 4.37 TeV	$n = 2$	1210.4491
	ADD non-resonant $\ell\ell/\gamma\gamma$	2γ or $2e, \mu$	–	–	4.7	🟦 M_S 4.18 TeV	$n = 3$ HLZ NLO	1211.1150
	ADD QBH $\rightarrow \ell q$	1 e, μ	1 j	–	20.3	🟩 M_{th} 5.2 TeV	$n = 6$	1311.2006
	ADD BH high N_{trk}	2 μ (SS)	–	–	20.3	🟩 M_{th} 5.7 TeV	$n = 6$, $M_D = 1.5$ TeV, non-rot BH	1308.4075
	ADD BH high $\sum p_T$	≥ 1 e, μ	≥ 2 j	–	20.3	🟩 M_{th} 6.2 TeV	$n = 6$, $M_D = 1.5$ TeV, non-rot BH	ATLAS-CONF-2014-016
	RS1 $G_{KK} \rightarrow \ell\ell$	2 e, μ	–	–	20.3	🟩 G_{KK} mass 2.47 TeV	$k/\overline{M}_{Pl} = 0.1$	ATLAS-CONF-2013-017
	RS1 $G_{KK} \rightarrow ZZ \rightarrow \ell\ell qq/\ell\ell\ell\ell$	2 or 4 e, μ	2 j or –	–	1.0	🟦 G_{KK} mass 845 GeV	$k/\overline{M}_{Pl} = 0.1$	1203.0718
	RS1 $G_{KK} \rightarrow WW \rightarrow \ell\nu\ell\nu$	2 e, μ	–	Yes	4.7	🟦 G_{KK} mass 1.23 TeV	$k/\overline{M}_{Pl} = 0.1$	1208.2880
	Bulk RS $G_{KK} \rightarrow HH \rightarrow b\bar{b}b\bar{b}$	–	4 b	–	19.5	🟩 G_{KK} mass 590-710 GeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2014-005
	Bulk RS $g_{KK} \rightarrow t\bar{t}$	1 e, μ	≥ 1 b, ≥ 1J/2j	Yes	14.3	🟩 g_{KK} mass 0.5-2.0 TeV	BR = 0.925	ATLAS-CONF-2013-052
	S^1/Z_2 ED	2 e, μ	–	–	5.0	🟦 $M_{KK} \approx R^{-1}$ 4.71 TeV		1209.2535
	UED	2 γ	–	Yes	4.8	🟦 Compact. scale R^{-1} 1.41 TeV		ATLAS-CONF-2012-072
Gauge bosons	SSM $Z' \rightarrow \ell\ell$	2 e, μ	–	–	20.3	🟩 Z' mass 2.86 TeV		ATLAS-CONF-2013-017
	SSM $Z' \rightarrow \tau\tau$	2 τ	–	–	19.5	🟩 Z' mass 1.9 TeV		ATLAS-CONF-2013-066
	SSM $W' \rightarrow \ell\nu$	1 e, μ	–	Yes	20.3	🟩 W' mass 3.28 TeV		ATLAS-CONF-2014-017
	EGM $W' \rightarrow WZ \rightarrow \ell\nu\, \ell'\ell'$	3 e, μ	–	Yes	20.3	🟩 W' mass 1.52 TeV		ATLAS-CONF-2014-015
	LRSM $W'_R \rightarrow t\bar{b}$	1 e, μ	2 b, 0-1 j	Yes	14.3	🟩 W' mass 1.84 TeV		ATLAS-CONF-2013-050
CI	CI $qqqq$	–	2 j	–	4.8	🟦 Λ 7.6 TeV	$\eta = +1$	1210.1718
	CI $qq\ell\ell$	2 e, μ	–	–	5.0	🟦 Λ 13.9 TeV	$\eta_{LL} = -1$	1211.1150
	CI $uutt$	2 e, μ (SS)	≥ 1 b, ≥ 1 j	Yes	14.3	🟩 Λ 3.3 TeV	$\|C\| = 1$	ATLAS-CONF-2013-051
DM	EFT D5 operator	–	1-2 j	Yes	10.5	🟩 M_* 731 GeV	at 90% CL for $m(\chi) < 80$ GeV	ATLAS-CONF-2012-147
	EFT D9 operator	–	1 J, ≤ 1 j	Yes	20.3	🟩 M_* 2.4 TeV	at 90% CL for $m(\chi) < 100$ GeV	1309.4017
LQ	Scalar LQ 1st gen	2 e	≥ 2 j	–	1.0	🟦 LQ mass 660 GeV	$\beta = 1$	1112.4828
	Scalar LQ 2nd gen	2 μ	≥ 2 j	–	1.0	🟦 LQ mass 685 GeV	$\beta = 1$	1203.3172
	Scalar LQ 3rd gen	1 e, μ, 1 τ	1 b, 1 j	–	4.7	🟦 LQ mass 534 GeV	$\beta = 1$	1303.0526
Heavy quarks	Vector-like quark $TT \rightarrow Ht + X$	1 e, μ	≥ 2 b, ≥ 4 j	Yes	14.3	🟩 T mass 790 GeV	T in (T,B) doublet	ATLAS-CONF-2013-018
	Vector-like quark $TT \rightarrow Wb + X$	1 e, μ	≥ 1 b, ≥ 3 j	Yes	14.3	🟩 T mass 670 GeV	isospin singlet	ATLAS-CONF-2013-060
	Vector-like quark $BB \rightarrow Zb + X$	2 e, μ	≥ 2 b	–	14.3	🟩 B mass 725 GeV	B in (B,Y) doublet	ATLAS-CONF-2013-056
	Vector-like quark $BB \rightarrow Wt + X$	2 e, μ (SS)	≥ 1 b, ≥ 1 j	Yes	14.3	🟩 B mass 720 GeV	B in (T,B) doublet	ATLAS-CONF-2013-051
Excited fermions	Excited quark $q^* \rightarrow q\gamma$	1 γ	1 j	–	20.3	🟩 q^* mass 3.5 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1309.3230
	Excited quark $q^* \rightarrow qg$	–	2 j	–	13.0	🟩 q^* mass 3.84 TeV	only u^* and d^*, $\Lambda = m(q^*)$	ATLAS-CONF-2012-148
	Excited quark $b^* \rightarrow Wt$	1 or 2 e, μ	1 b, 2 j or 1 j	Yes	4.7	🟩 b^* mass 870 GeV	left-handed coupling	1301.1583
	Excited lepton $\ell^* \rightarrow \ell\gamma$	2 e, μ, 1 γ	–	–	13.0	🟩 ℓ^* mass 2.2 TeV	$\Lambda = 2.2$ TeV	1308.1364
Other	LRSM Majorana ν	2 e, μ	2 j	–	2.1	🟦 N^0 mass 1.5 TeV	$m(W_R) = 2$ TeV, no mixing	1203.5420
	Type III Seesaw	2 e, μ	–	–	5.8	🟩 $N^\pm$ mass 245 GeV	$\|V_e\|$=0.055, $\|V_\mu\|$=0.063, $\|V_\tau\|$=0	ATLAS-CONF-2013-019
	Higgs triplet $H^{\pm\pm} \rightarrow \ell\ell$	2 e, μ (SS)	–	–	4.7	🟦 $H^{\pm\pm}$ mass 409 GeV	DY production, BR($H^{\pm\pm} \rightarrow \ell\ell$)=1	1210.5070
	Multi-charged particles	–	–	–	4.4	🟦 multi-charged particle mass 490 GeV	DY production, $\|q\| = 4e$	1301.5272
	Magnetic monopoles	–	–	–	2.0	🟦 monopole mass 862 GeV	DY production, $\|g\| = 1g_D$	1207.6411

🟦 $\sqrt{s}$ = 7 TeV 🟩 $\sqrt{s}$ = 8 TeV

*Only a selection of the available mass limits on new states or phenomena is shown.

Summary and prospects

I sincerely hope that my overview of

- **recent ATLAS results on quarkonium physics (yesterday), and**
- **the Higgs boson observation by ATLAS (today)**

has been interesting and/or useful for at least some people in the audience

The *prospects* are bright: on *quarkonium* front:

- **More production cross sections for individual states, in ever wider kinematic ranges**
- **$W+J/\psi$, $Z+$ $W+J/\psi$, $J/\psi+J/\psi$ production**
- **Searches for exotic quarkonium-like states**

On the *Higgs boson* front:

- **Cross section evolution with energy**
- **Time for precision BR measurements, searches for deviations from SM predictions**
- **Searches for more Higgs-like states**

Will keep many ATLAS members busy for the foreseeable future…

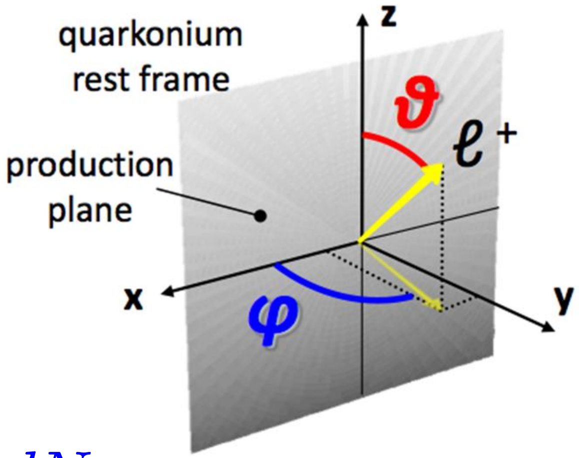
For public results from ATLAS see https://twiki.cern.ch/twiki/bin/view/AtlasPublic

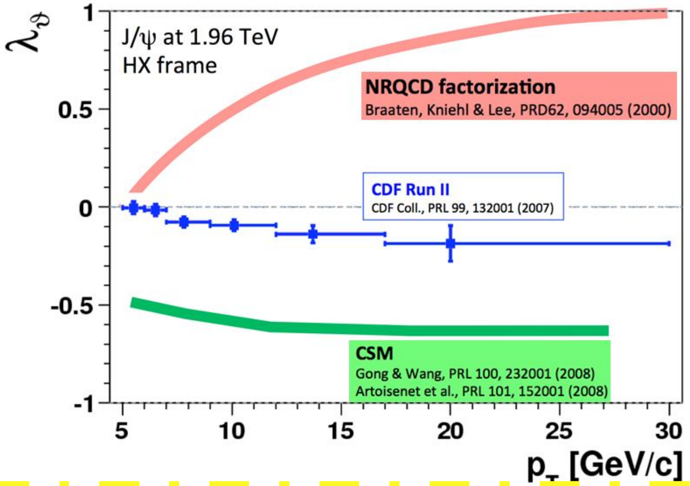
THANKS FOR LISTENING!

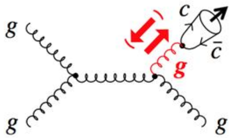
BACKUP SLIDES

Spin-alignment measurements

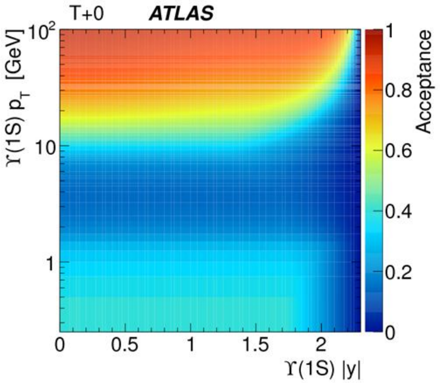
Measurement of spin-alignment (or 'polarisation') of quarkonia has historically proven to be a challenging observable to correctly predict

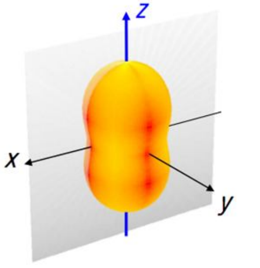






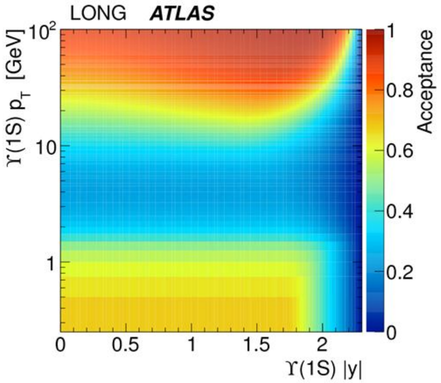
$$\frac{dN}{d\Omega} = 1 + \lambda_{\theta^\star}\cos^2\theta^\star + \lambda_{\phi^\star}\sin^2\theta^\star\cos 2\phi^\star + \lambda_{\theta^\star\phi^\star}\sin 2\theta^\star\cos\phi^\star$$

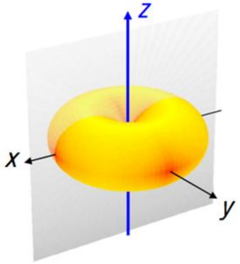




Transverse polarisation

$\frac{dN}{d\Omega} \propto 1+\cos^2\theta^\star$





Longitudinal polarisation

$\frac{dN}{d\Omega} \propto 1-\cos^2\theta^\star$

Measurement of Br($B^\pm \to \chi_{c1}K^\pm$)

Branching fraction measurement

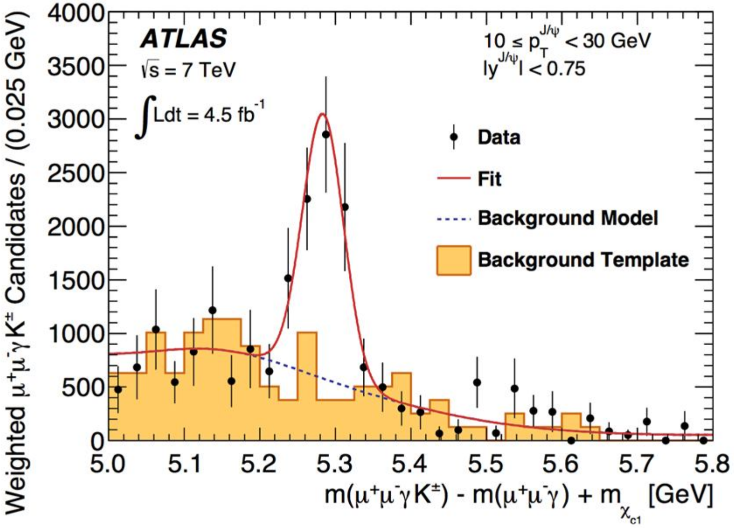
Using same χ_c data sample and selections, can extract measurement of Br($B^\pm \to \chi_{c1}K^\pm$)

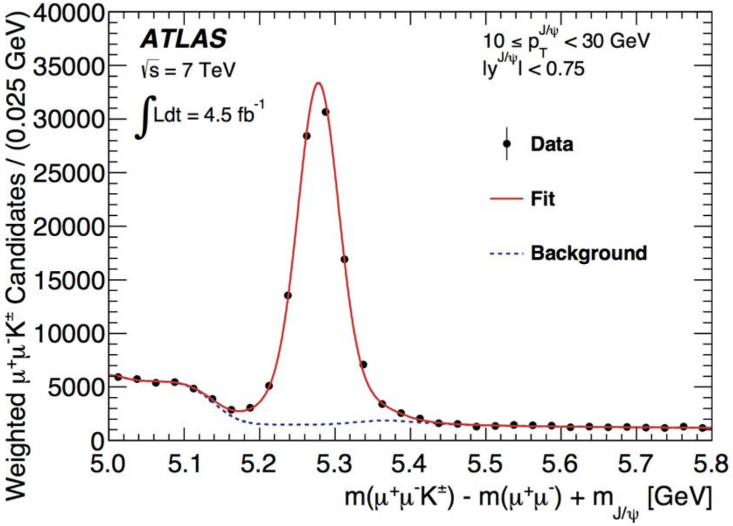
Use precisely-known $B^\pm \to J/\psi K^\pm$ decay as control.

$$\mathcal{B}\left(B^\pm \to \chi_{c1}K^\pm\right) = \mathcal{A}_B \cdot \frac{N^B_{\chi_{c1}}}{N^B_{J/\psi}} \cdot \frac{\mathcal{B}\left(B^\pm \to J/\psi K^\pm\right)}{\mathcal{B}\left(\chi_{c1} \to J/\psi\,\gamma\right)}$$

Hadron collider measurement not far from best B-factory results; prospects for improvements!

$B^\pm \to \chi_{c1}K^\pm$





$B^\pm \to J/\psi K^\pm$