Overview of ATLAS
Experiment and Results

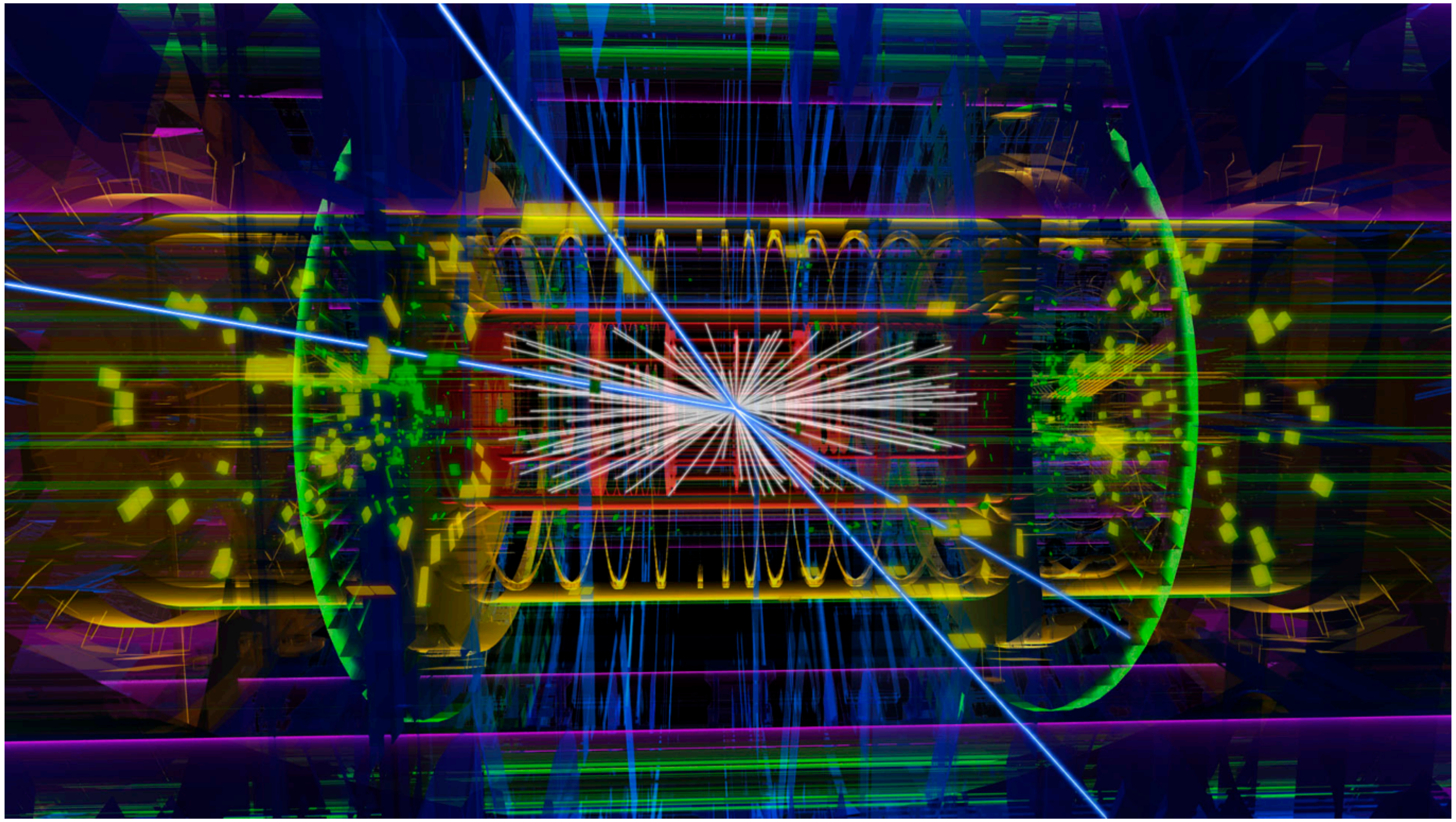
Michel Lefebvre, UVic
TRIUMF Workshop on LHC Results
2011/12/14

"The most prominent issue for the LHC is the quest for the origin of the spontaneous symmetry breaking mechanism in the electroweak sector of the Standard Model (...) The Higgs search is therefore used as a first benchmark for the detector optimization"

ATLAS Technical Proposal
15 December 1994

Content

- A few words on LHC operation and performance
- Overview of the ATLAS detector
- SM results
- Higgs highlights: See Pierre Savard's talk!
- BSM highlights: See Georges Azuelos' talk!
- A look ahead

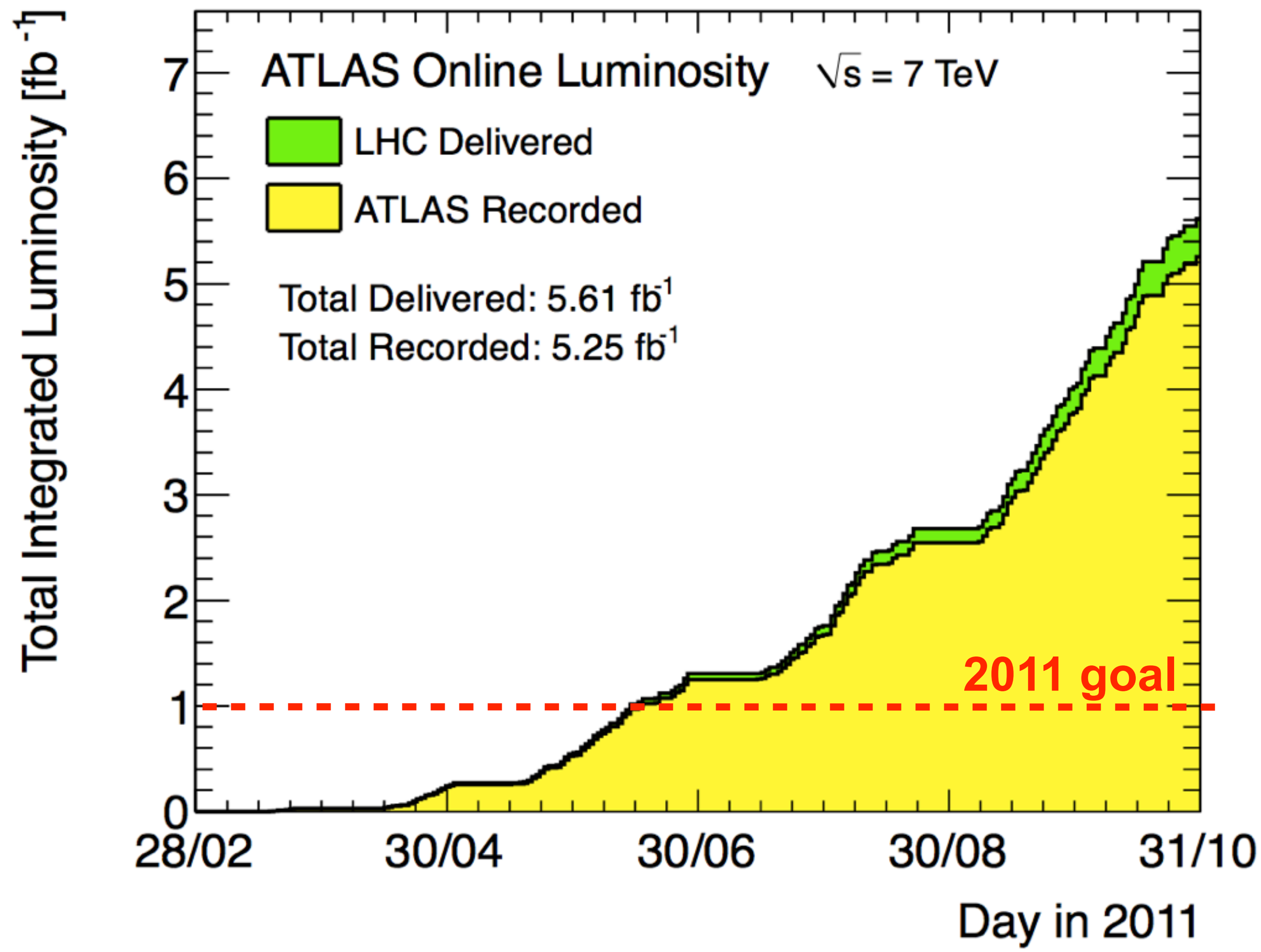


The LHC

Superb LHC performance!!

Parameter	2010	2011	Nominal
N (10^{11} p/b)	1.2	1.5	1.15
k (n bunches)	368	1380	2808
B. spacing	150	50	25
ε (μm rad)	2.4-4	1.9-2.3	3.75
β* (m)	3.5	1	0.55
L ($cm^{-2}s^{-1}$)	$2\ 10^{32}$	$3.6\ 10^{33}$	10^{34}
Stored Energy(MJ)	28	110	360

D.Fournier, HCP2011



$$L = \frac{k N_1 N_2 f}{4\pi\sigma_x^*\sigma_y^*}$$

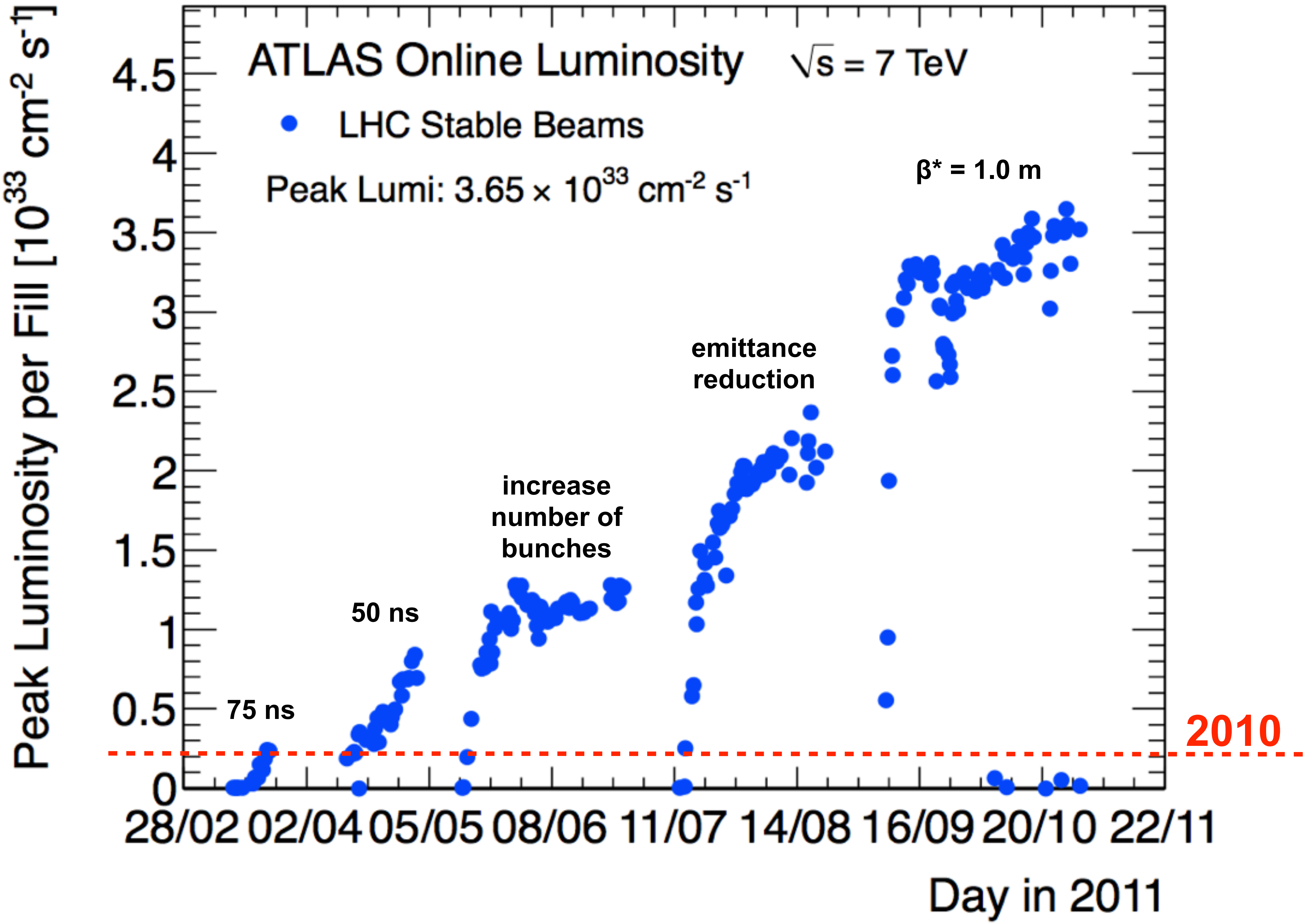
$\sigma^* = \sqrt{\beta^*\varepsilon}$ beam size at collision point

$f = 11.25\ \mathrm{kHz}$ machine revolution frequency

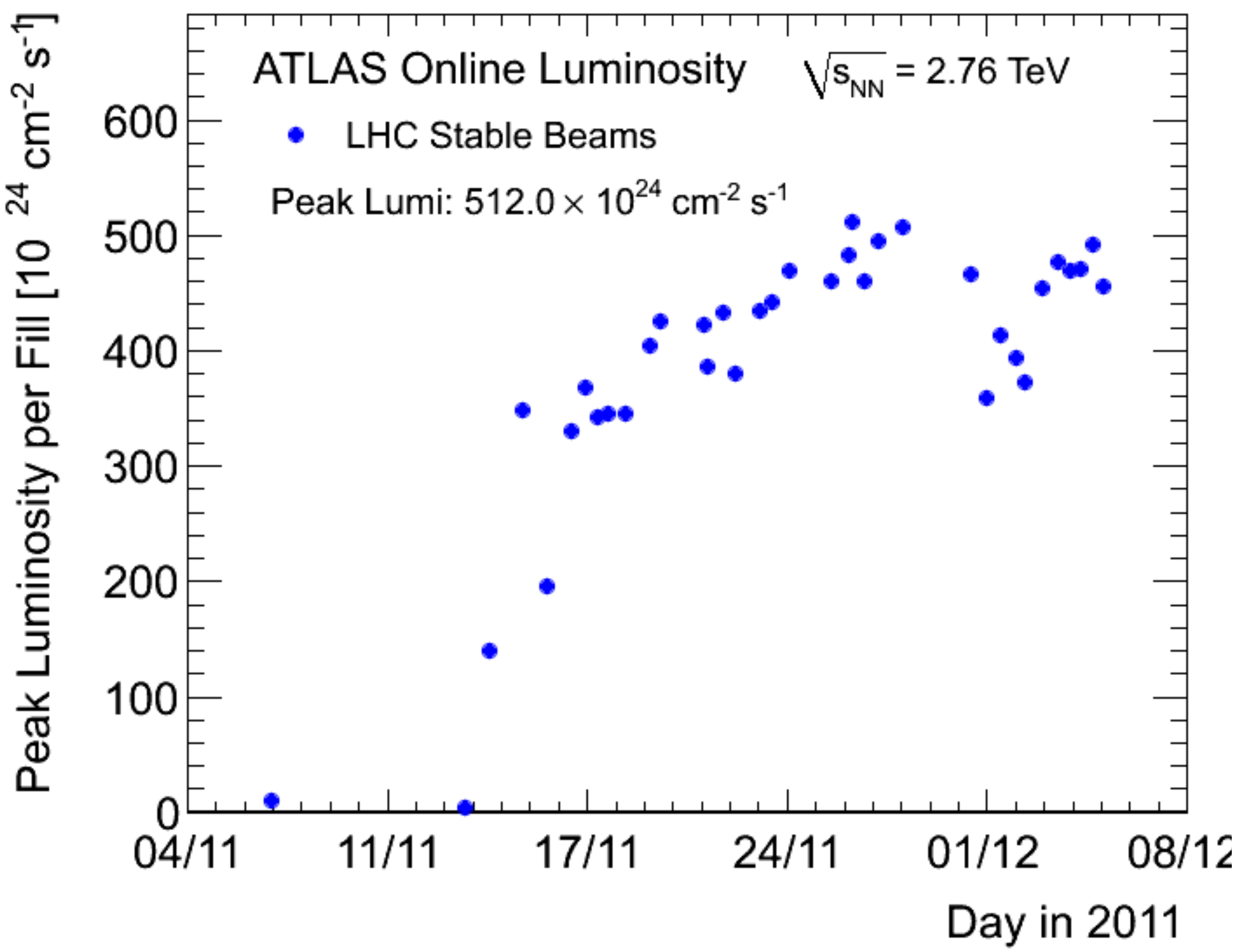
~117 -fold increase in integrated luminosity compared to 2010 !

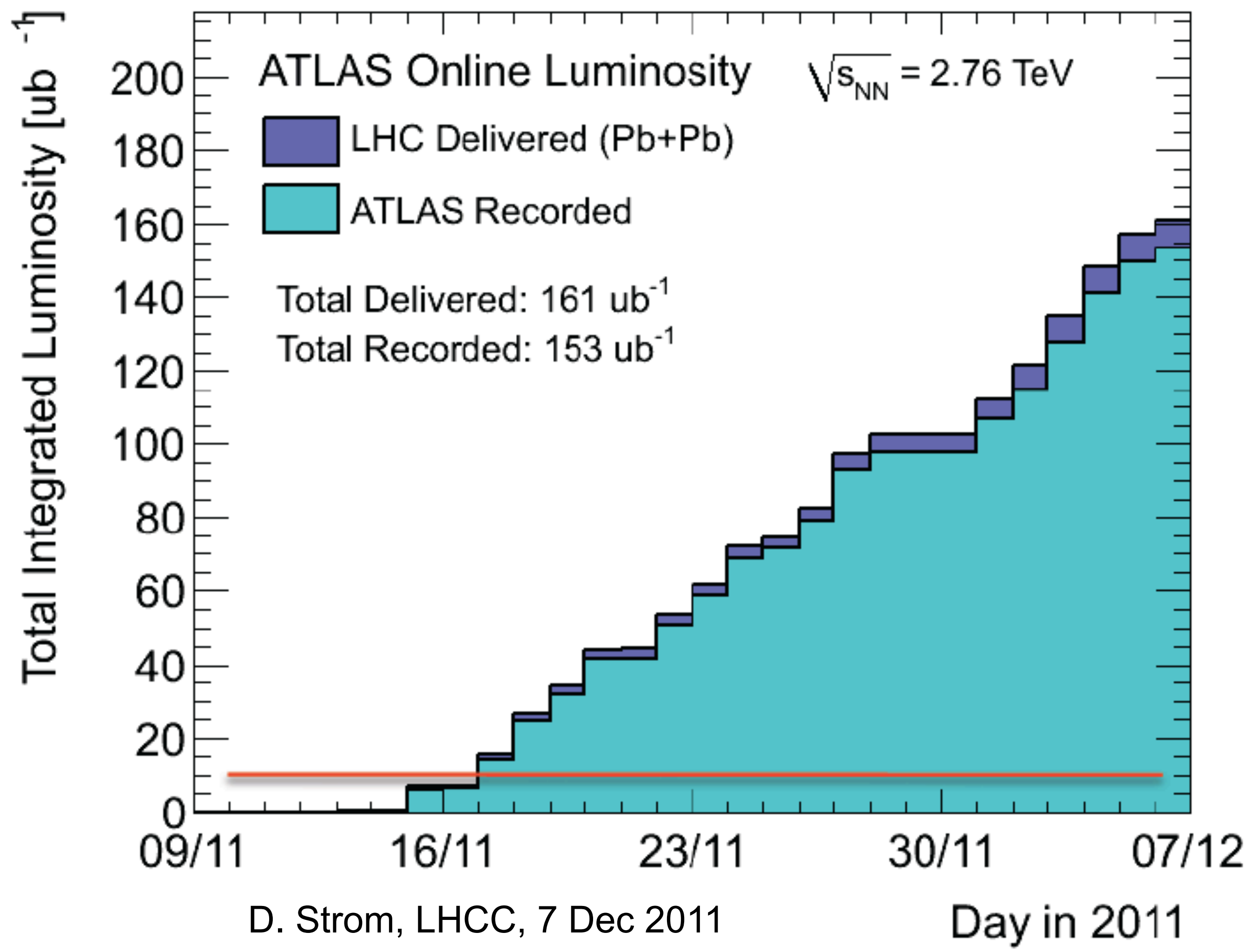
~20 -fold increase in peak luminosity compared to 2010 !

Increase of peak luminosity over 2011



Pb-Pb operation in 2011





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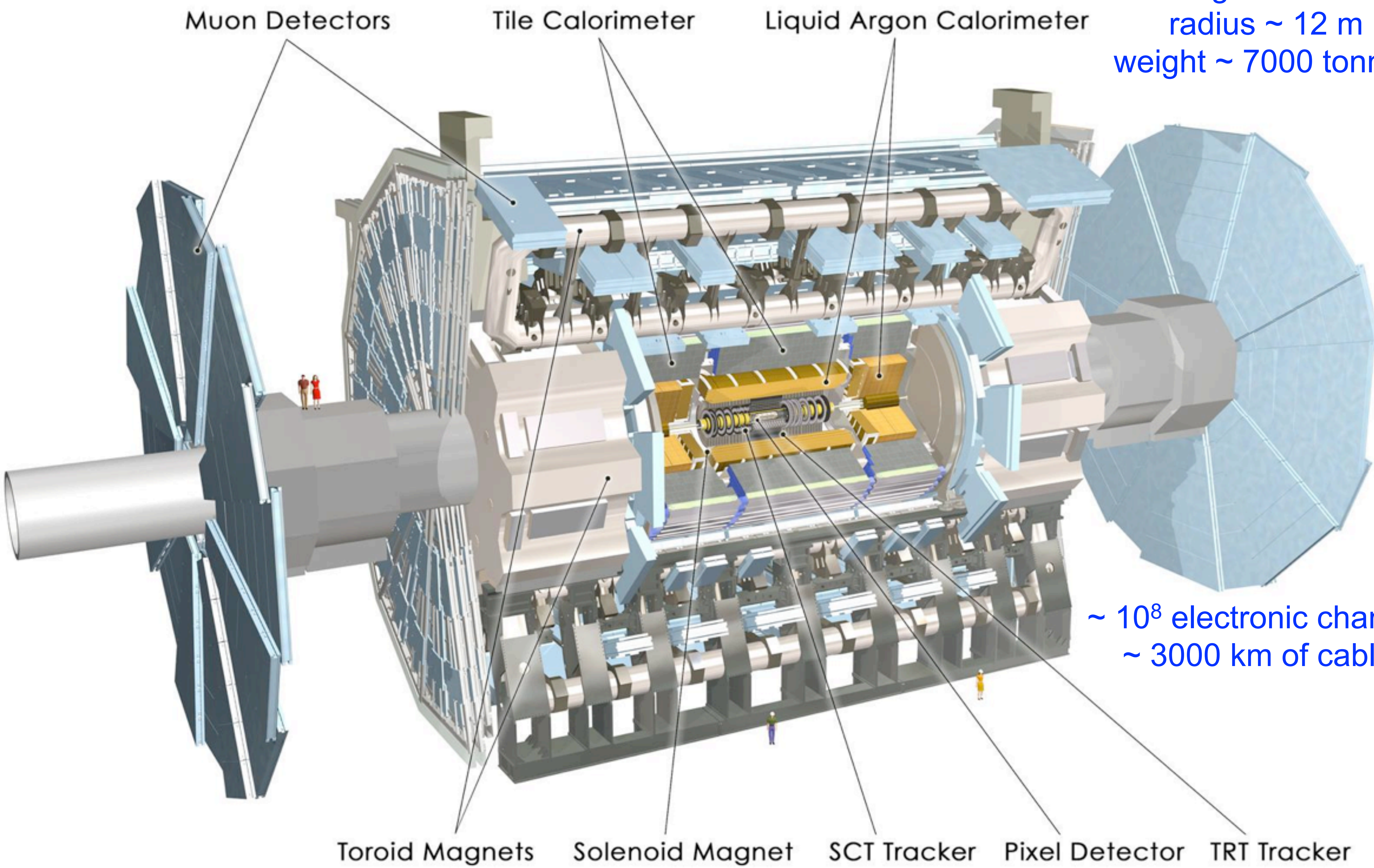
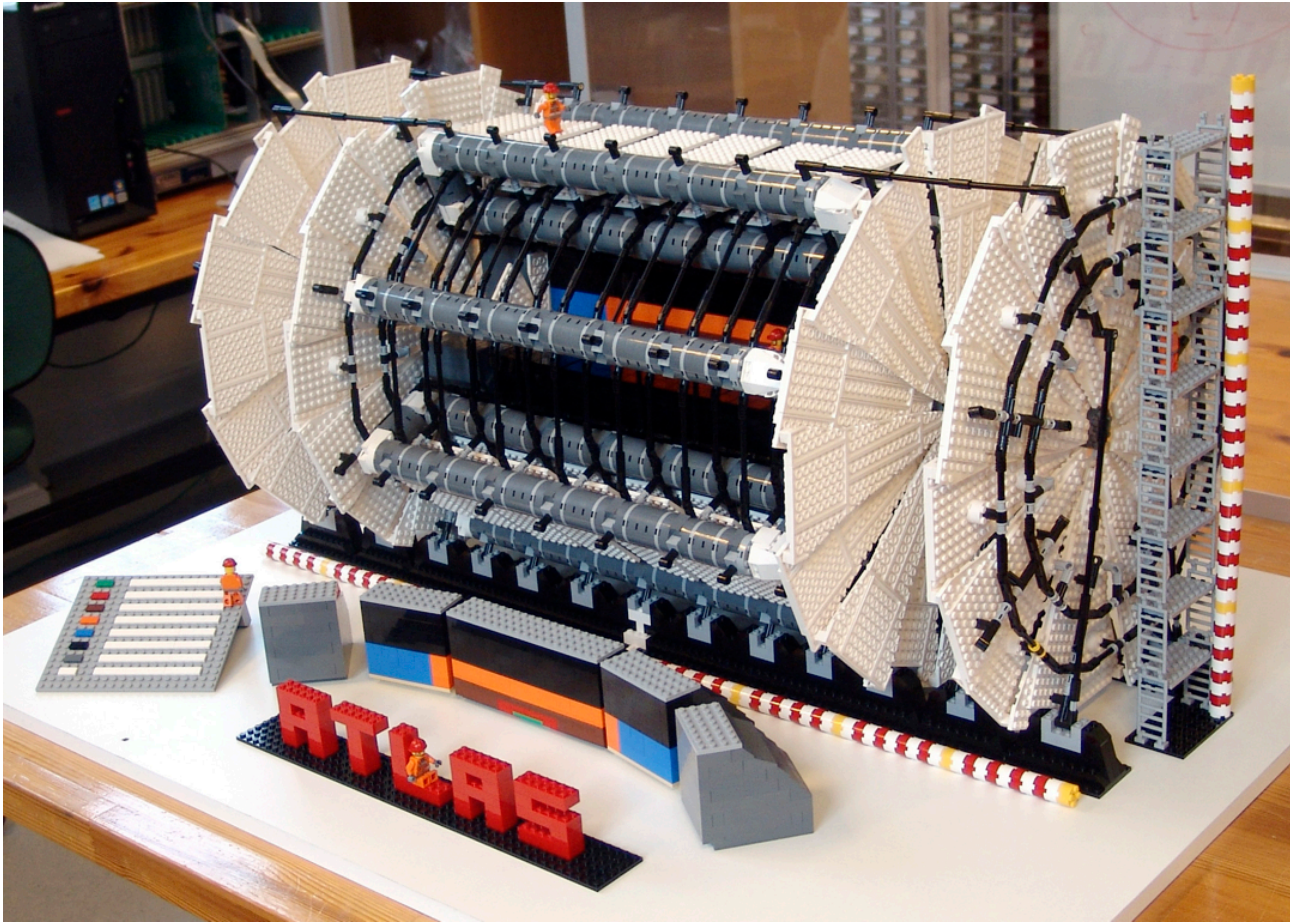
~15 times more data than in 2010!

The ATLAS detector

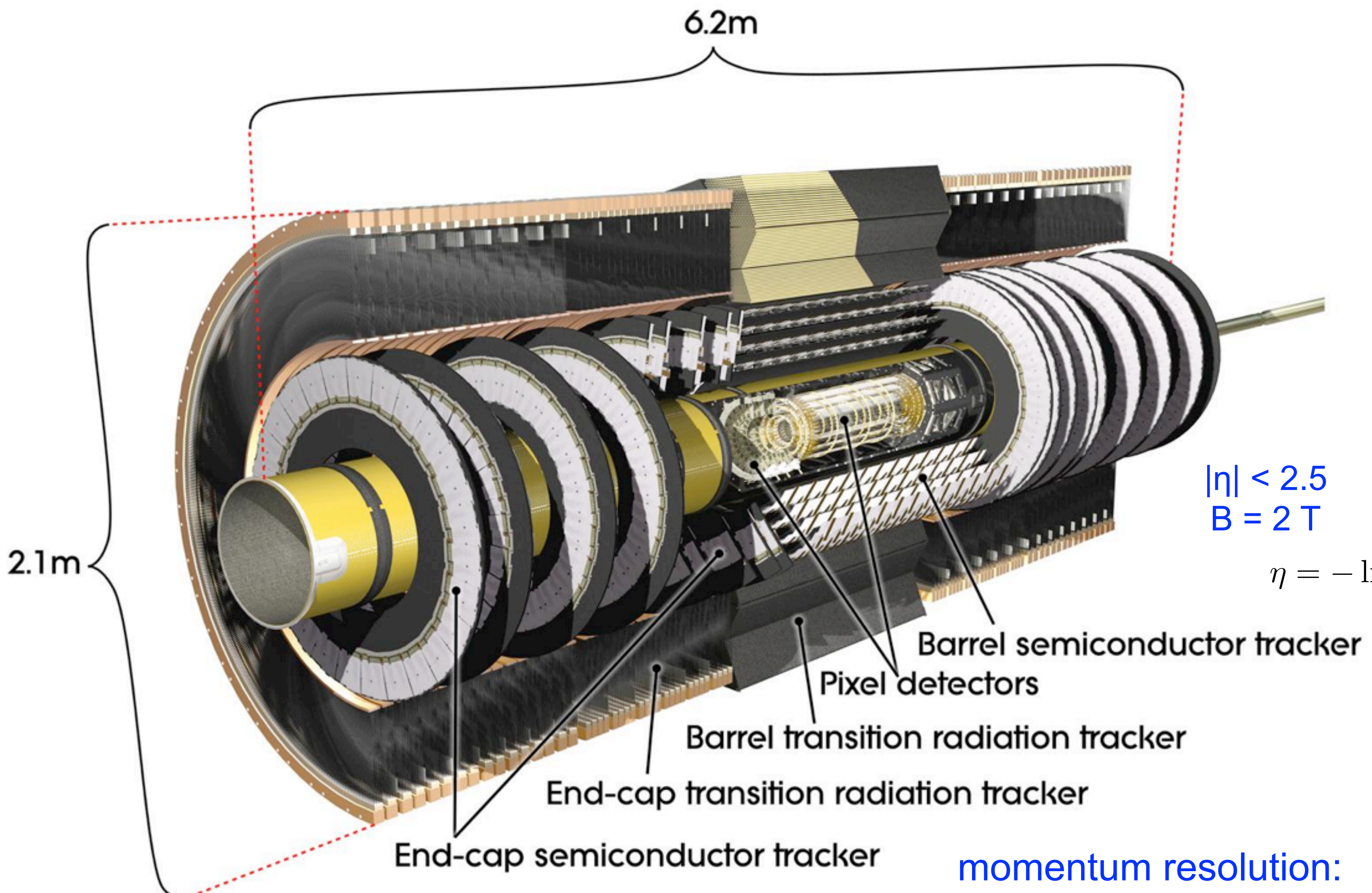
length ~ 46 m
radius ~ 12 m
weight ~ 7000 tonnes



~ 10^8 electronic channels
~ 3000 km of cables


ATLAS

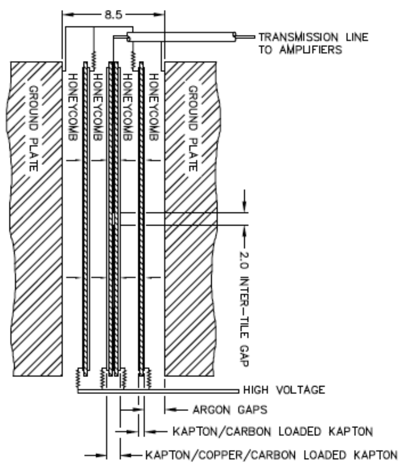
The ATLAS Inner Detector



$|\eta| < 2.5$
$B = 2$ T

$$\eta = -\ln\left[\tan\left(\frac{\theta}{2}\right)\right]$$

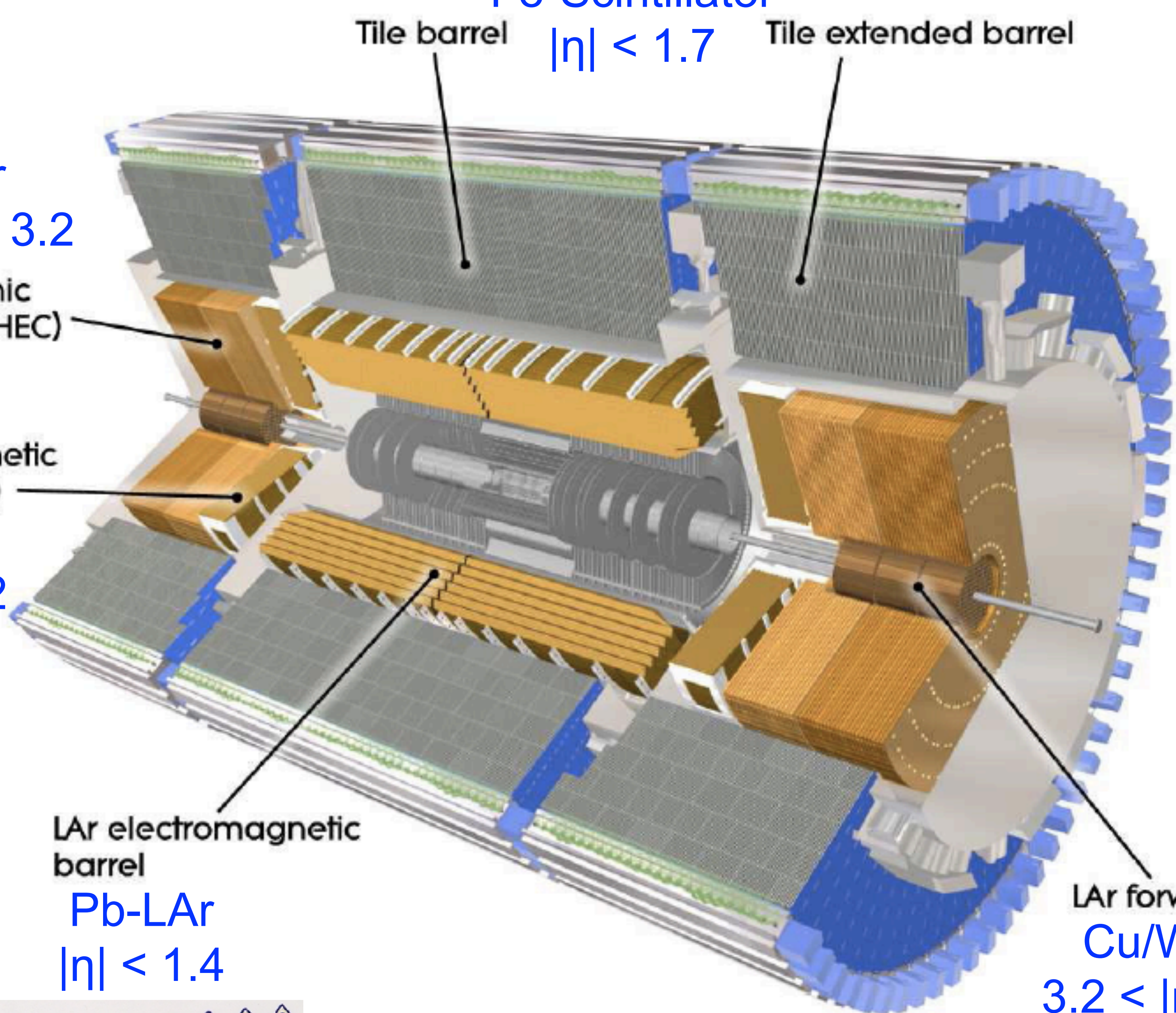
momentum resolution:
$\sigma/p_T \sim 3.8\times10^{-4}\, p_T\,(\mathrm{GeV}) \oplus 0.015$



The ATLAS Calorimeters

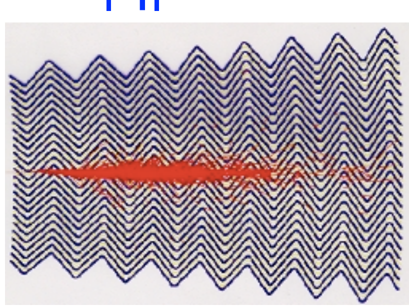
Fe-Scintillator
$|\eta| < 1.7$

Cu-LAr
$1.5 < |\eta| < 3.2$



Pb-LAr
$1.375 < |\eta| < 3.2$

Pb-LAr
$|\eta| < 1.4$

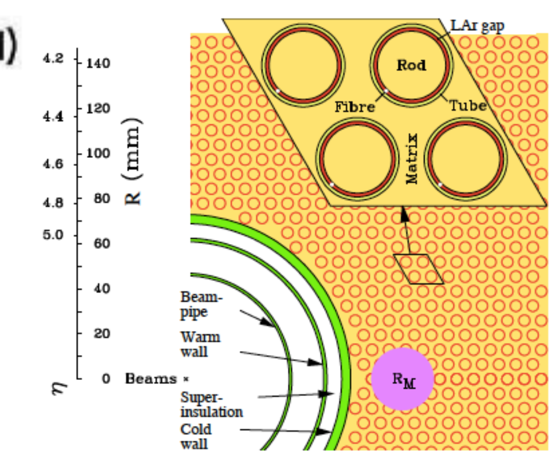


Cu/W-LAr
$3.2 < |\eta| < 4.9$

Segmented in pseudo-rapidity η and azimuthal angle ϕ

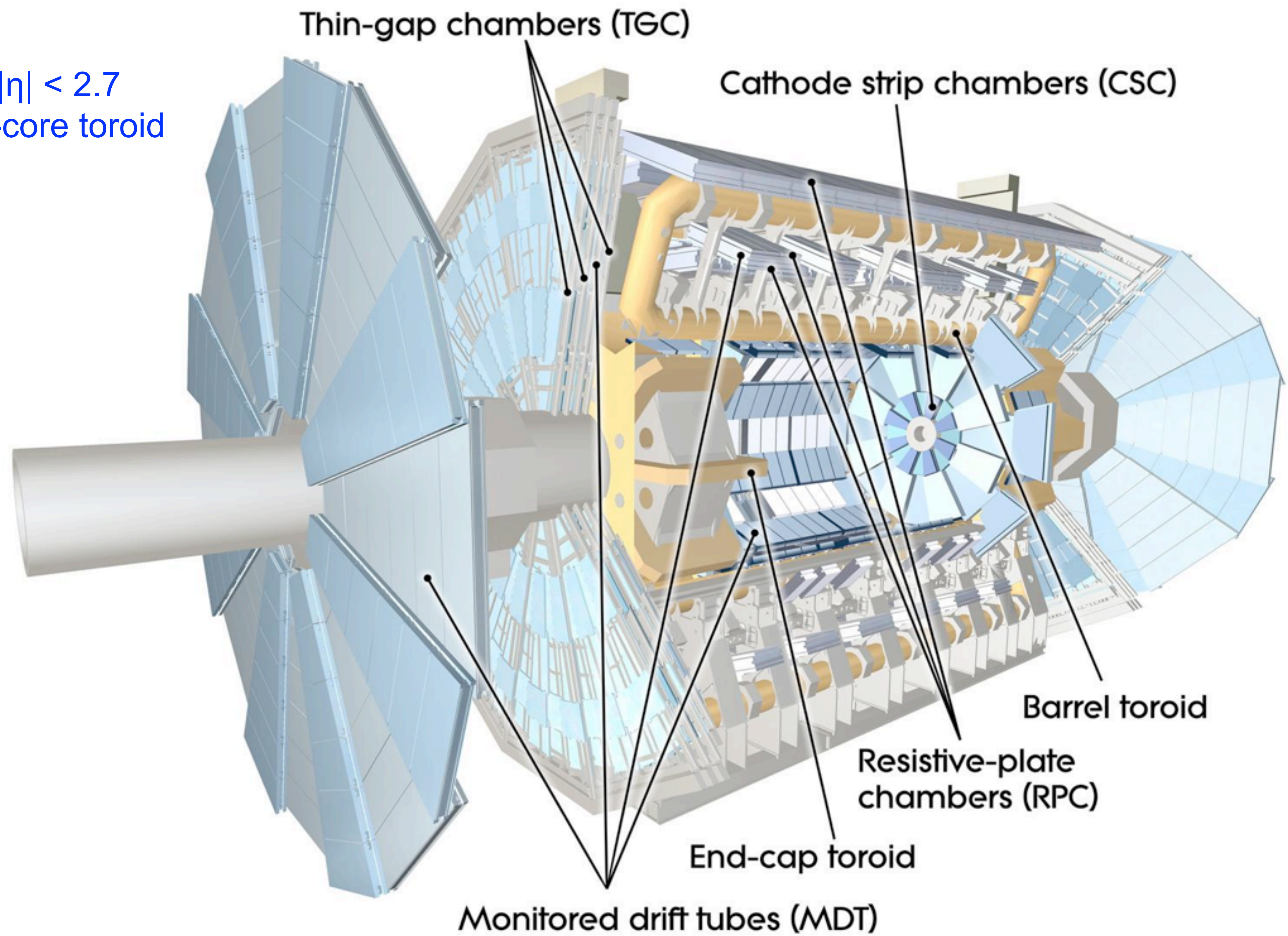
$$\eta = -\ln\left[\tan\left(\frac{\theta}{2}\right)\right]$$

- LAr system: 182,468 cells
- Tile system: 10,364 cells



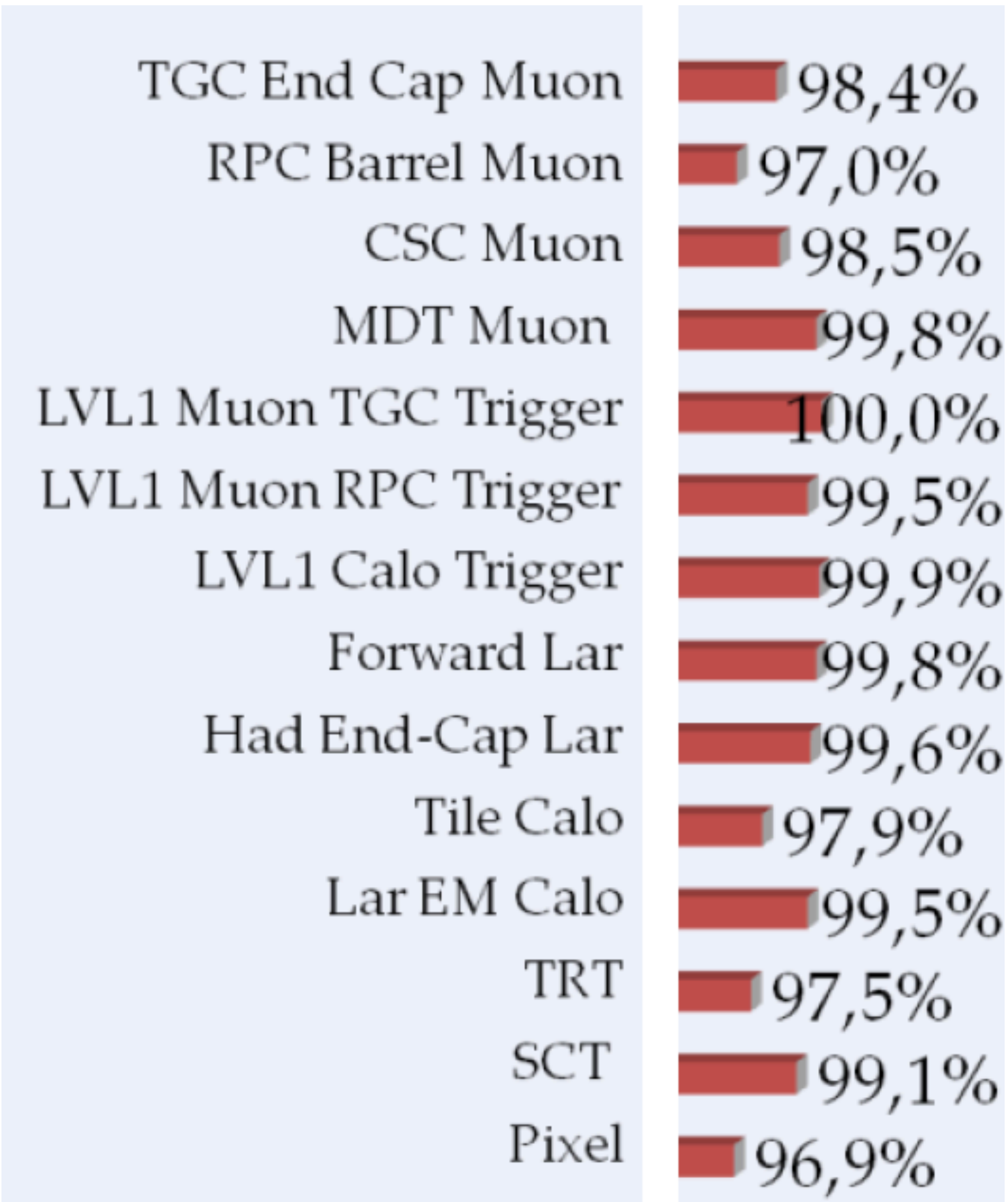
The ATLAS Muon Detectors

|η| < 2.7
air-core toroid

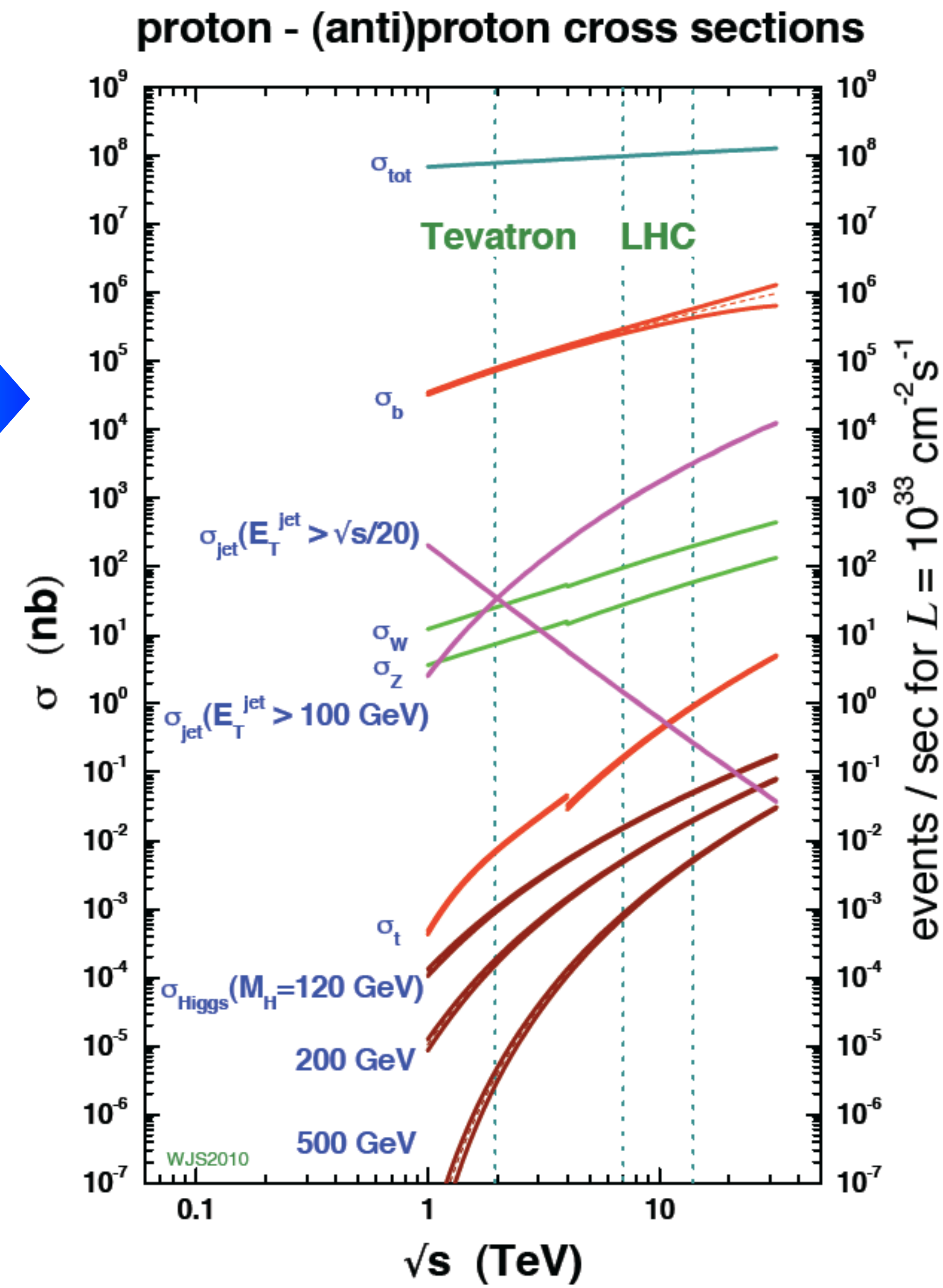


Getting down to business

% live ATLAS channels



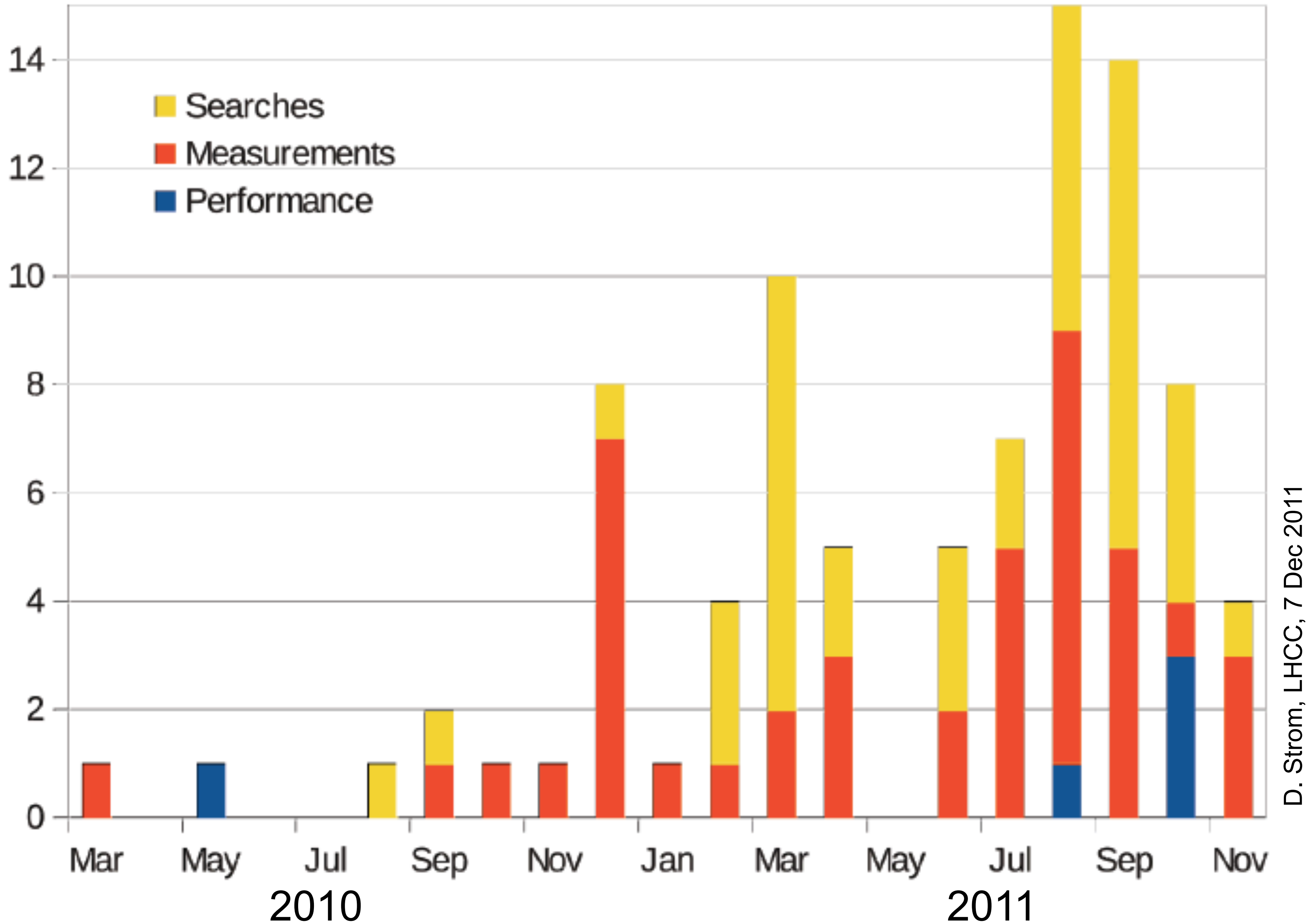
D.Fournier, HCP2011



ATLAS publications on collision data

88 papers submitted

261 public CONF notes



Luminosity normalization

- Accurate measurement of the luminosity is very important
  - often one of the dominant systematic uncertainties in SM cross sections
  - affects knowledge of background levels for searches, hence sensitivity

$$L = \frac{k N_1 N_2 f}{2\pi \Sigma_x \Sigma_y} = \frac{\mu_{\rm vis} k f}{\sigma_{\rm vis}}$$

characterize beam profile

For a reference run with ATLAS luminosity monitors recorded, perform a van der Meer scan, where beams are separated by steps of known distance

Measure $\mu_{\rm vis}^{\rm max}, \ \Sigma_x, \ \Sigma_y$ from Gaussian fits

then $\sigma_{\rm vis} = \mu_{\rm vis}^{\rm max} \frac{2\pi \Sigma_x \Sigma_y}{N_1 N_2}$ bunch charge product measured separately

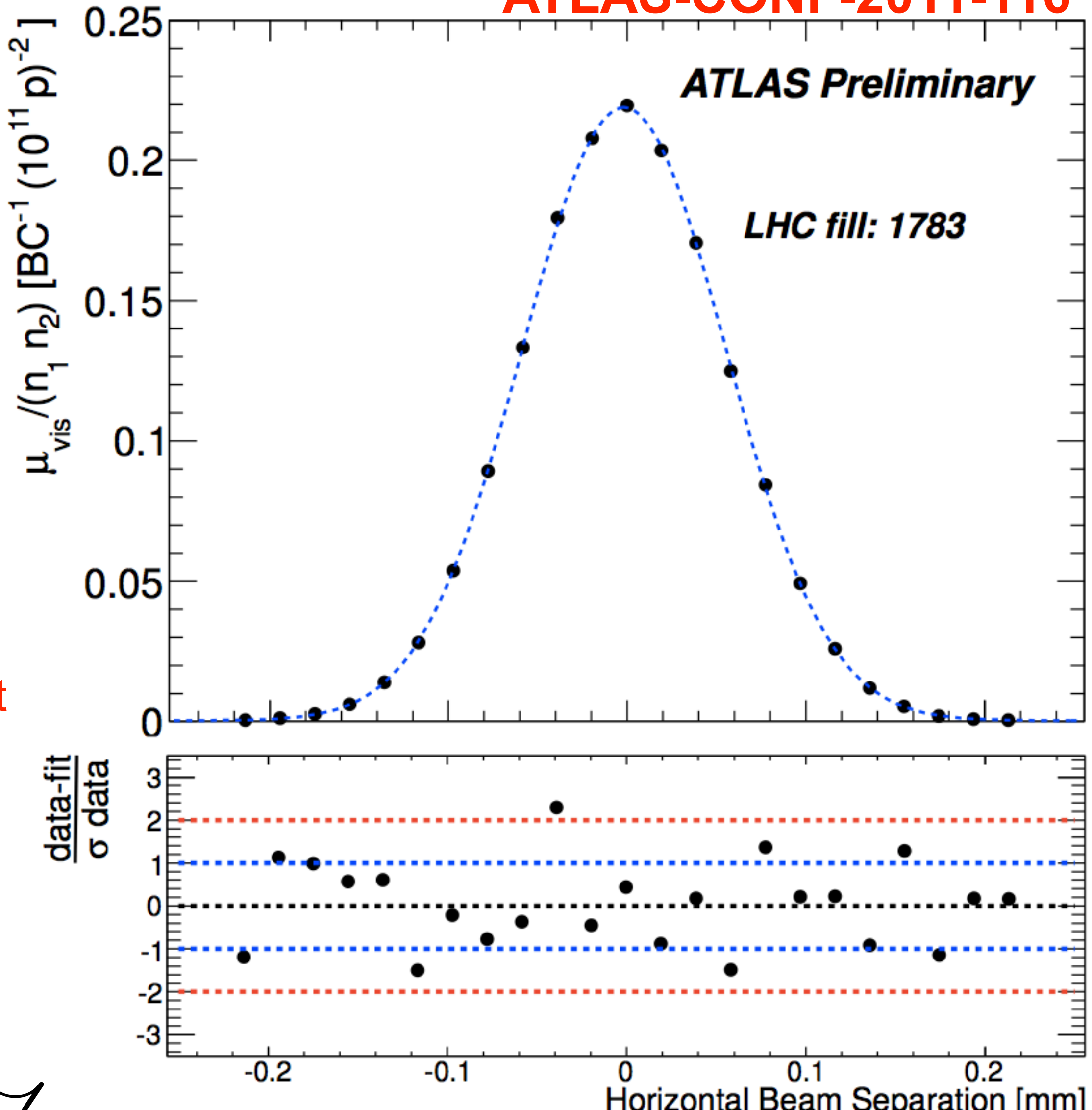
per luminosity detector and algorithm
per BCID

For a given run, obtain the luminosity from

$$L = \frac{\mu_{\rm vis} k f}{\sigma_{\rm vis}}$$

Study of uncertainty yields $\frac{\delta L}{L} = 3.7\%$

ATLAS-CONF-2011-116

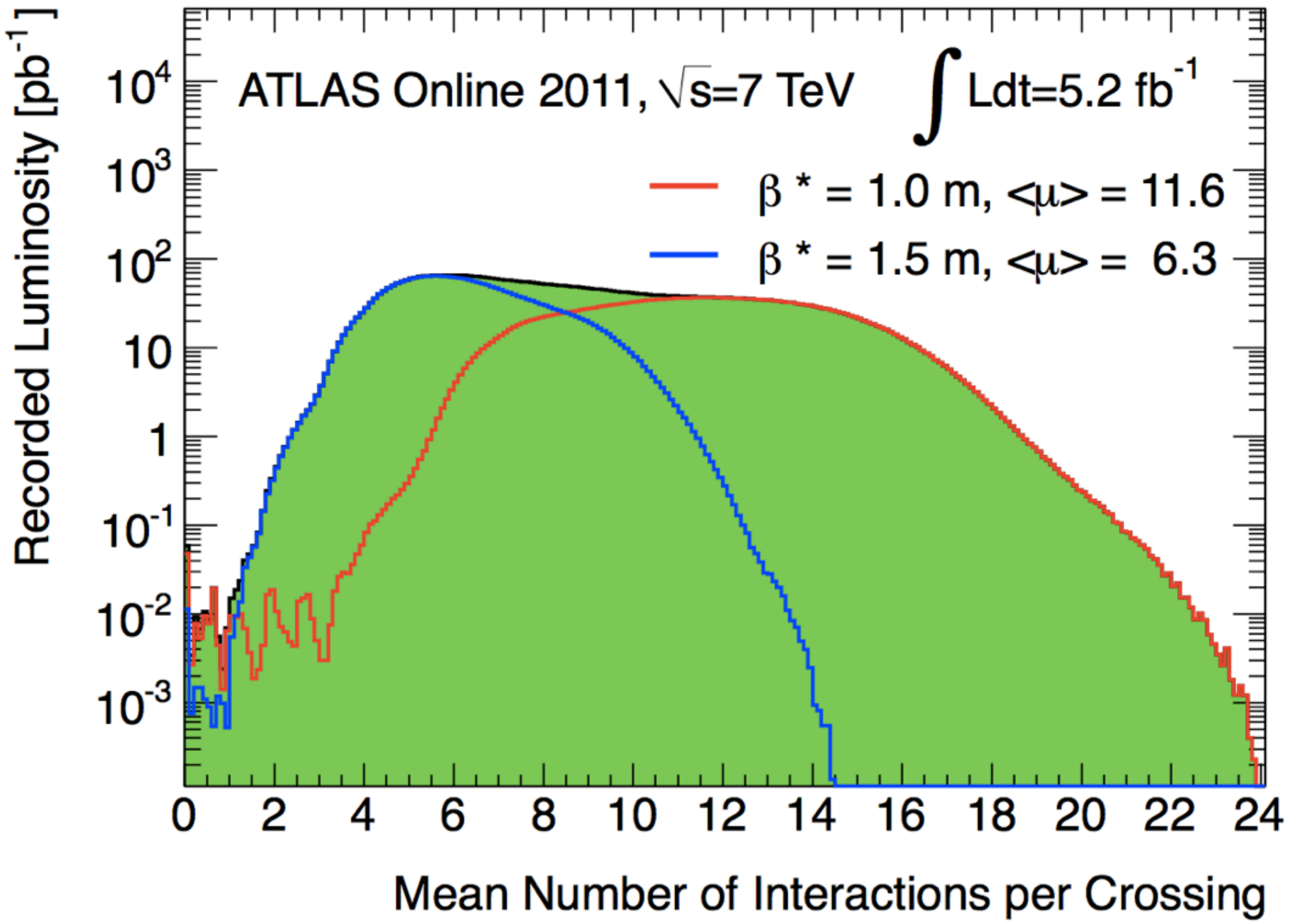


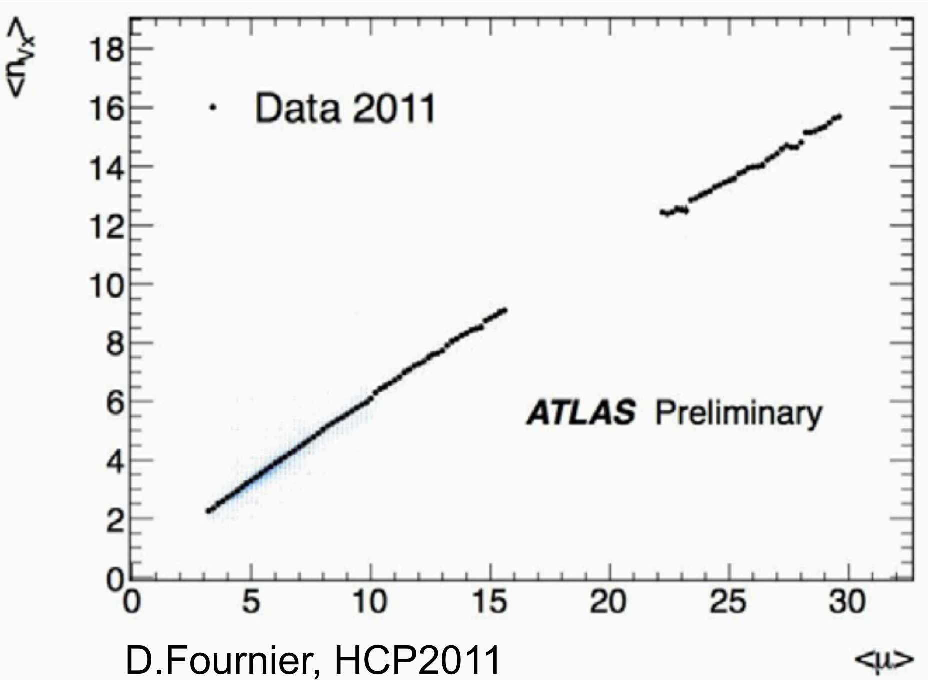
Pile-up

- In-time pile-up
  - due to collisions in one bunch crossing (BC)
- Out-of-time pile-up
  - superposition of signal from preceding (and following) BC
- Relevant parameters
  - μ: luminosity-weighted mean number of interaction per BC

$$\mu = \frac{L\sigma_{\mathrm{inel}}}{kf}$$

    - dispersion includes bunch-to-bunch variations and drop of L with time
  - N_{VX}: number of reconstructed primary vertices per BC
    - event-by-event proxy for μ

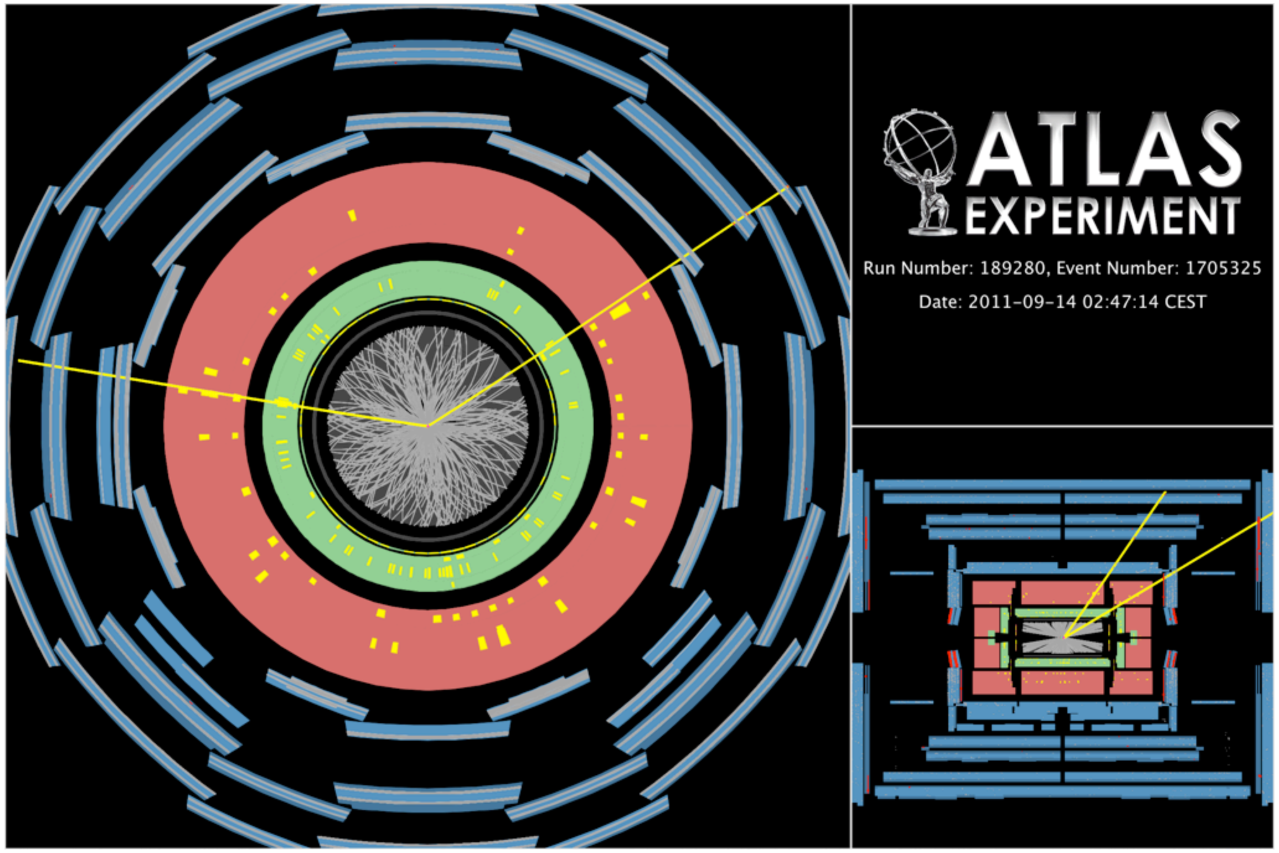




D.Fournier, HCP2011

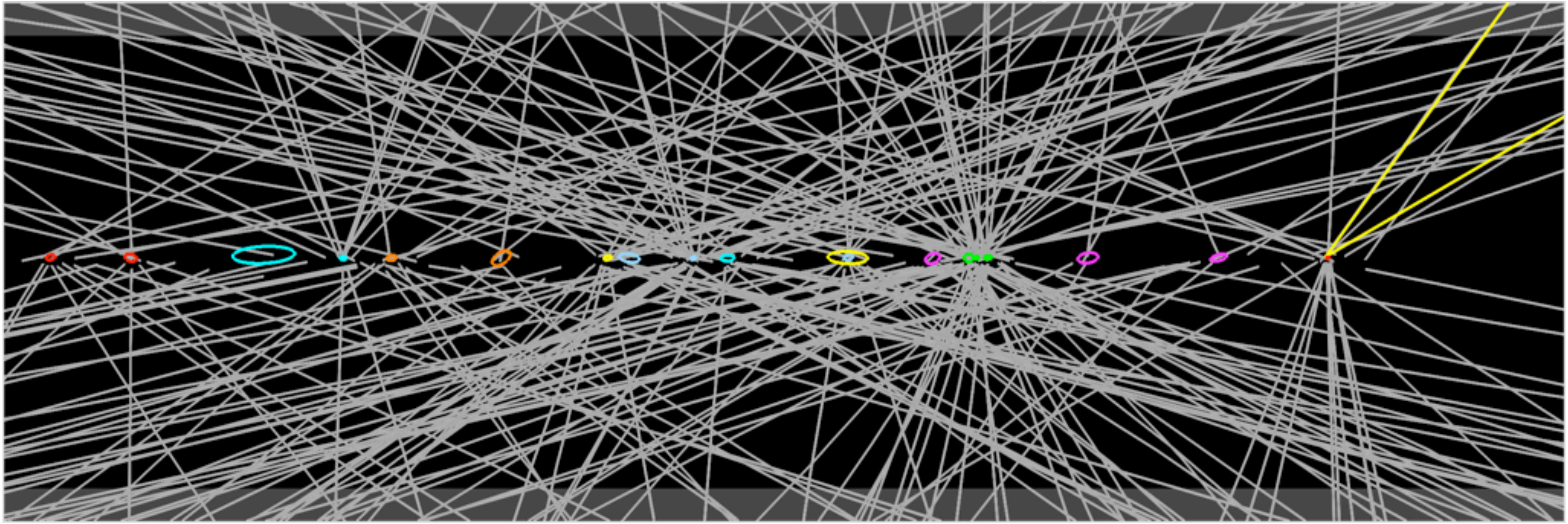
Z→μμ event with N_{VX} = 20

~typical for fall 2011 running with β* = 1 m



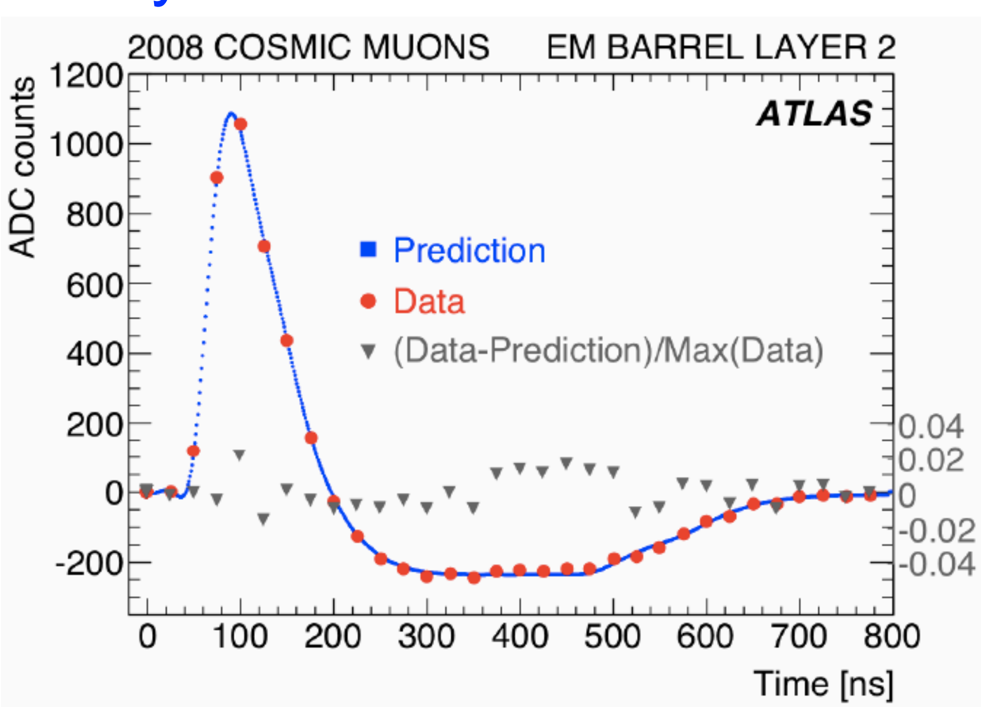
The track p_T threshold is 0.4 GeV and all tracks are required to have at least 2 Pixel and 7 SCT hits. The vertices shown are reconstructed using tracks with p_T greater than 0.4 GeV.

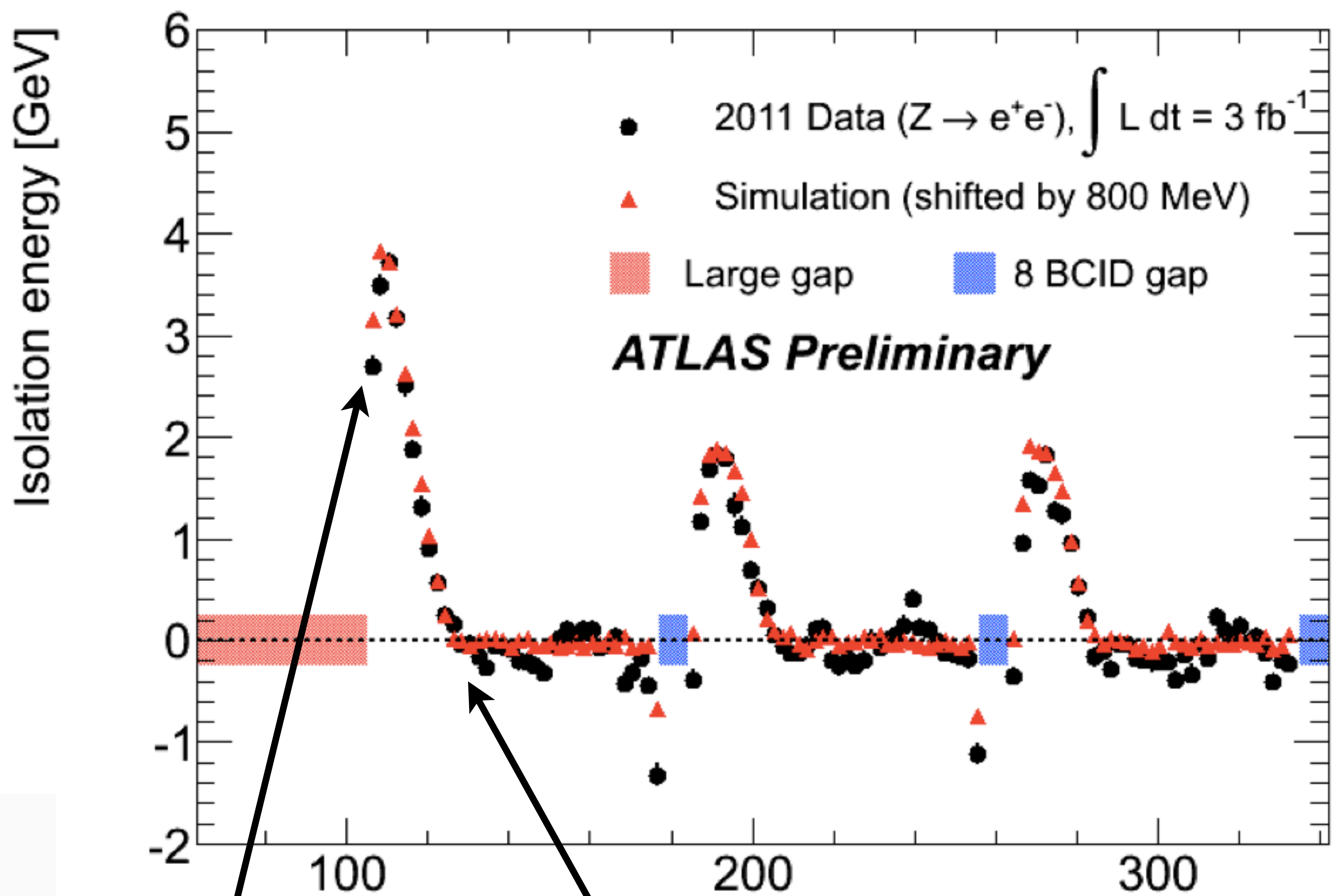
Ellipses have are 20 X.



e± and photon isolation energy

- e± and photon isolation criteria important to reject backgroud
- photon isolation criteria
  - E_T < 5 GeV inside a cone of R = 0.4 centred on photon direction
  - does not include core energy of the EM deposit
  - underlying event and in-time pile-up subtracted using an “ambient energy density” evaluated event-by-event





Excellent understanding of out-of-time pile-up on LAr calorimeter signal

DAQ and Data Quality

- Overall data taking efficiency 93.5%
  - without warm-start: 94.7%

Cause	Inefficiency
Dead time	1.0
Warm-start	1.2
DAQ Actions	1.2
Equipment Failure (incl. Human Resp.)	2.8

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- Extensive Data Quality procedure and checks
  - only data that are flagged of good quality are fit for analysis
  - excellent performance of all sub-detectors

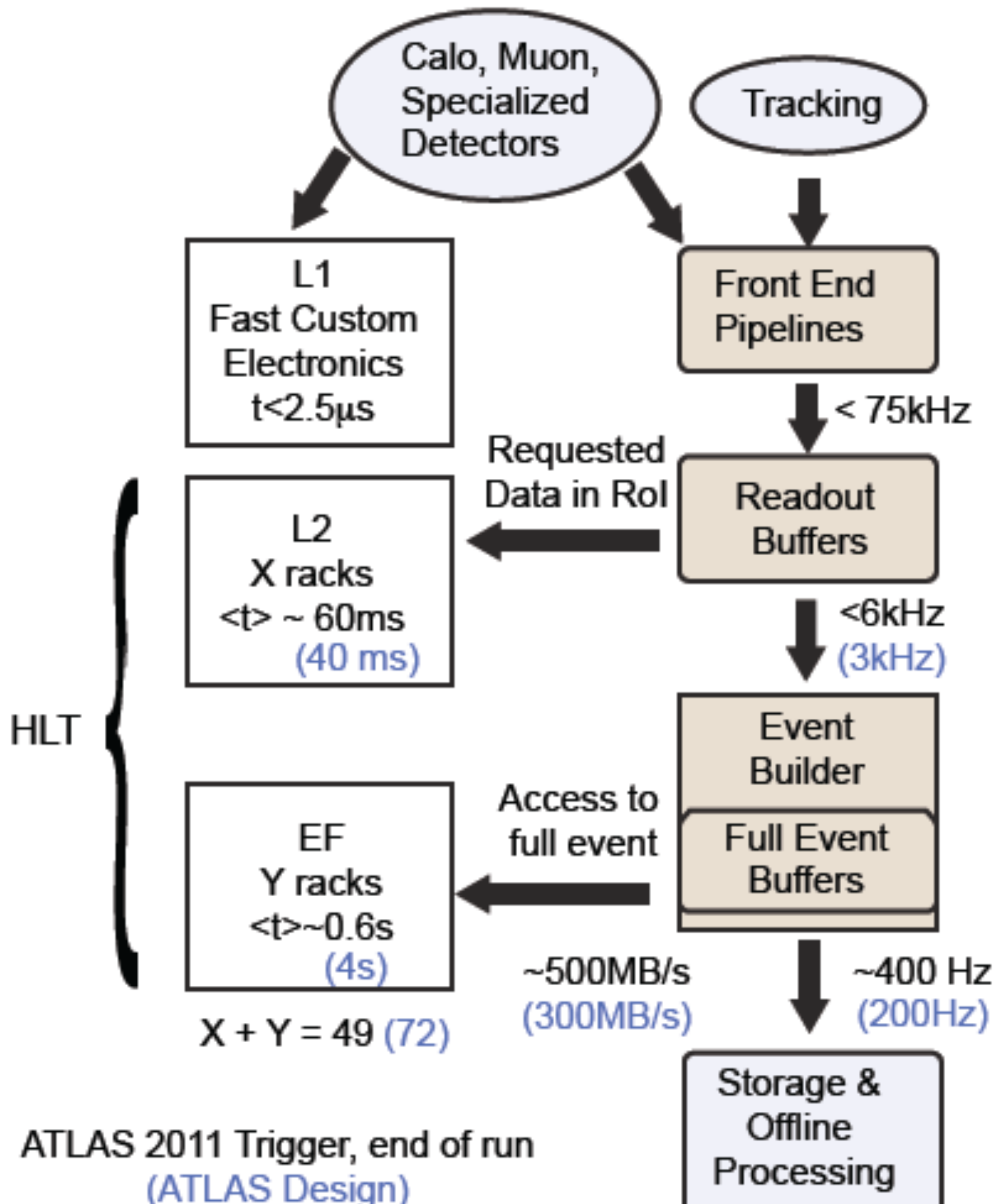
Luminosity weighted fraction of data after data quality cuts used for analysis

Inner Tracking Detectors			Calorimeters				Muon Detectors				Magnets	
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.8	99.6	99.2	97.5	99.2	99.5	99.2	99.4	98.8	99.4	99.1	99.8	99.3

Luminosity weighted relative detector uptime and good quality data delivery during 2011 stable beams in pp collisions at $\sqrt{s}$=7 TeV between March 13th and October 30th (in %), after the summer 2011 reprocessing campaign

DQ efficiency for physics analysis ≥ 90%

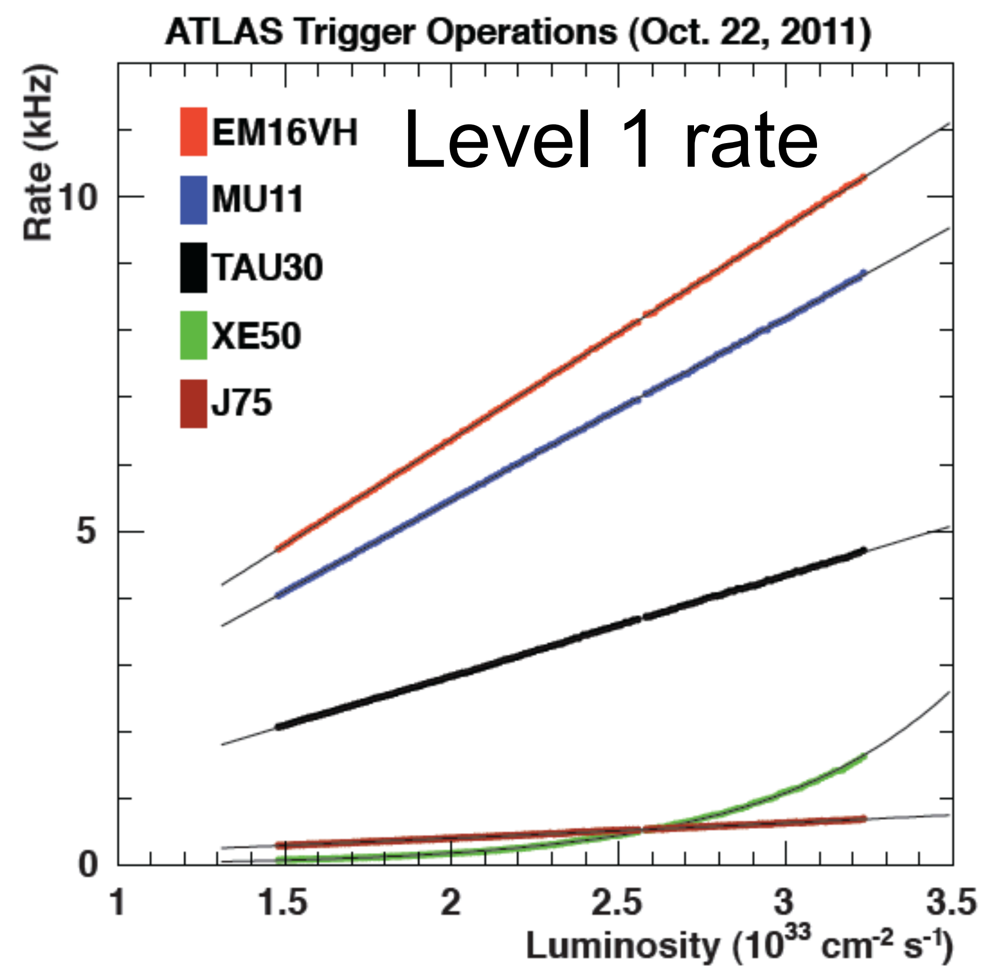
Trigger and DAQ



Submitted to EPJC

D. Strom, LHCC, 7 Dec 2011

- DAQ readout rate significantly beyond design
  - lower thresholds
- Sophisticated tools in place to predict resource usage throughout system
- Menus and algorithms
  - ~200 Level 1 items
  - ~500 Level 2 chains
  - ~500 Event Filter chains

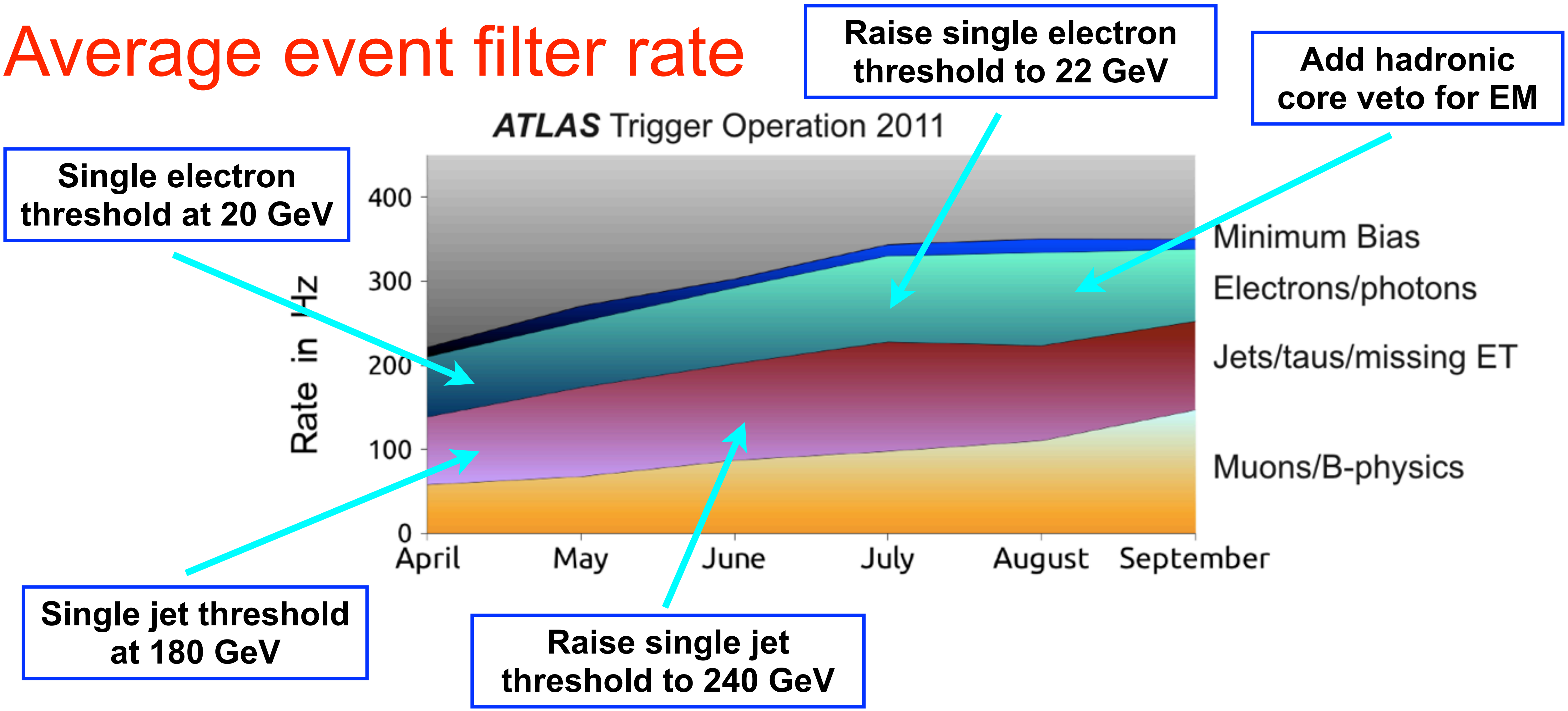


2011: from 20 MHz to ≳ 300 Hz on disk.

Over 10^{14} events through the trigger system!

Trigger evolution in 2011

Average event filter rate



Level 1			High Level Trigger						
Muon	Calo	CTP	electron	photon	muon	tau	jet	b-jet	missing E_T
100	100	100	100	100	100	99.5	97.3	99.5	100

Luminosity weighted relative trigger quality delivery during 2011 stable beams in pp collisions at $\sqrt{s}$=7 TeV between March 13th and June 29th (in %).

2011 proton trigger menu

End of run L = 3.3 × 10^{33} $cm^{-2}s^{-1}$

	Offline Selection	Trigger Selection		L1 Rate (kHz) at 3e33	EF Rate (Hz) at 3e33
		L1	EF		
Single leptons	Single muon > 20GeV	11 GeV	18 GeV	8	100
	Single electron > 25GeV	16 GeV	22 GeV	9	55
Two leptons	2 muons > 17, 12GeV	11GeV	15,10GeV	8	4
	2 electrons, each > 15GeV	2x10GeV	2x12GeV	2	1.3
	2 taus > 45, 30GeV	15,11GeV	29,20GeV	7.5	15
Two photons	2 photons, each > 25GeV	2x12GeV	20GeV	3.5	5
Single jet plus MET	Jet pT > 130 GeV & MET > 140 GeV	50 GeV & 35 GeV	75GeV & 55GeV	0.8	18
MET	MET > 170 GeV	50 GeV	70GeV	0.6	5
Multi-jets	5 jets, each pT > 55 GeV	5x10GeV	5x30GeV	0.2	9
TOTAL				**<75**	**~400 (mean)**

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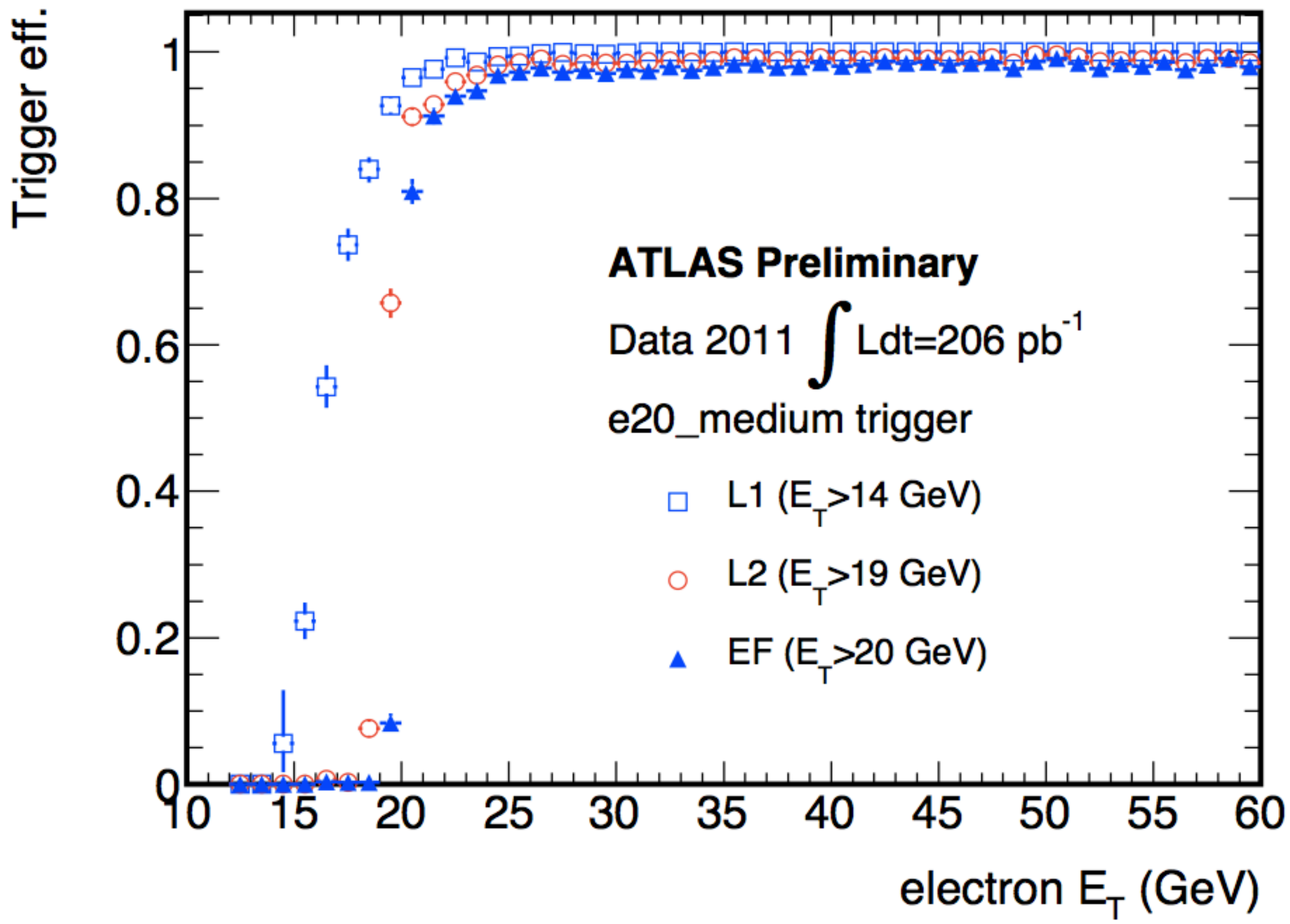
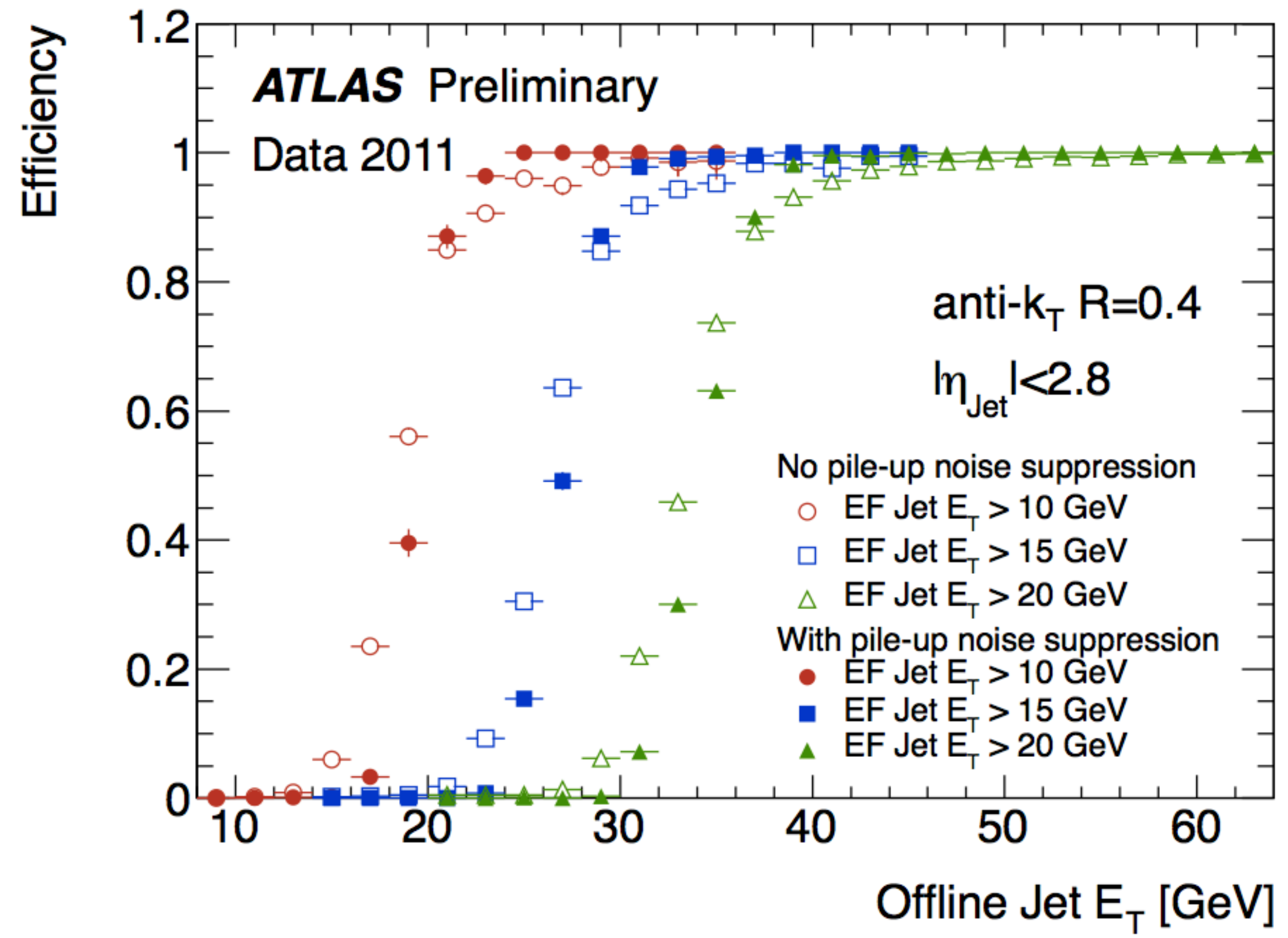
High Level Trigger performance

Single electron trigger efficiency at L1, L2 and EF levels, measured with Z → ee events using the tag-and-probe method

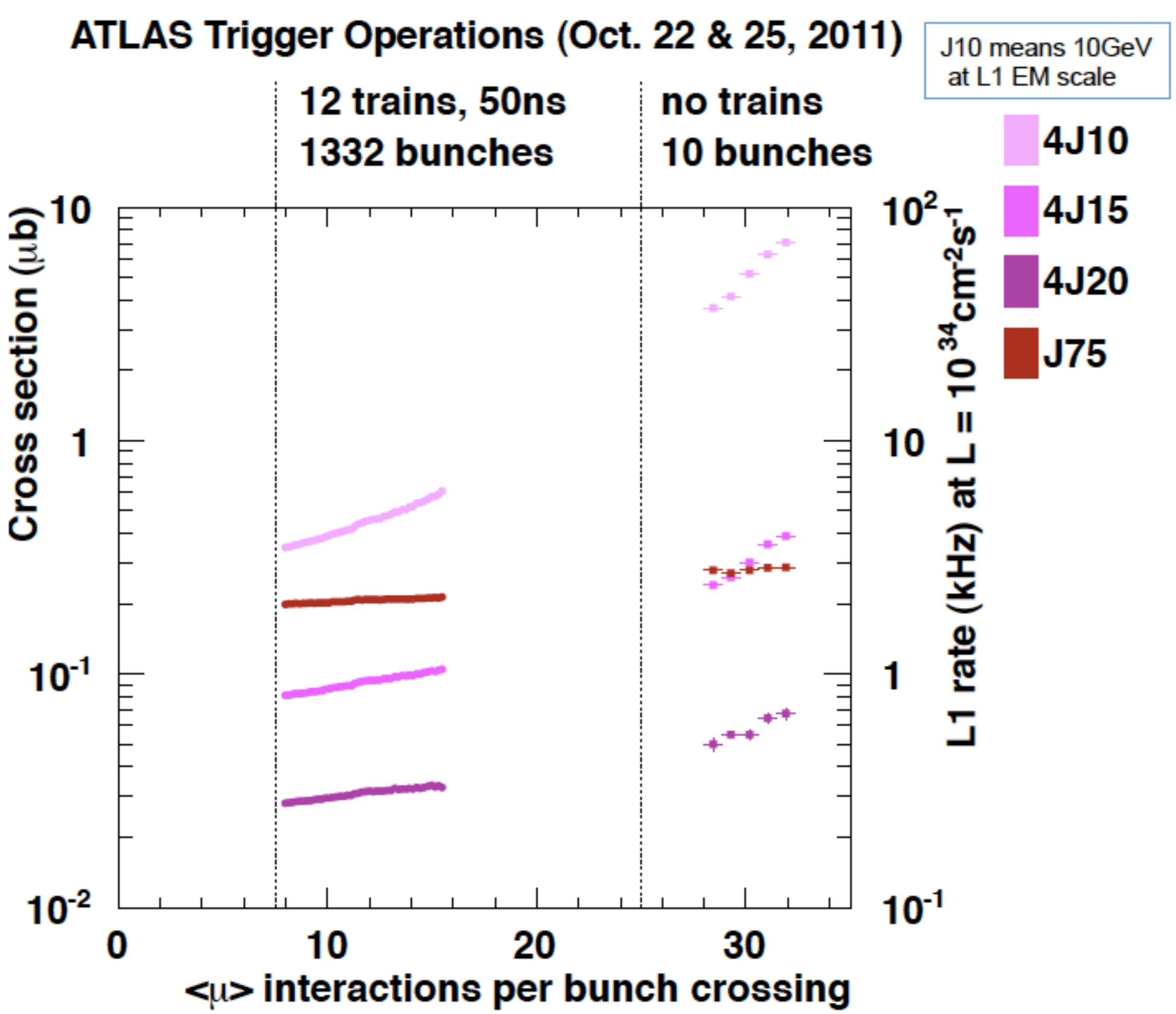




Single jet trigger efficiency at EF level. Pile-up noise suppression significantly improves the quality of the turn-on curves.

HLT performance and pile-up

- Most trigger cross sections have limited dependence on pile-up
  - Level 2 CPU time linear with pile-up for key algorithms
  - Multi-jet rates and missing E_T are especially sensitive to pile-up
  - Many handles to control rates



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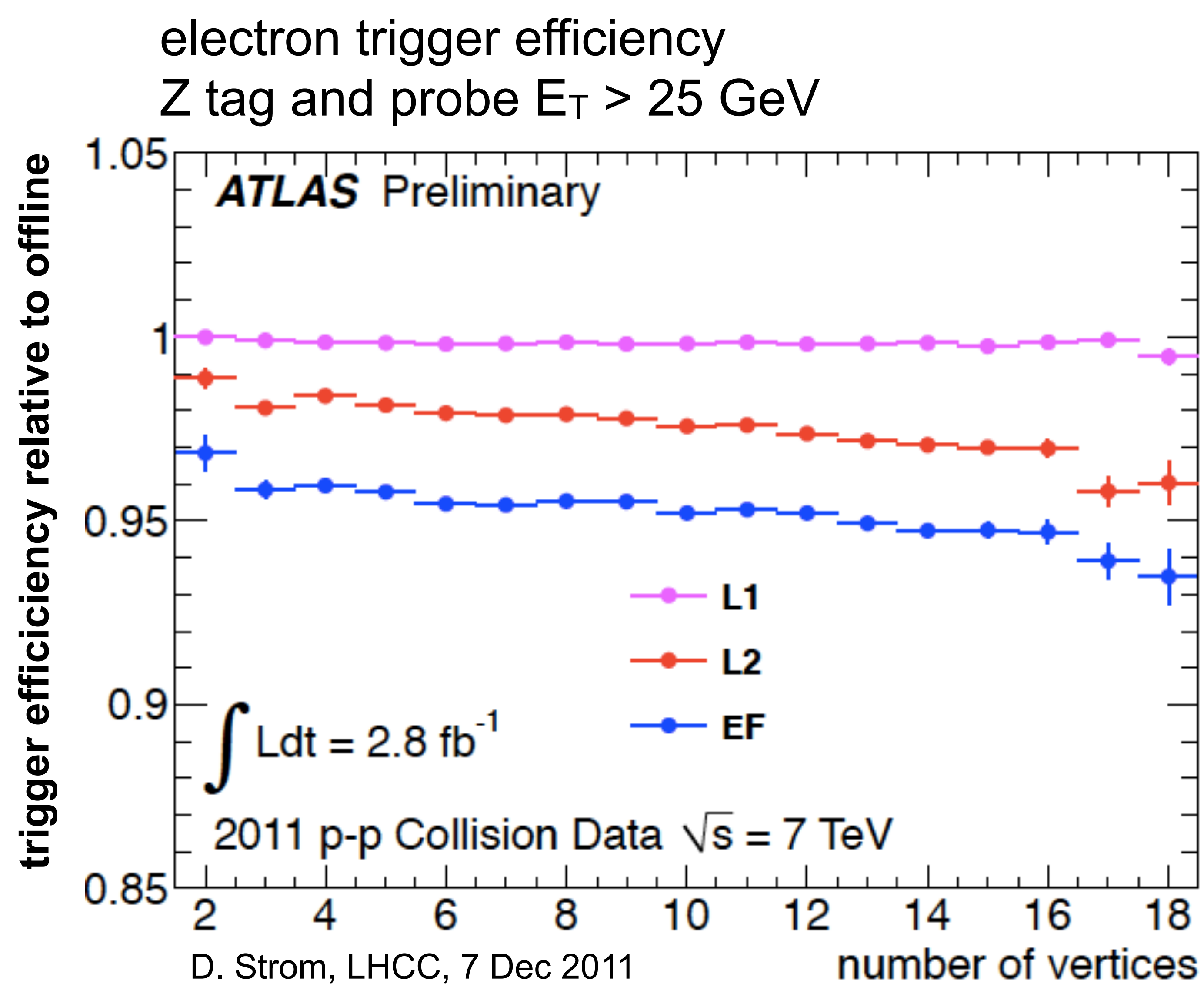

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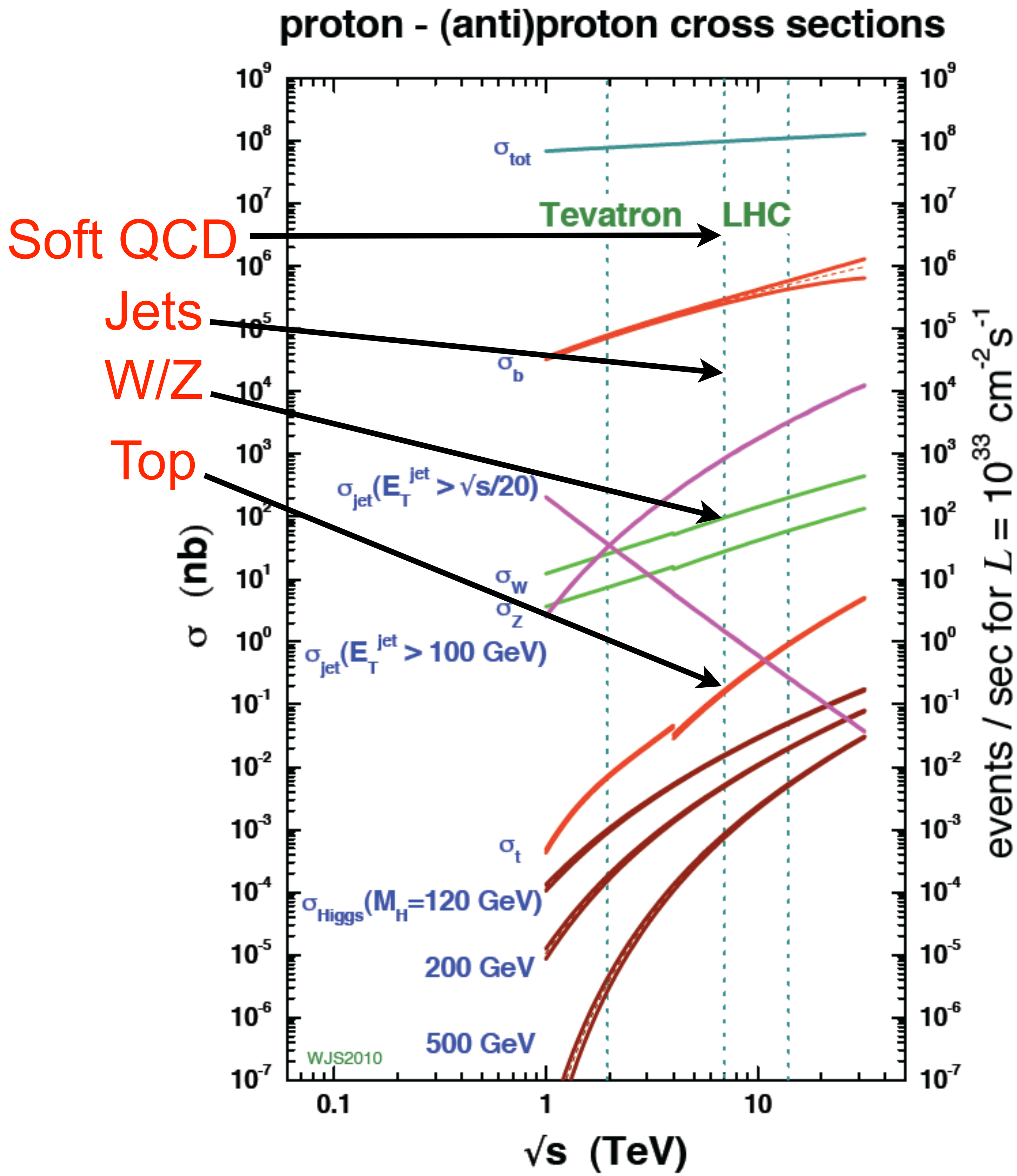
Standard Model in ATLAS

- Re-discovery of the SM
  - Validating SM predictions at a higher energy
    - precise measurement of SM parameters
  - ATLAS detector commissioning and calibration
- Needed for searches for new physics
  - understanding backgrounds
  - look for processes with cross sections > 10 orders of magnitude smaller than total cross section!



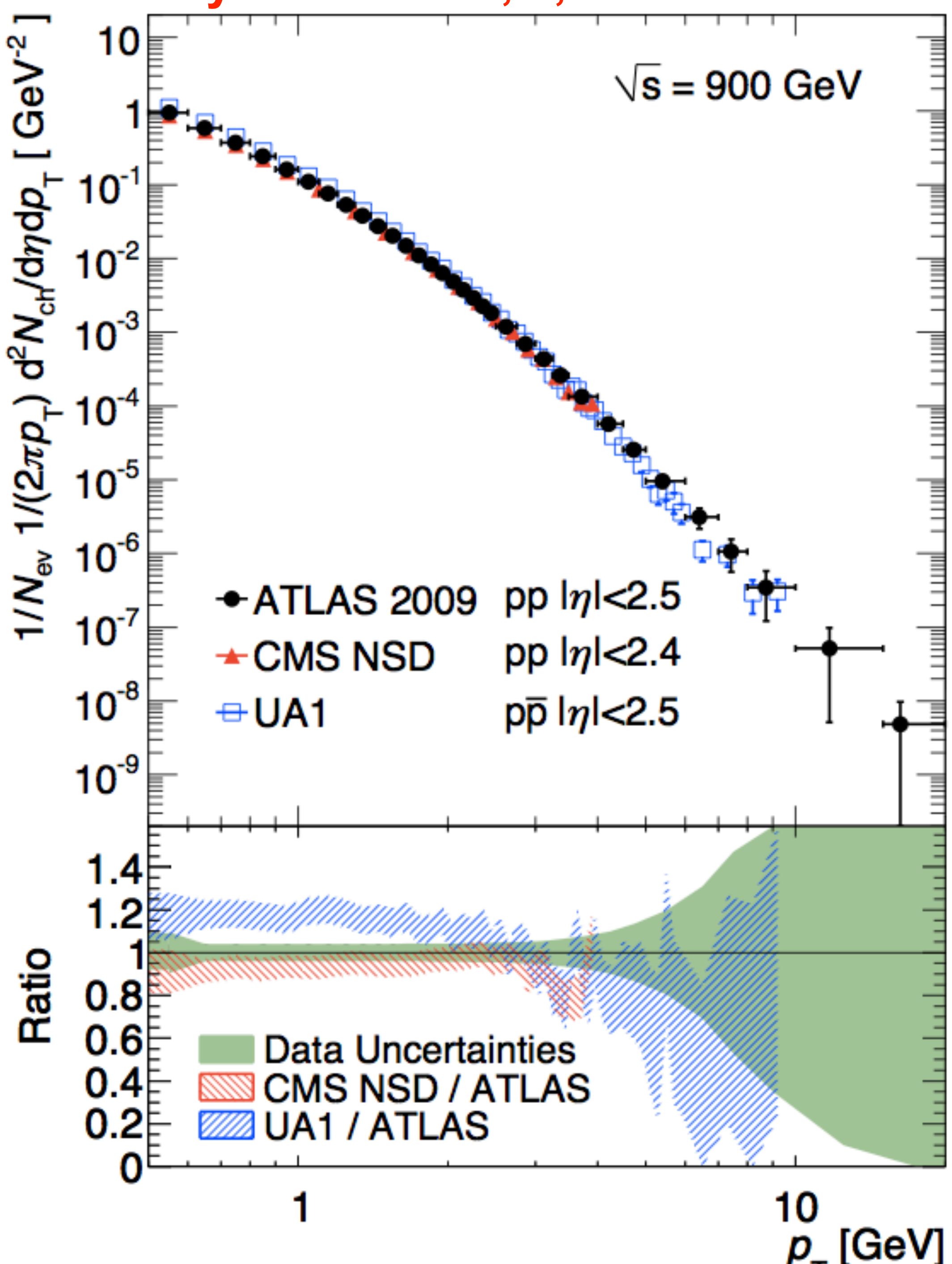
Standard Model in ATLAS

- ATLAS SM, Top, B working groups
  - Soft QCD
    - multiplicities, correlations, underlying event, inelastic cross section, rapidity gap cross sections, ...
  - Jet Physics
    - cross sections, shape, mass, ...
  - W/Z Physics
    - cross sections, p_T distributions, V+jet(s), decays, ...
  - Direct Photons
    - isolated prompt photon and di-photon cross section
  - Electroweak
    - WW, WZ, ZZ, Wγ, Zγ cross sections
  - Top
    - cross sections, mass, single top, properties
  - B
    - Onia, b, B → J/ψ, rare b-decays, hadronic B decays

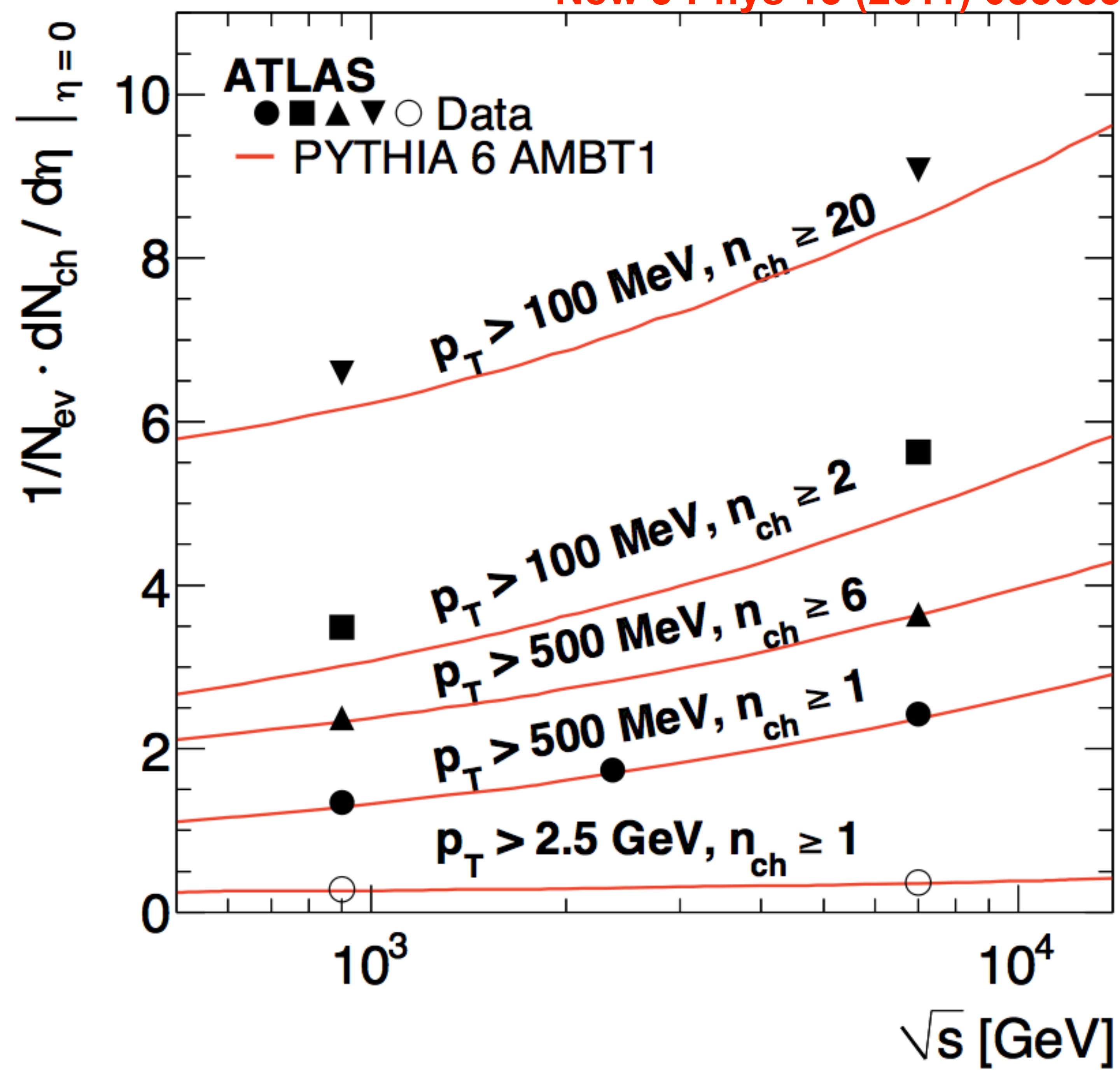
Soft QCD: charged particle multiplicities

- Results at 0.9, 2.36 and 7 TeV

Phys Lett B 688, 1, 21

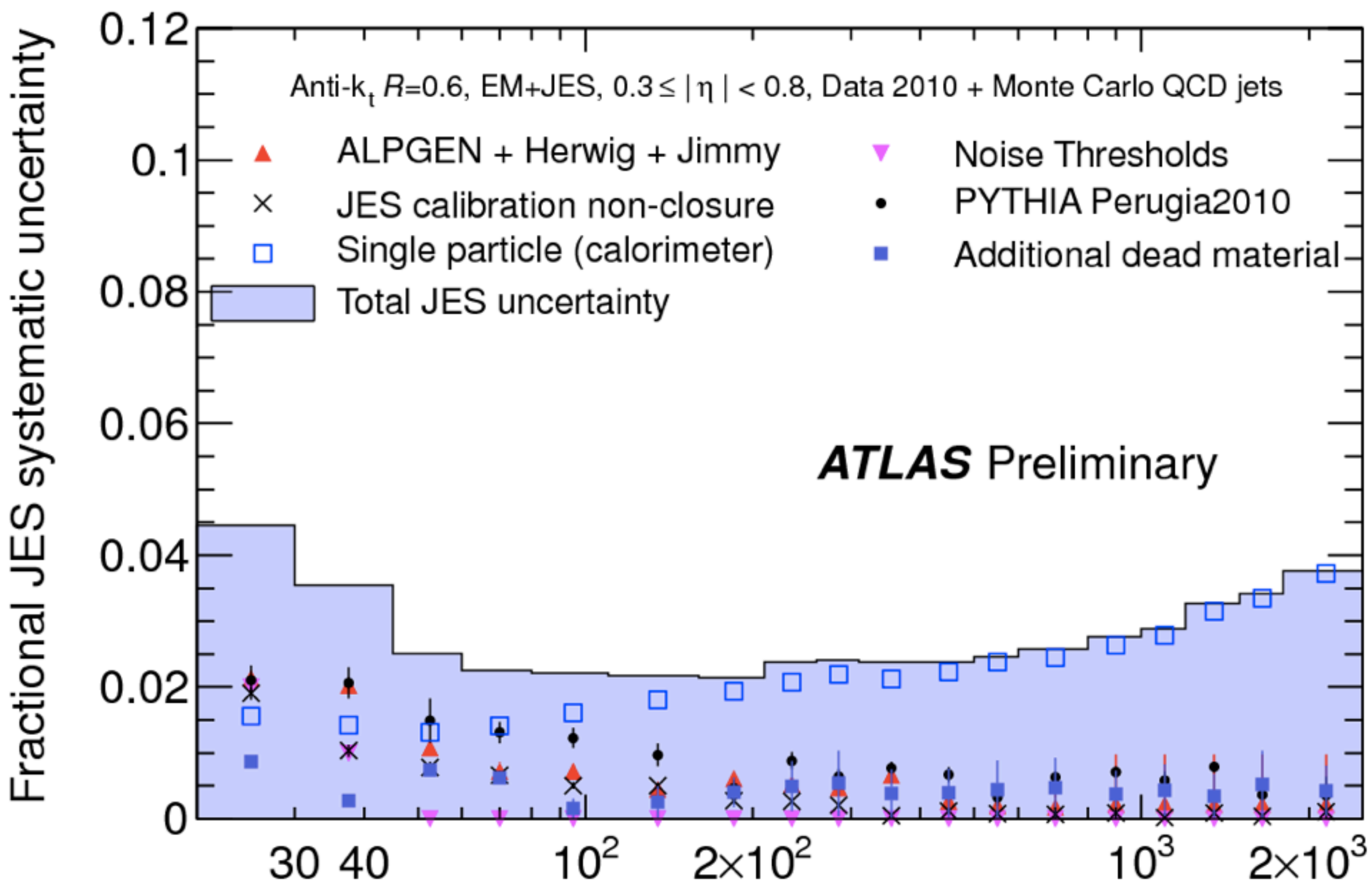


New J Phys 13 (2011) 053033



Hadronic jets

- Hadronic jet production is the dominant high p_T process at the LHC
  - jet energy scale uncertainty is the main source of uncertainty for many physics measurements
  - enormous progress made in 2011



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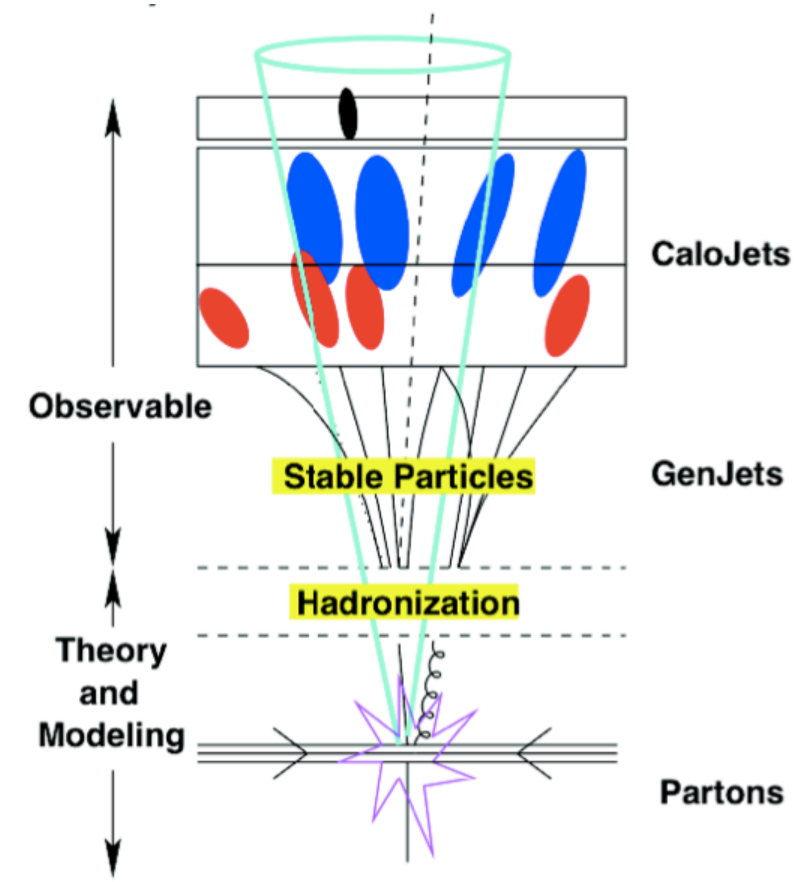
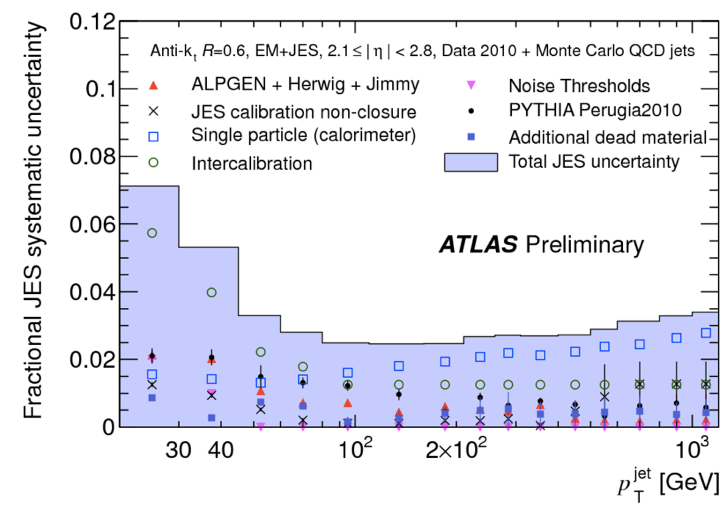
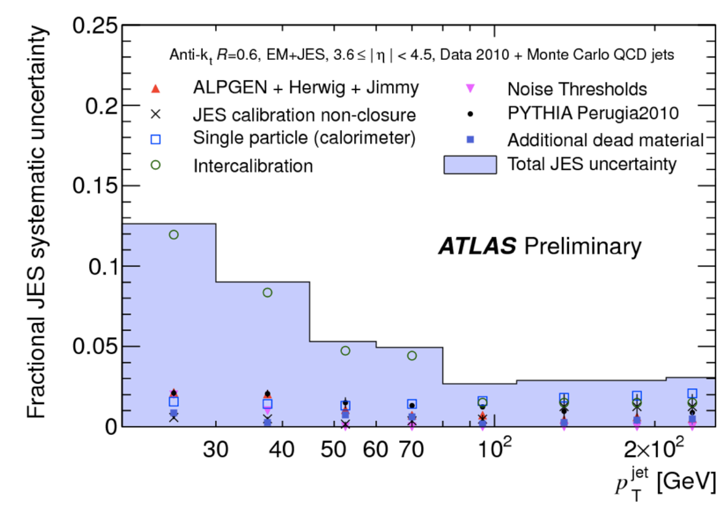
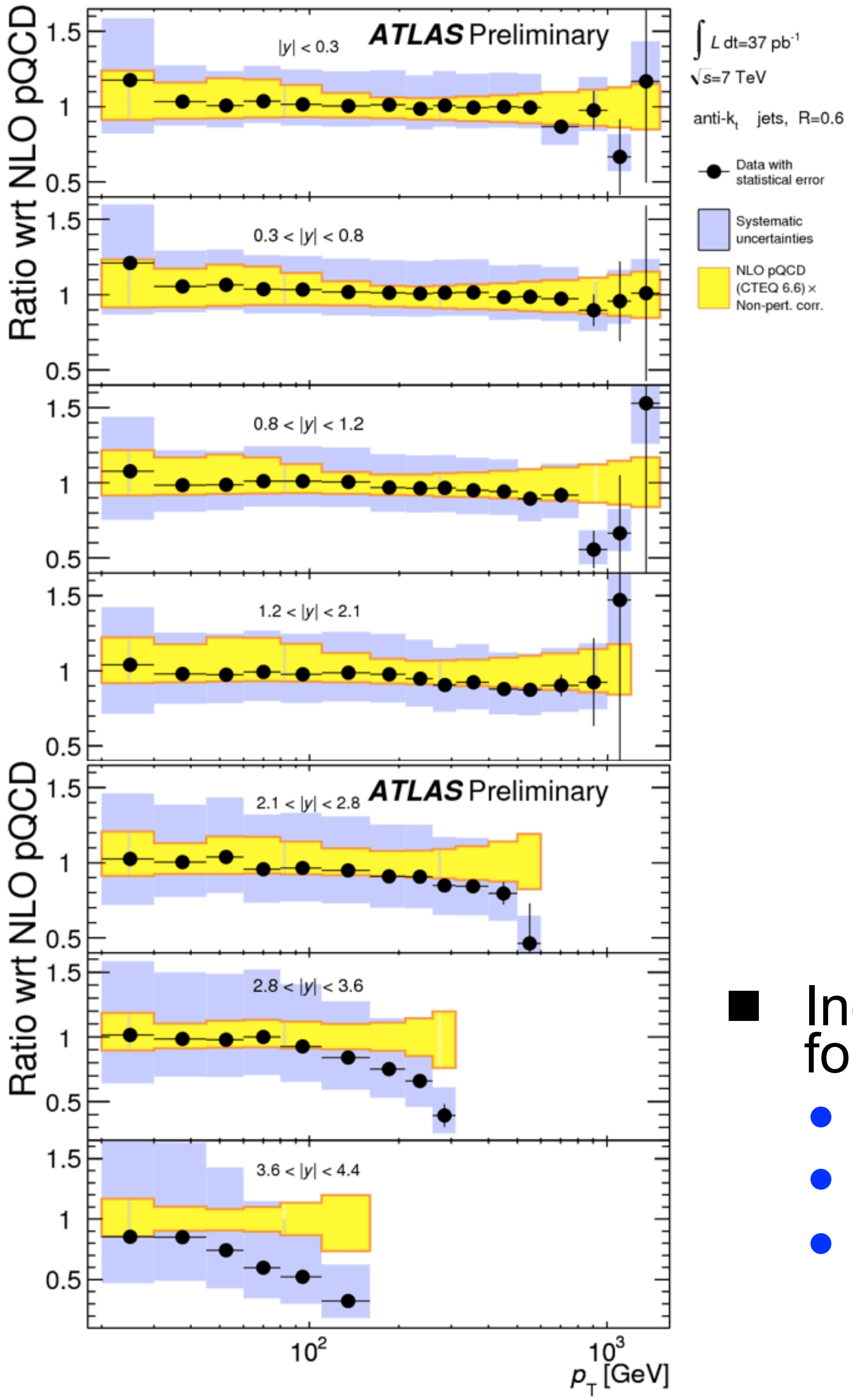
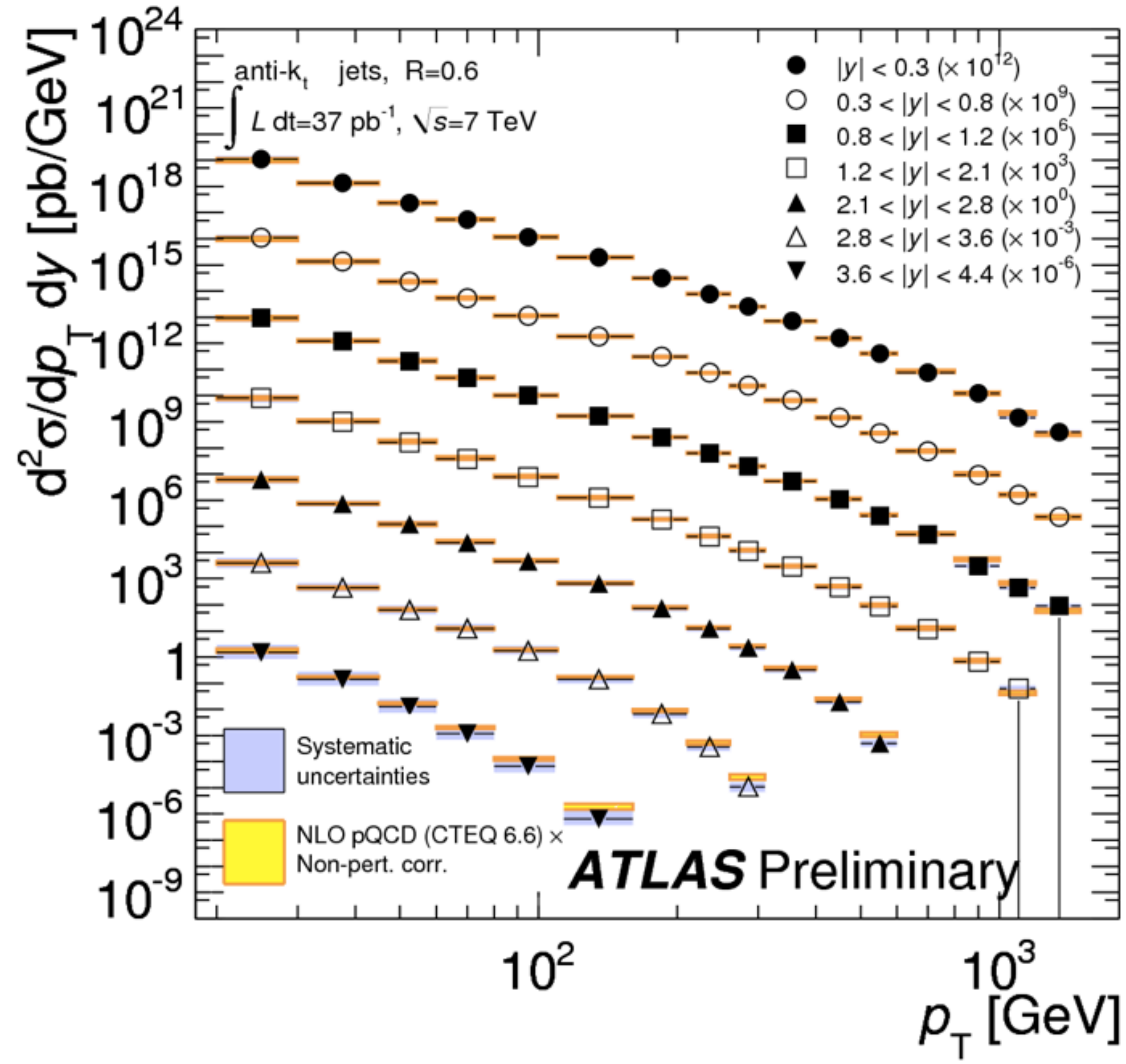






Jet physics

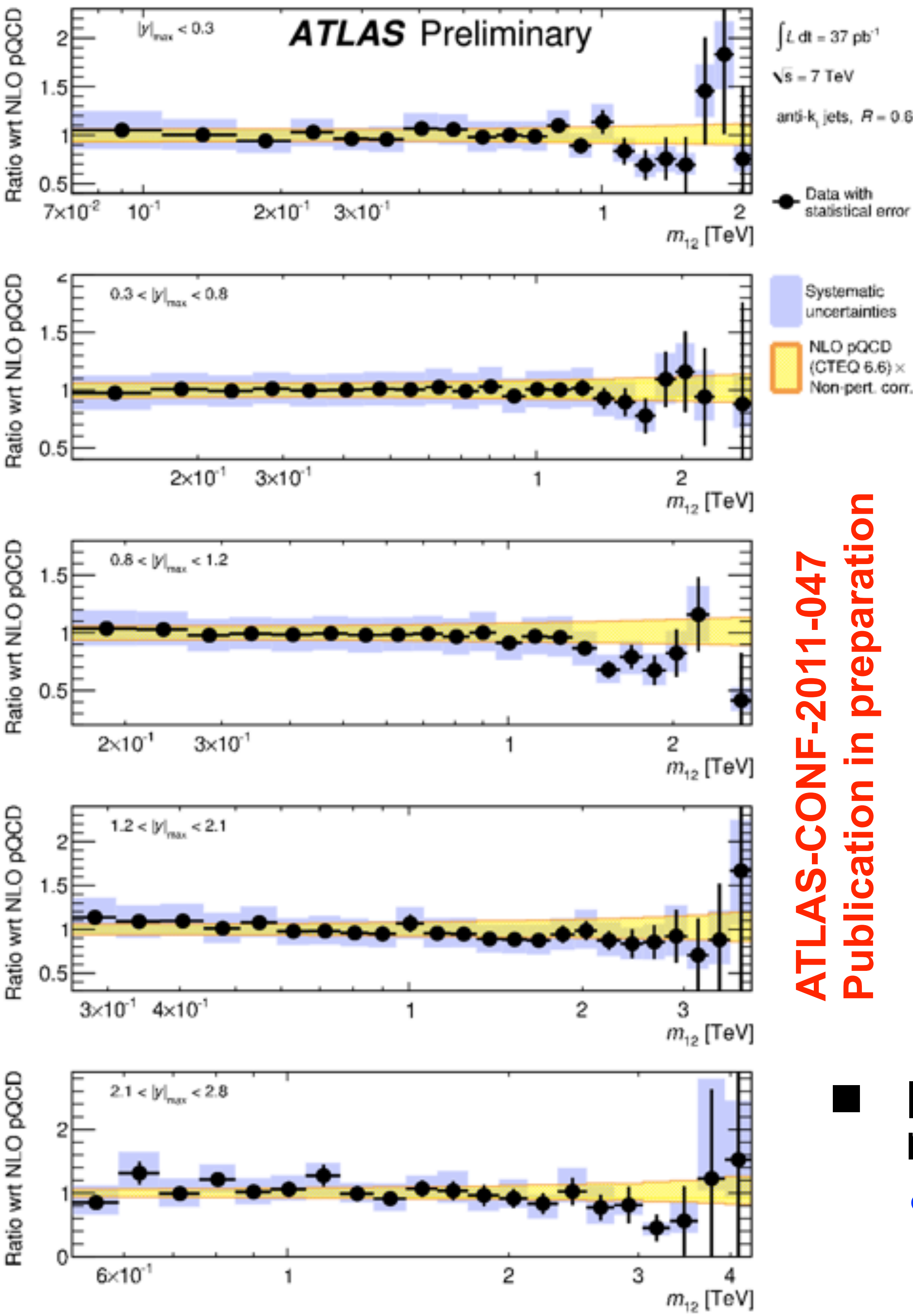




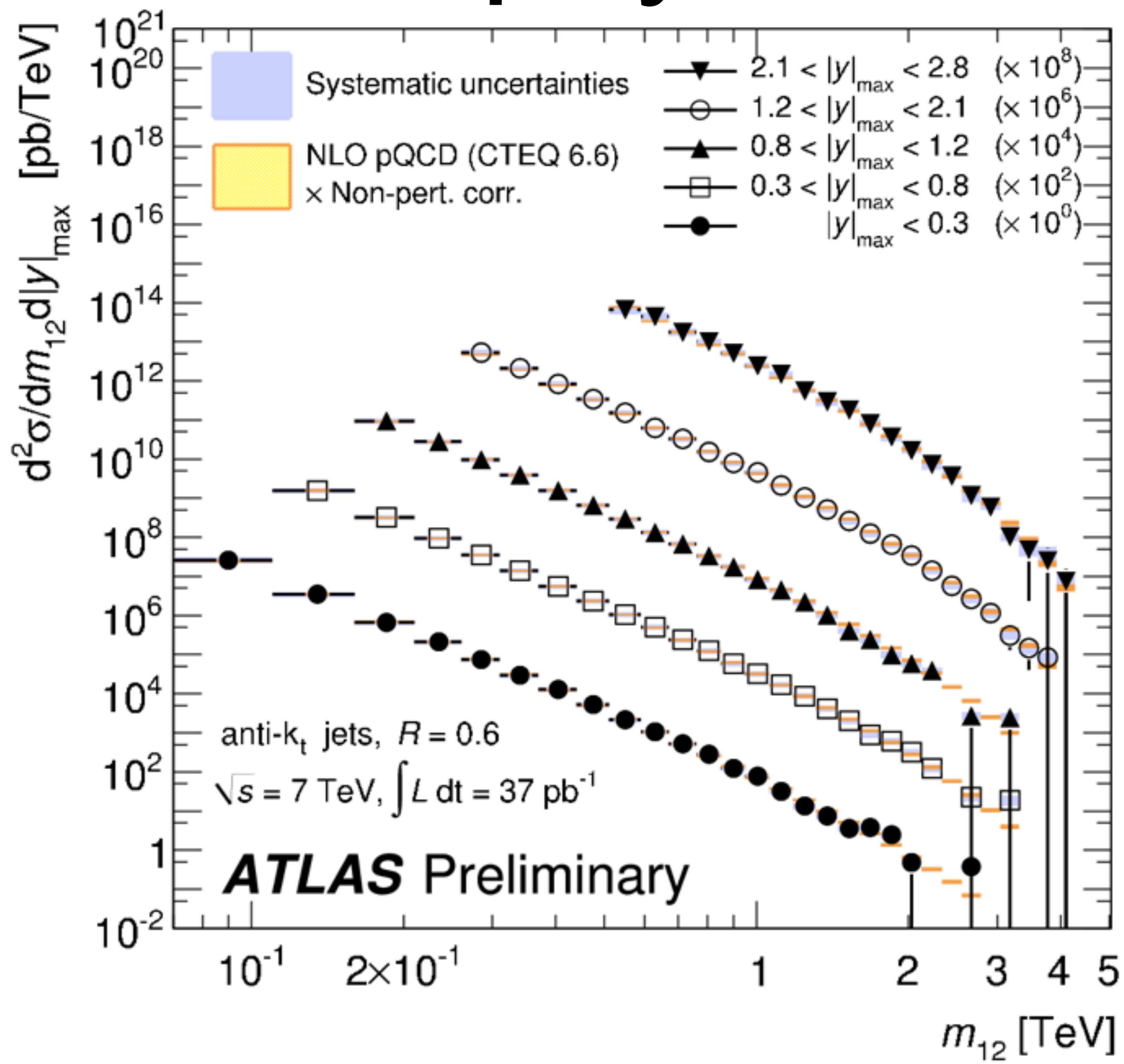
ATLAS-CONF-2011-047
Publication in preparation

- Inclusive jet double-differential cross section vs p_T for various rapidity regions
  - probe over 12 orders of magnitude in cross section!
  - systematic uncertainty dominated by jet energy scale
  - overall good agreement with NLO pQCD (+ soft QCD corrections)
    - except very forward region: work in progress to constrain PDFs

Jet physics

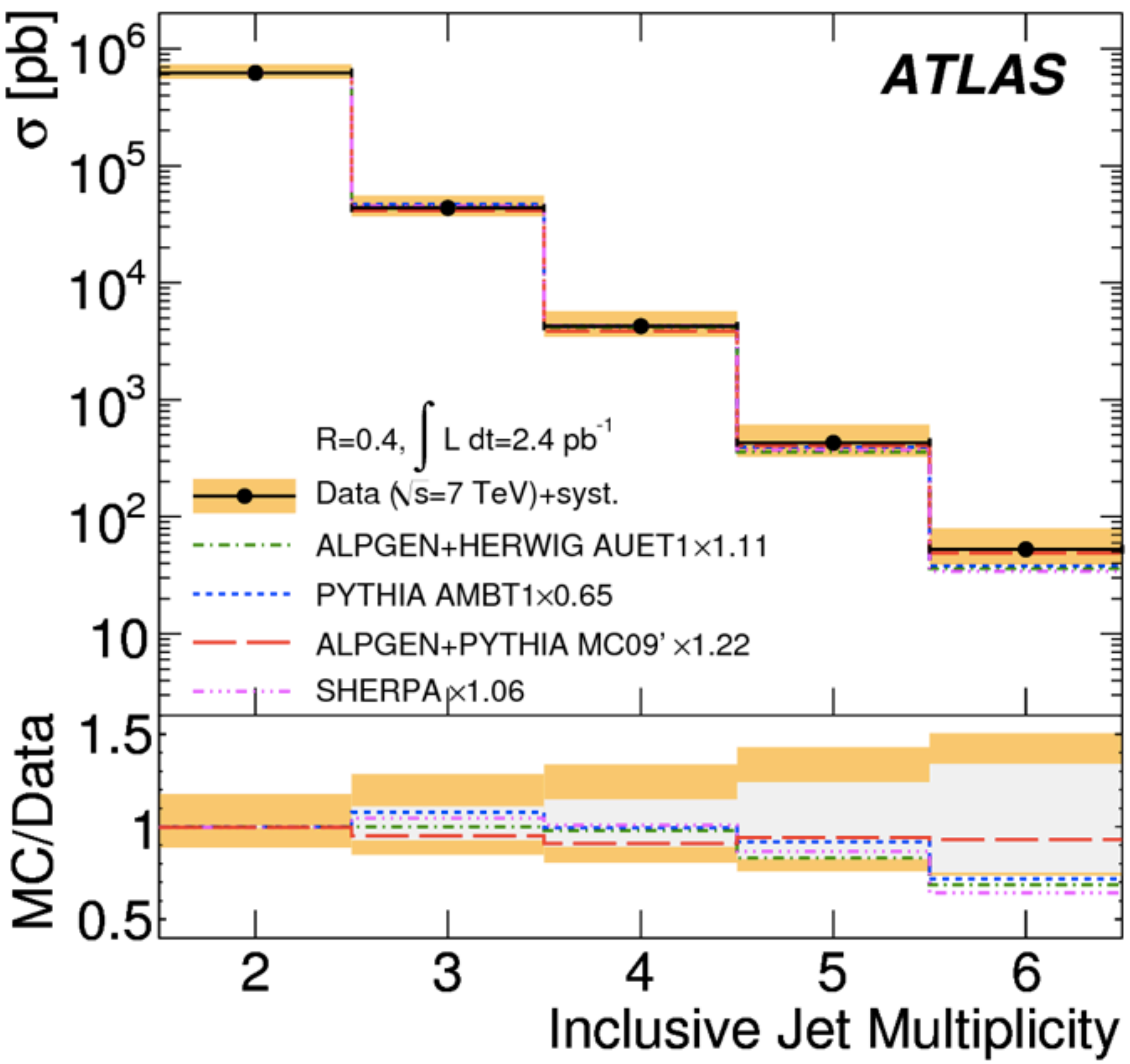


ATLAS-CONF-2011-047
Publication in preparation

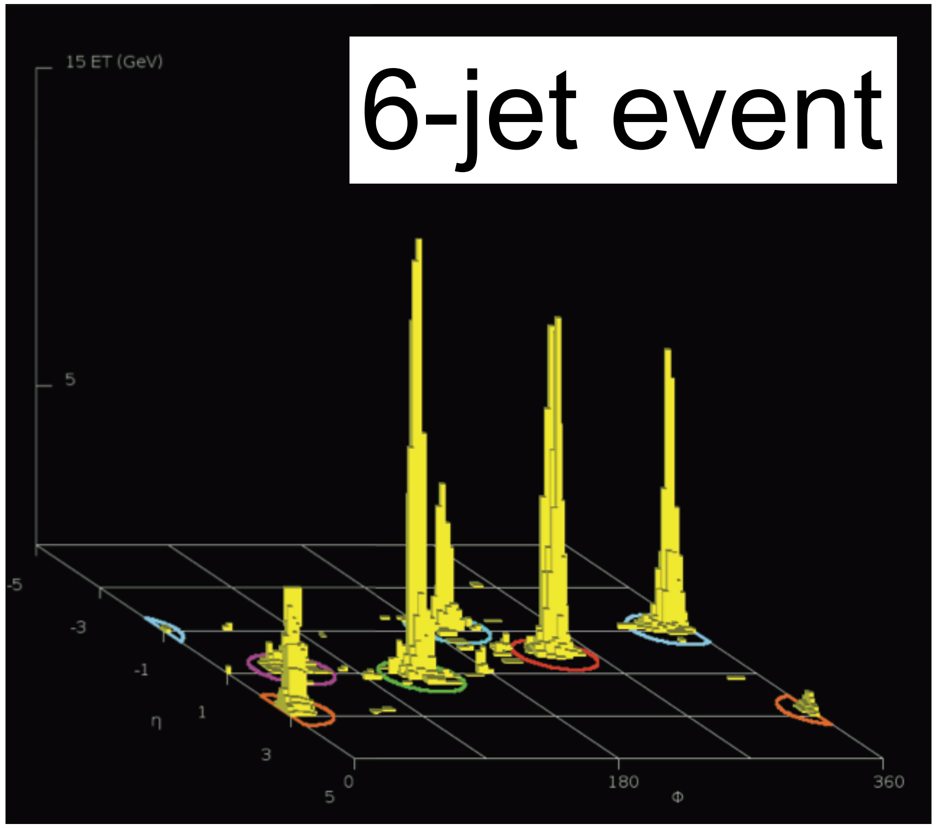


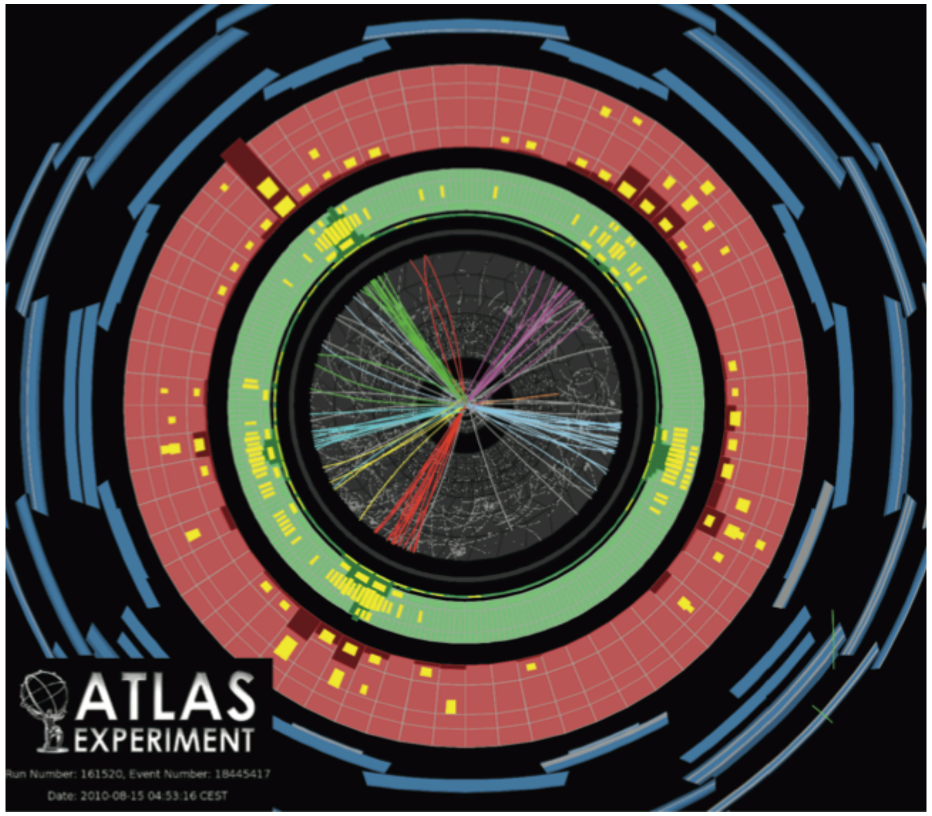
- Dijet double-differential cross section vs dijet mass for various max rapidity of two leading jets
  - overall good agreement with NLO pQCD (+ soft QCD corrections)

Jet physics: multijets



accepted in EPJC



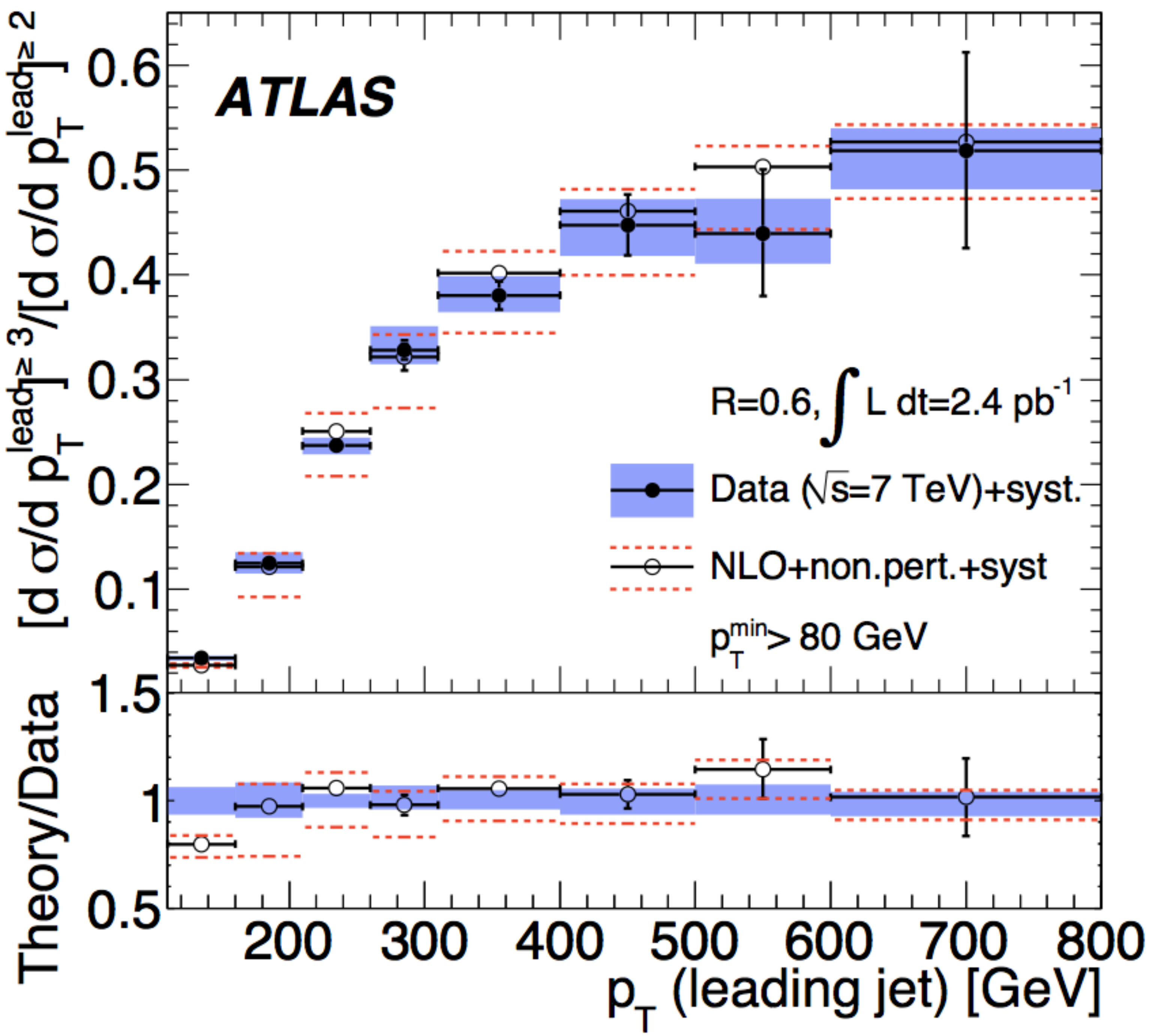


LO MC normalized to the measured inclusive dijet cross section. The systematic error on the measurement does not include the luminosity uncertainty

Jet physics: multijets

- three-to-two jet ratio
- test of NLO pQCD
  - NLOJet++ 4.1.2
  - parton-to-particle correction factor obtained using PYTHIA and HERWIG++
  - MSTW 2008 NLO
- also aim at extracting α_S
  - note in preparation (EB)
  - figure here includes theoretical error from varying α_S by ±0.002

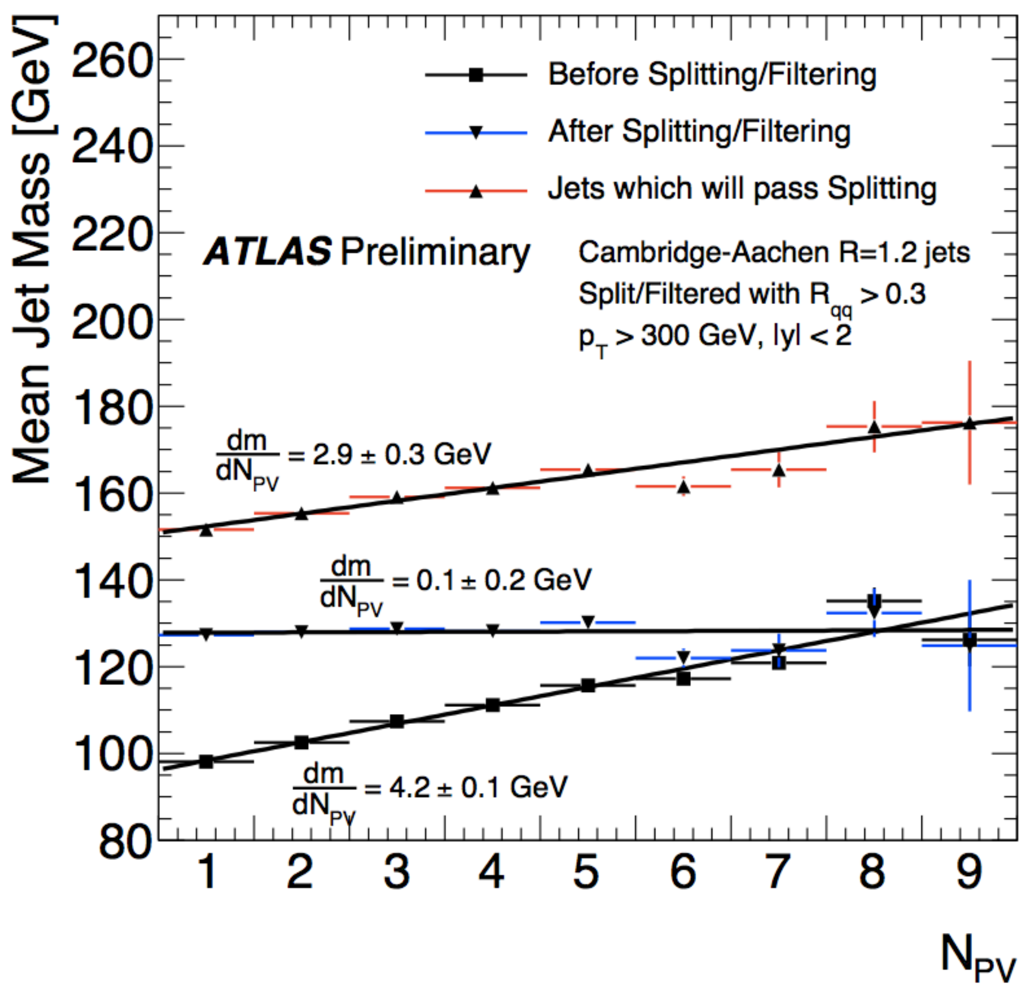
accepted in EPJC

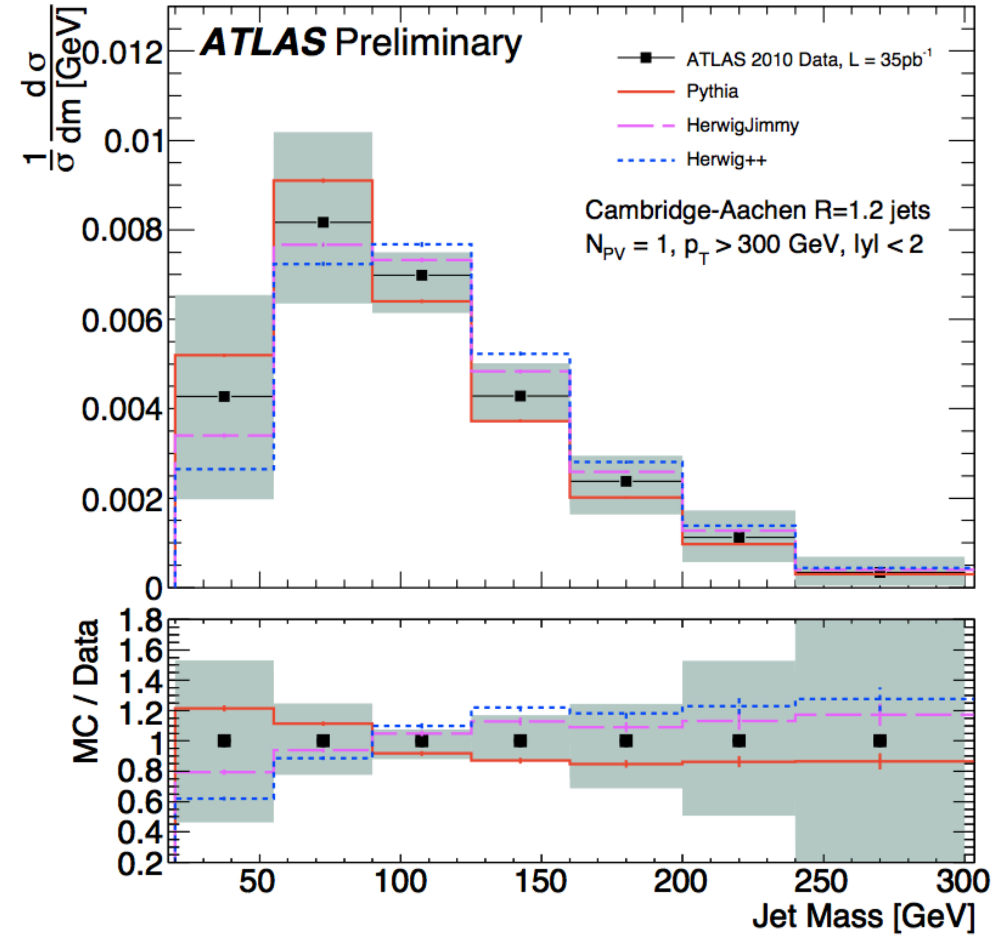


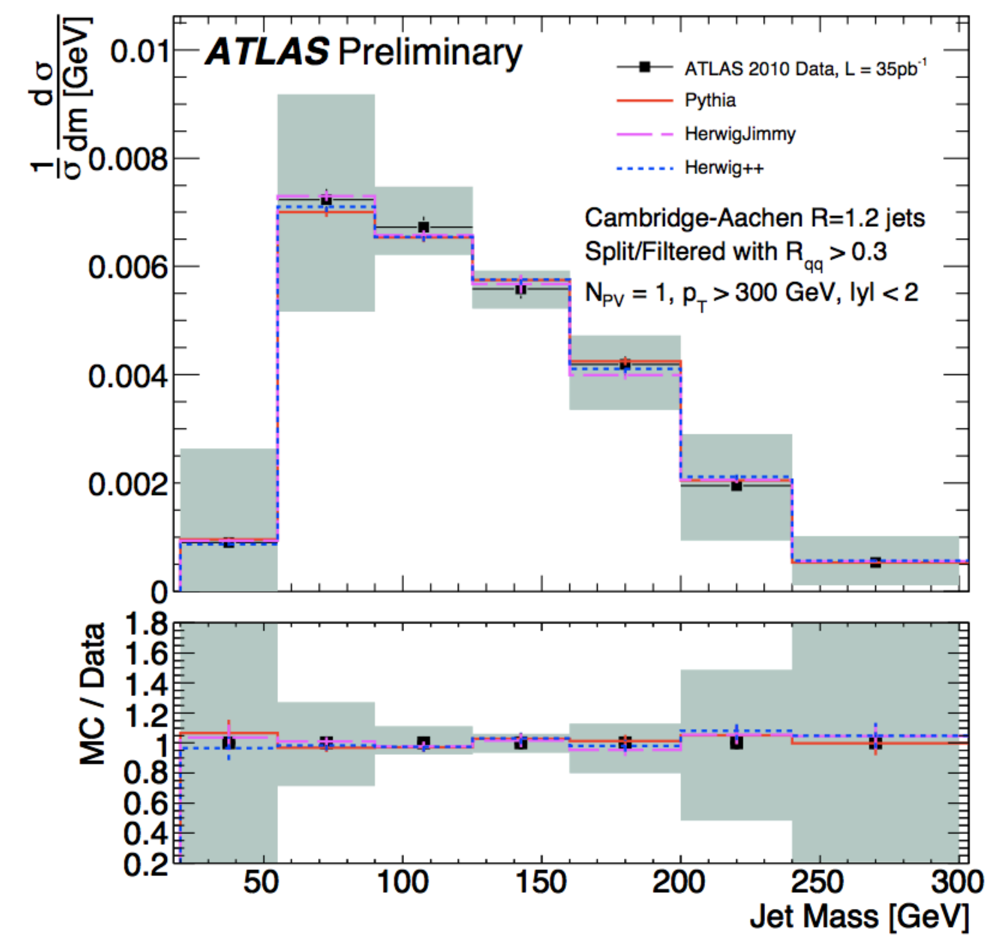
Jet mass and substructure

ATLAS-CONF-2011-073

- Jet mass encodes information about both parton shower and a possible origin in a heavy particle decay
- Fat jets are split and soft radiation is filtered out
  - filtering reduces differences in generator predictions and removes impact of pileup!

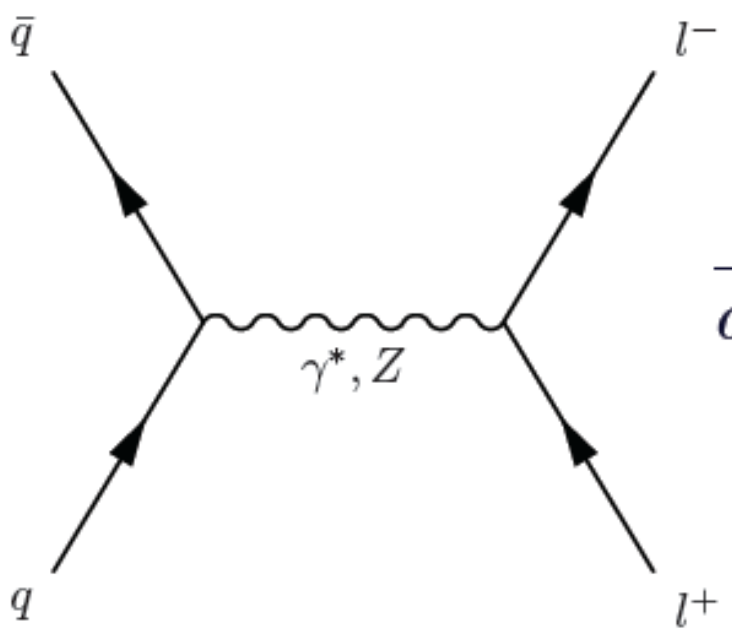






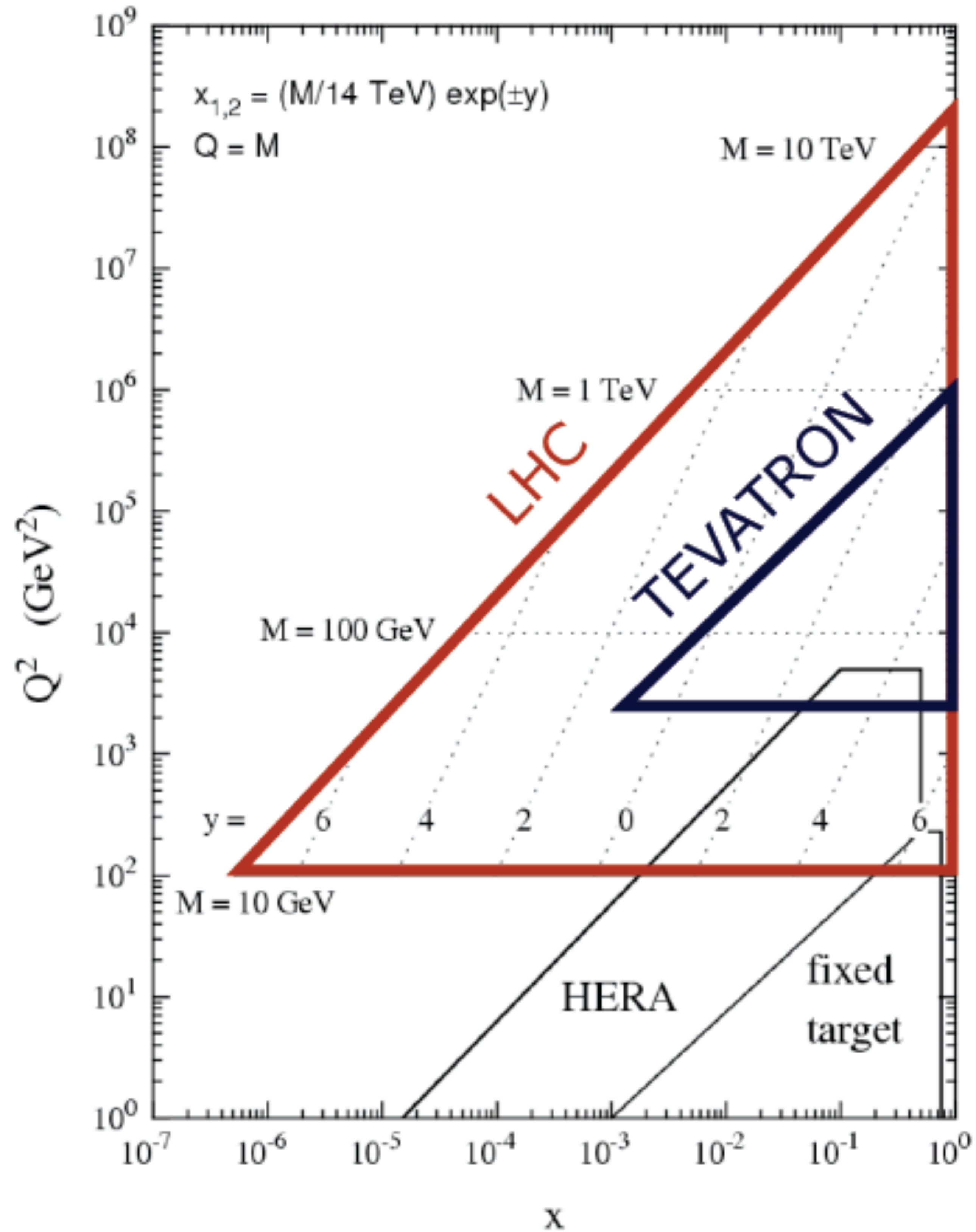
Low mass Drell-Yan cross section

- DY process can help improve our understanding of the proton structure
  - PDF uncertainty one of the dominant uncertainties for SM measurements
    - DY sensitive to sea-quark PDF
  - LHC probes low x and high Q2: at 7 TeV probing as low as 10^{-4} in x



$$\frac{d\sigma}{dm_{ll}} \propto m_{ll}^{-3}$$

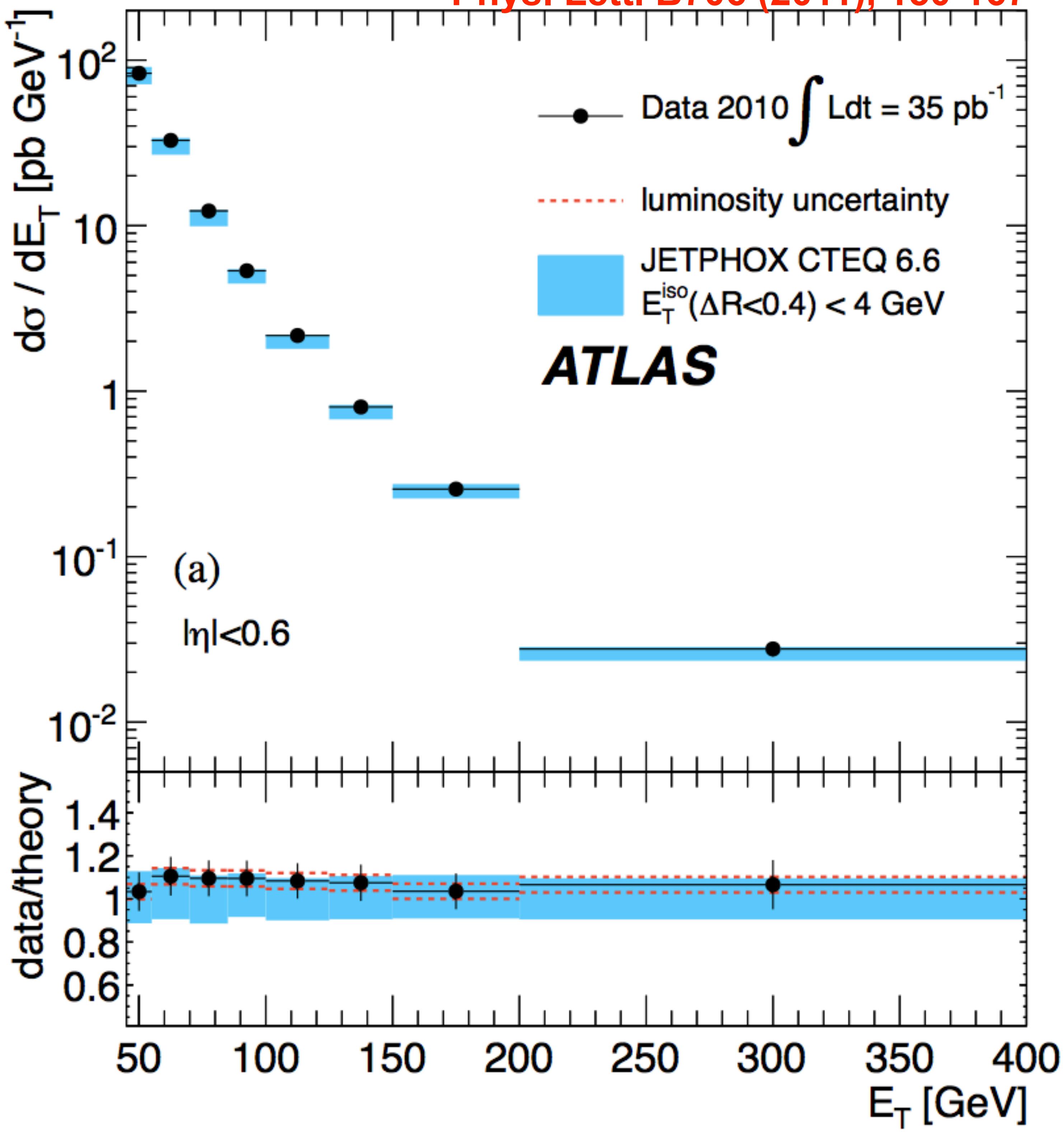
in preparation



Prompt photons

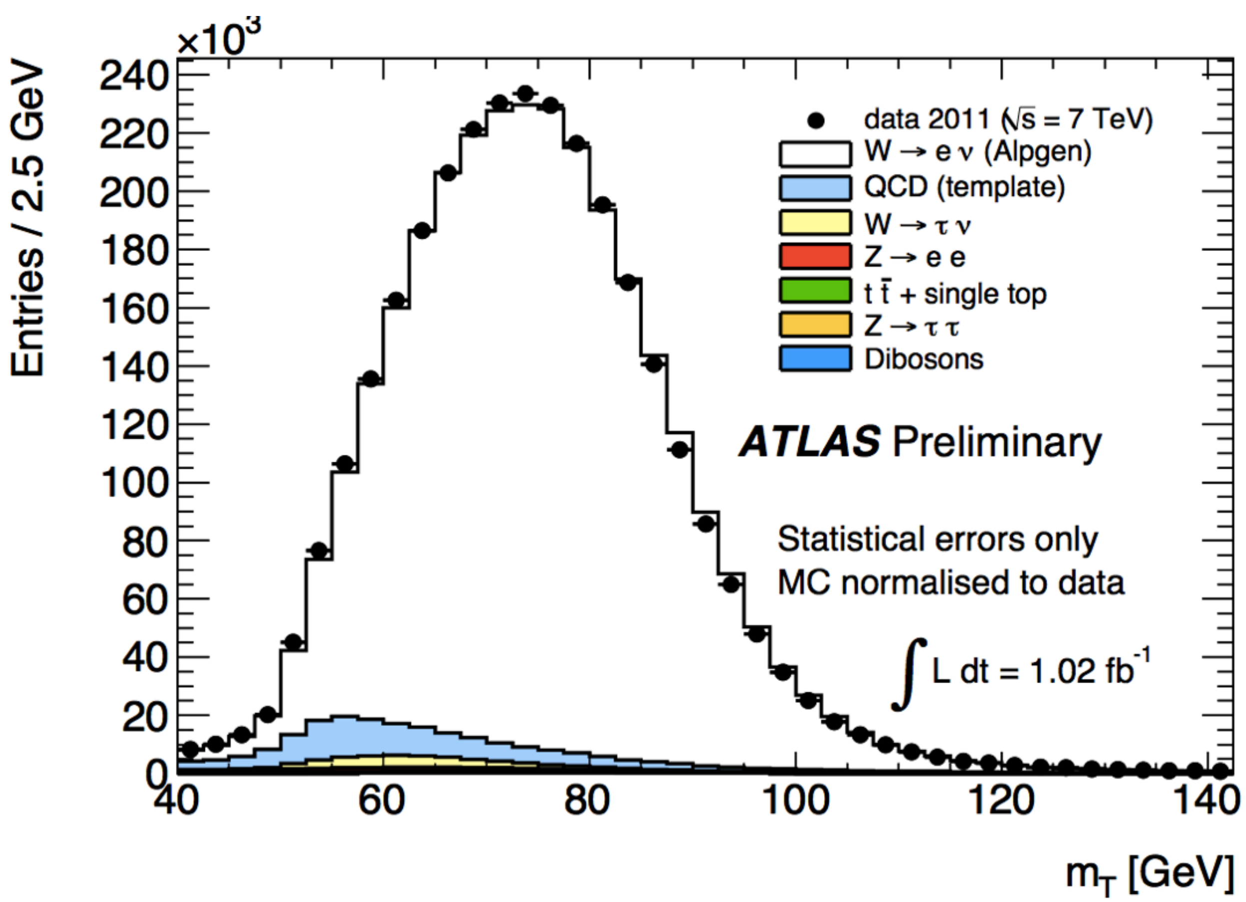
- Good agreement with pQCD over 4 orders of magnitude in cross section
  - sensitive to the gluon content of the proton
- Also important test of photon detection
  - converted and non-converted photons
  - transverse isolation and effect of
    - underlying event
    - pile-up
  - calorimeter shower shape

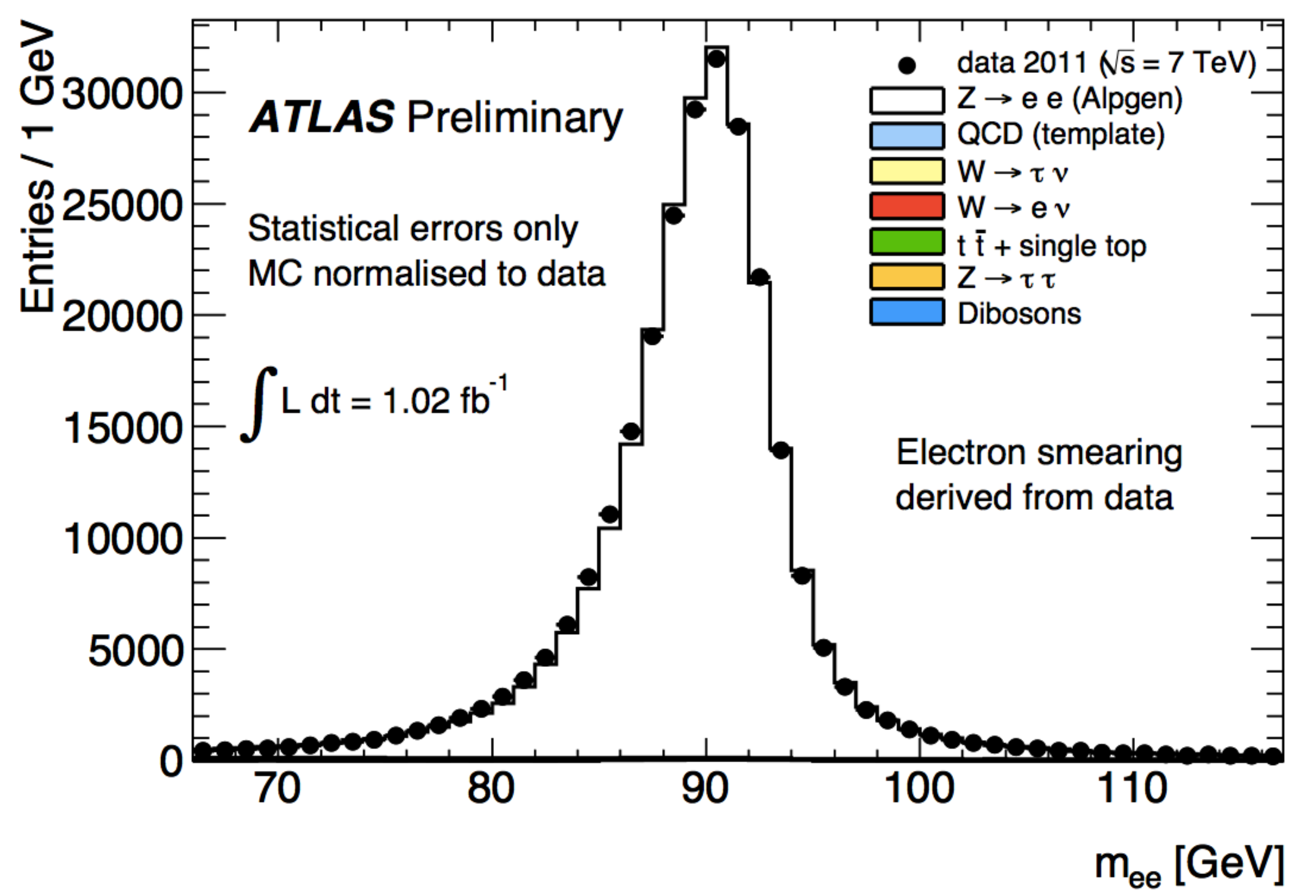
Phys. Lett. B706 (2011), 150-167



W/Z physics

- W/Z reconstruction essential for most analyses
  - either as signature for signal or background
  - large samples available
    - evaluate and calibrate detector performance (energy scale, ETMiss, ...)
    - towards precision EW measurements

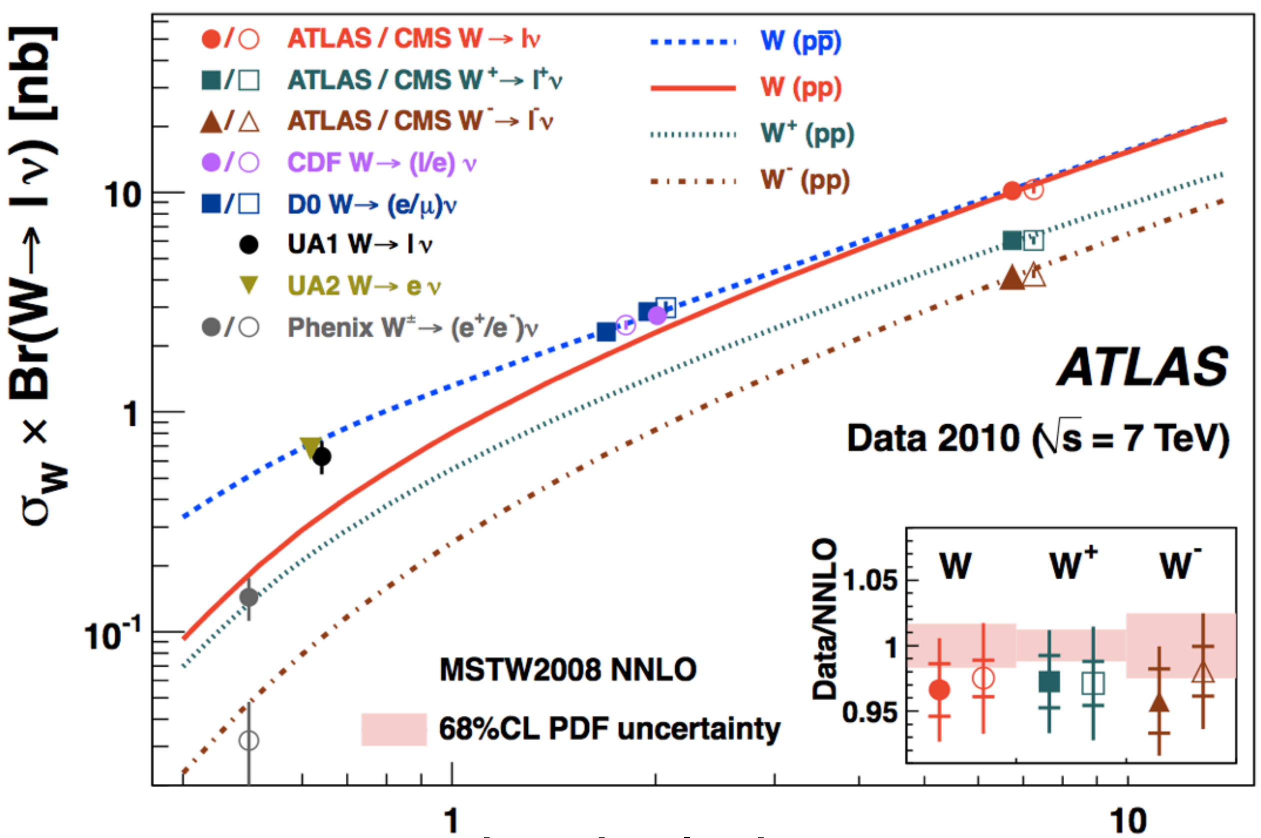




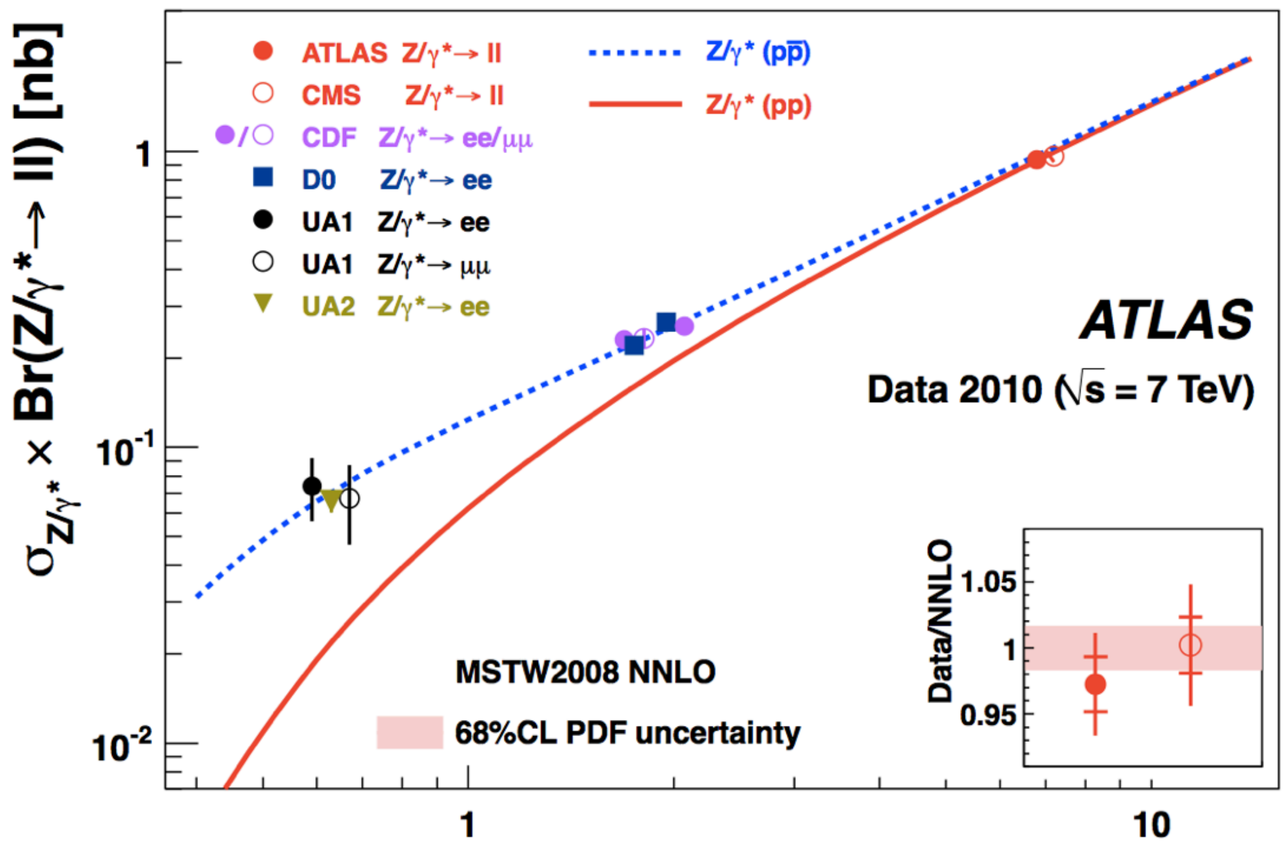
W/Z physics

- Inclusive production cross section (35 pb^{-1})

Submitted to PRD



outer error bar includes luminosity uncertainty



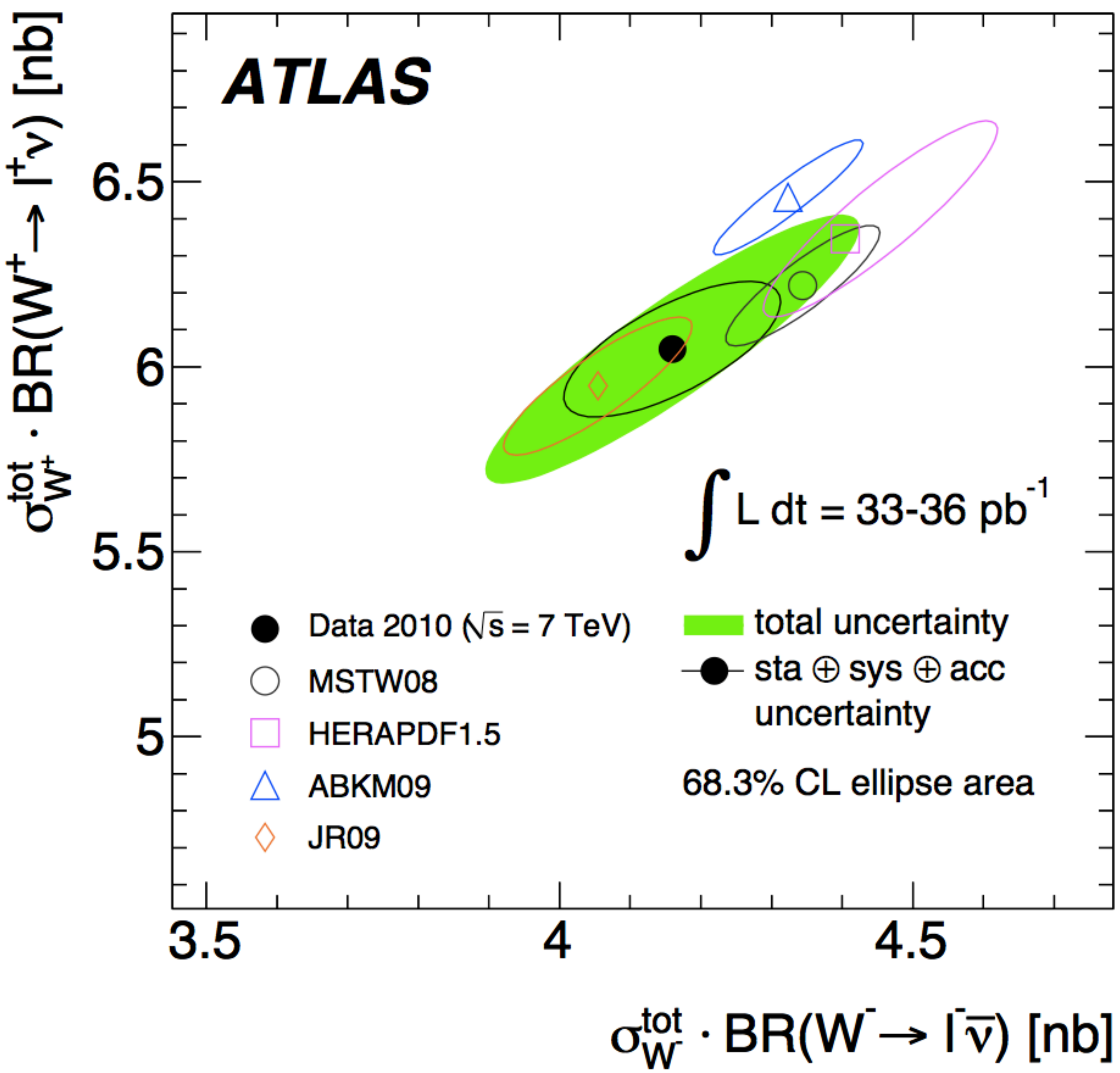
experimental mass range taken into account in inset

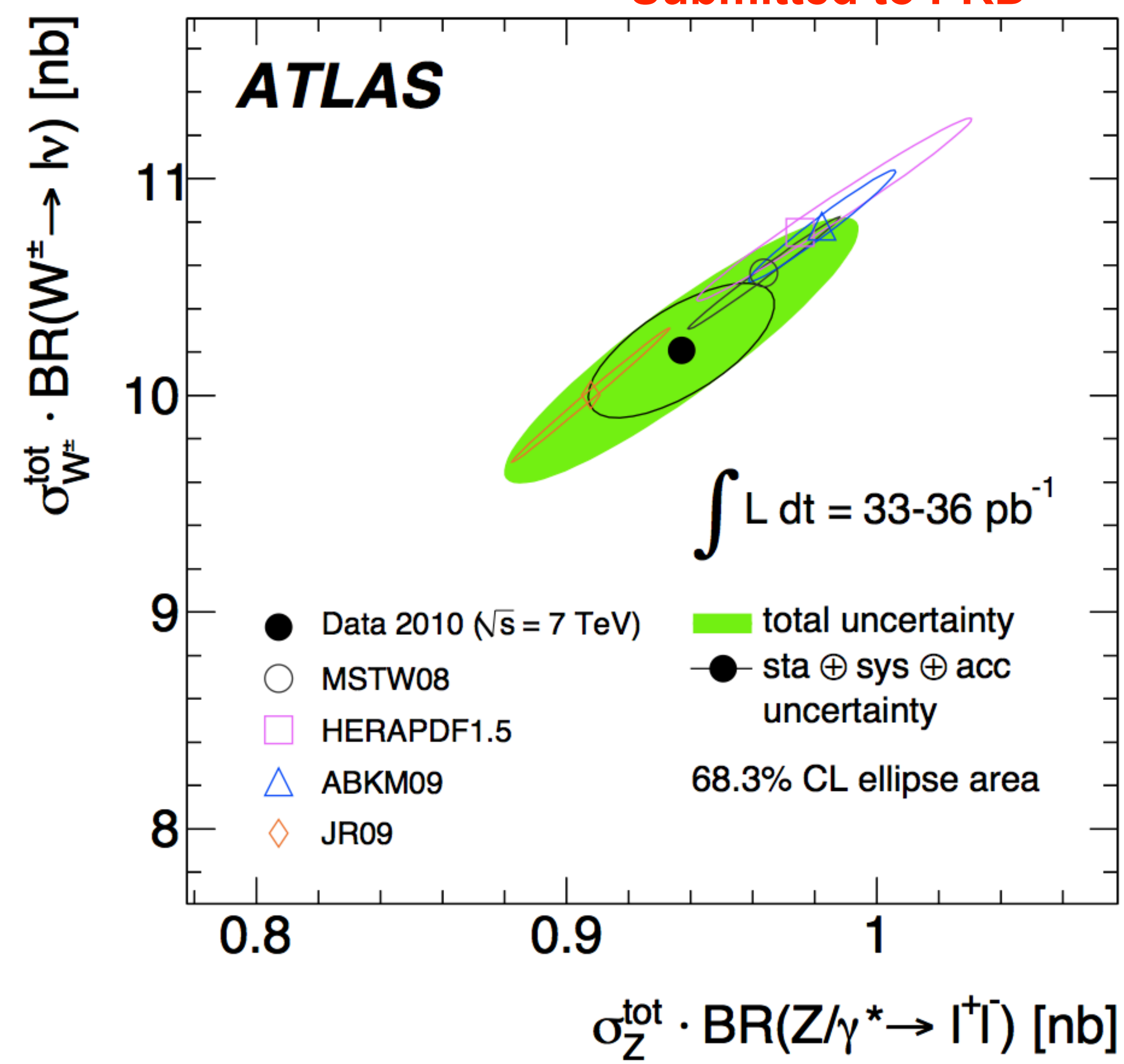
- measurements cover a wide range of kinematic phase space
  - stringent test of SM predictions
- precision reaches a few percent!

W/Z physics

- Production cross section: W^+ vs W^- and $W^\pm$ vs Z
  - luminosity uncertainty is the dominant error
  - universality of the PDFs and pQCD at high orders still work at LHC!
    - validity of QCD evolution equations for the PDFs
    - constraint on the partonic content of the proton

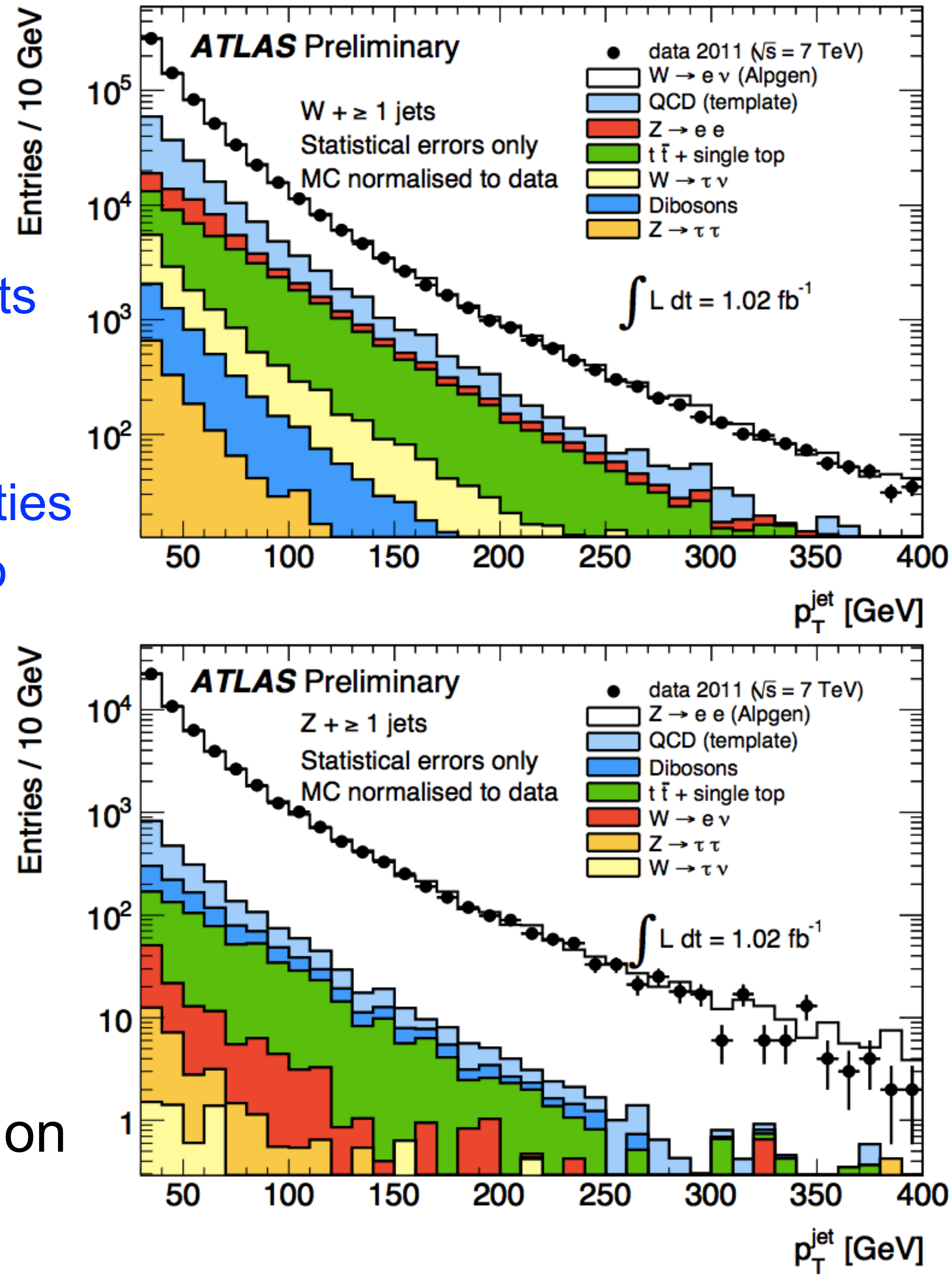
Submitted to PRD





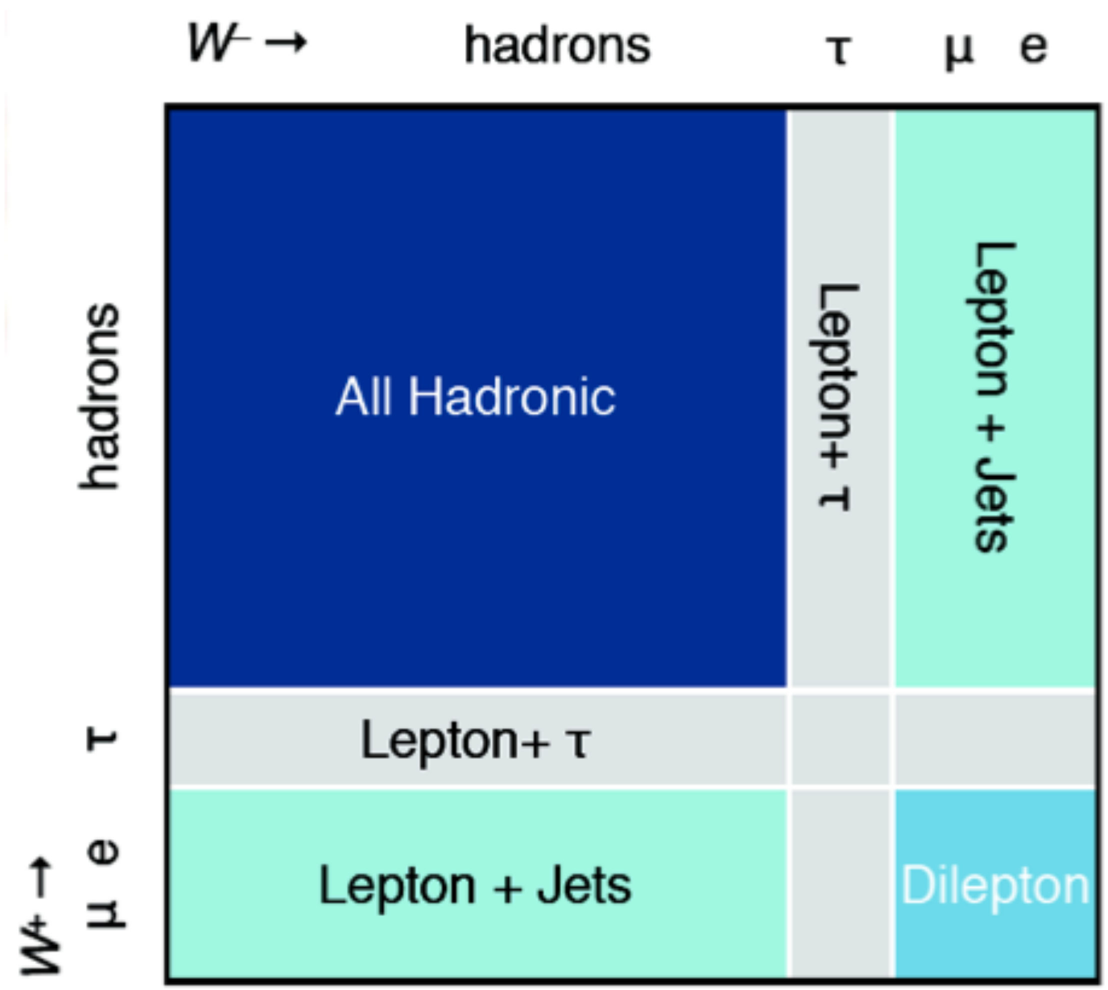
W/Z + jet(s)

- Very important measurement at the start of LHC
  - exclusive final states W/Z + n-jets
  - b-jet production rate
- Ratio of W+1jet / Z+1jet
  - cancellations of many uncertainties
  - model-independent sensitivity to new physics couplings to leptons and jets
  - **Submitted to PLB**
  - good agreement with SM so far
- Important background to many searches
  - understanding SM W/Z + n-jets essential
- Can also consider event shape variables instead of (or in addition to) jet multiplicity



Top physics

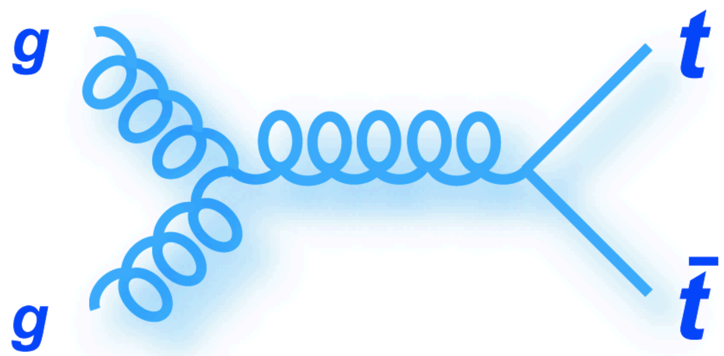
- Top quark
  - late 2011, production at ~1 Hz !!
  - mostly produced in top-antitop pairs
  - BR(t→Wb)~100%
- Decays before hadronizing
  - study an unbound quark!
- Most massive fundamental particle (so far)
  - Yukawa coupling close to 1
  - large mass affects EW observables through loop corrections
  - top plays a special role in many BSM theories
- Signature: multiple leptons, jets, and missing E_T
  - dominant background for non-all-hadronic channels
    - W/Z + jets
    - QCD jets

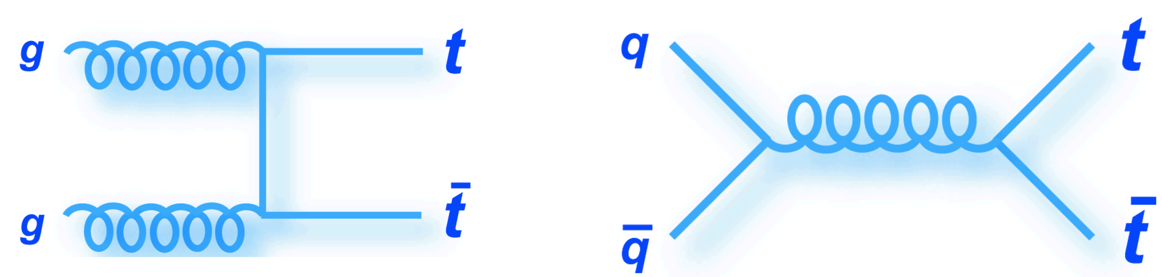


- Event selection
  - high p_T leptons
  - at least 3 jets
  - cut on missing E_T and transverse mass

Top-antiTop pair production cross section

- One of the benchmark measurements of ATLAS





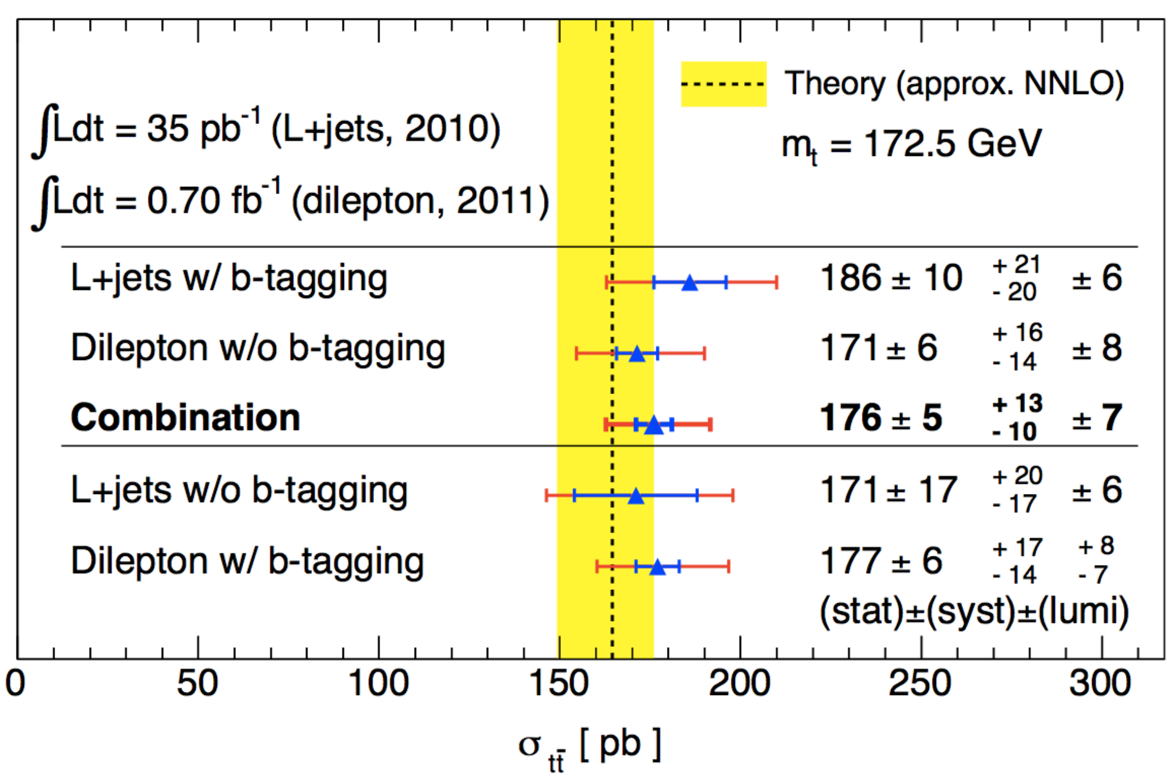
http://www-d0.fnal.gov/Run2Physics/top/top_public_web_pages/top_feynman_diagrams.html

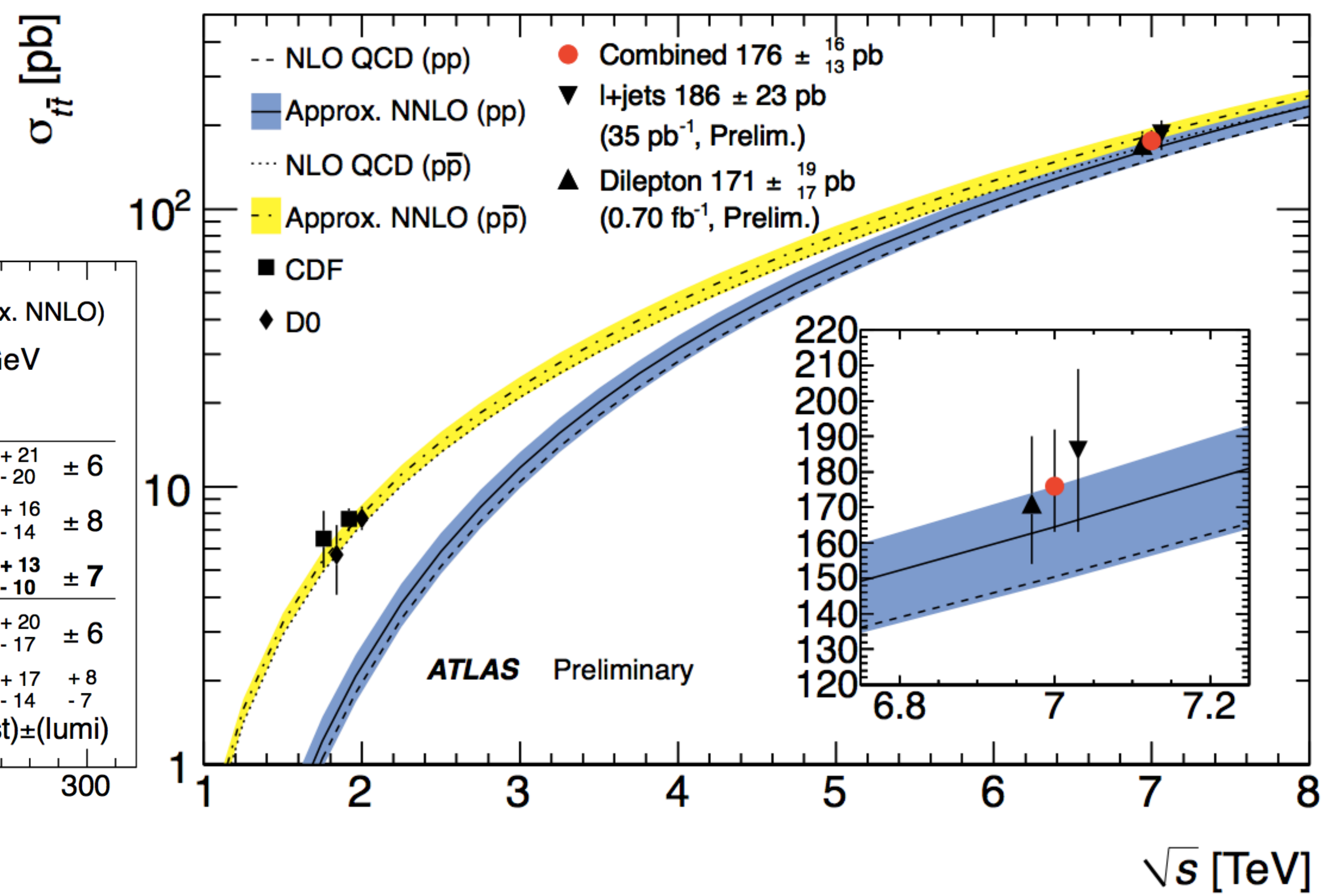
- 3 analyses to produce combined result
  - lepton+jets without b-tagging — **ATLAS-CONF-2011-121**
    - simultaneous fit in 6 channels
      - (3, 4, >=5 jets) X (e, μ)
  - dilepton without b-tagging and with a least 1 b-tagged jet — **ATLAS-CONF-2011-100**
    - ee, eμ, μμ
  - μ + tau(h) + jets — **ATLAS-CONF-2011-119**
    - using boosted decision tree to identify taus
- All hadronic — **ATLAS-CONF-2011-140**
  - 1.02 fb^{-1}: 167 ± 18 (stat) ± 78 (syst) ± 6 (lumi) pb
- ttbar + photon — **ATLAS-CONF-2011-153**
  - 1.04 fb^{-1}: σBR = 2.0 ± 0.5 (stat) ± 0.7 (syst) ± 0.08 (lumi) pb

Top-antiTop pair production cross section

- Statistical Combination: reaching theoretical precision!
  - single lepton and dilepton measurements
  - good agreement with SM predictions
    - 176 ± 5 (stat) ± 13/10 (syst) ± 7 (lumi) pb

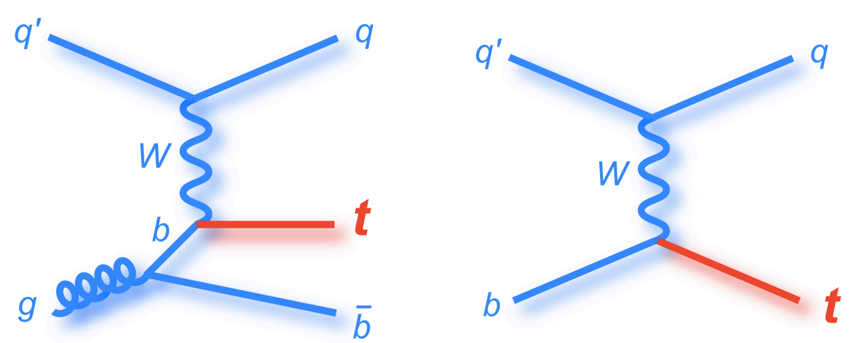
ATLAS-CONF-2011-108



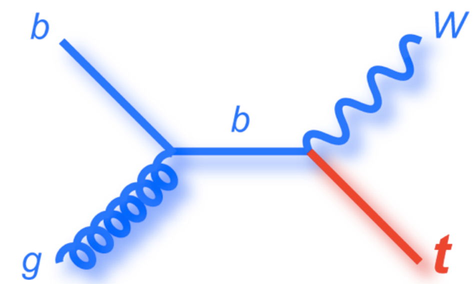


Single top production

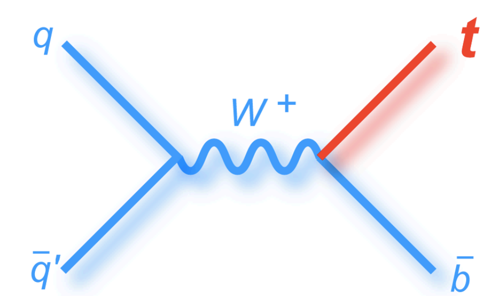
- Top quark can be produced singly through the EW interaction
  - production rate related to V_{tb} and sensitive to new physics involving top quarks: main diagrams:



t-channel



Wt associated production

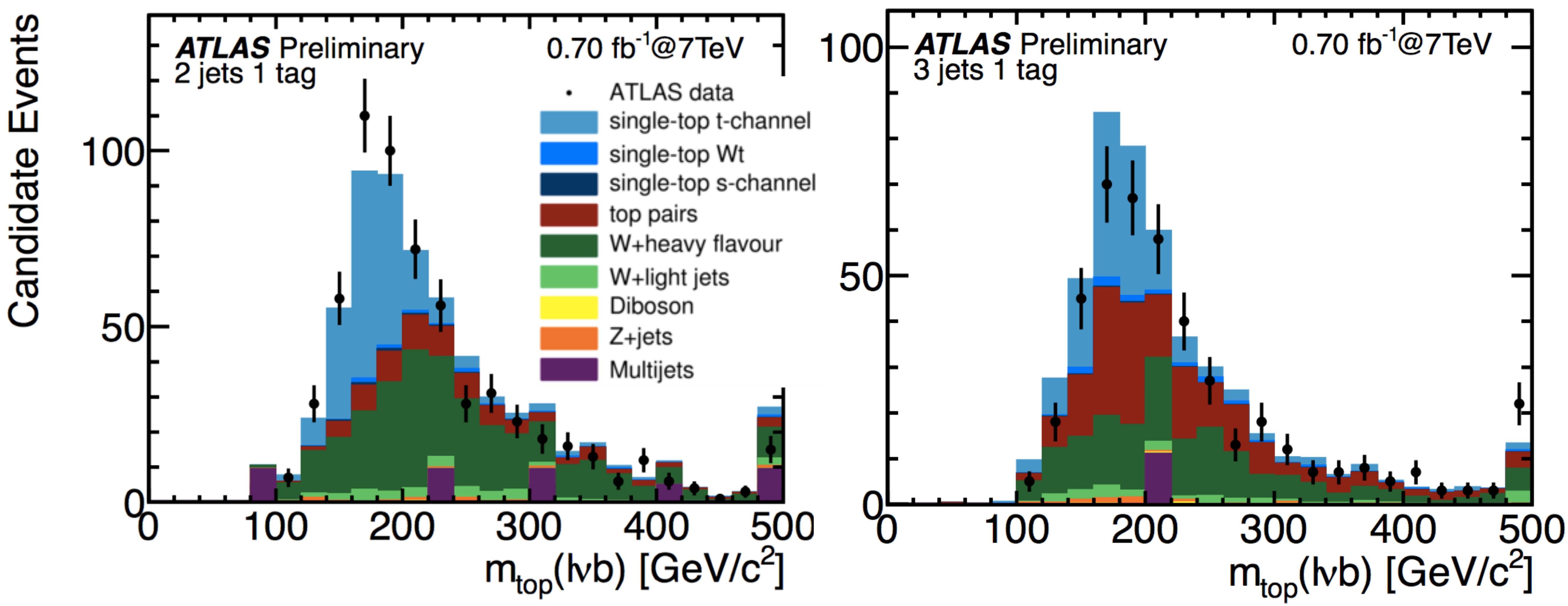


s-channel

- t-channel **ATLAS-CONF-2011-101**
  - cut-based and neural network analysis, expect 64.6 pb
    - result: 90 ± 9 (stat) ± 31/20 (syst) pb → within ~1.1 sigma of SM
- Wt-channel **ATLAS-CONF-2011-104**
  - cut-based analysis in dilepton channel, expect 15.7 pb
    - result: < 39.1 pb (expected limit 40.6 pb) → limit ~$2.5\times\sigma_{SM}$
- s-channel **ATLAS-CONF-2011-118**
  - cut-based analysis, expect 4.6 pb
    - result: < 26.5 pb → limit ~$5\times\sigma_{SM}$

Single top: t-channel

- Selection cuts include **ATLAS-CONF-2011-101**
  - $|\eta(\text{l-Jet})| > 2.0$ $H_T > 210$ GeV (scalar sum of p_T of l, nu, j_1, j_2)
  - $\Delta\eta(\text{bjets-ujet1}) > 1.0$ $150 < M_{lnub} < 190$ GeV
- Result: 90 ± 9 (stat) ± 31/20 (syst) pb



The t-channel contribution is normalized to the measured combined cut-based cross section

Top properties

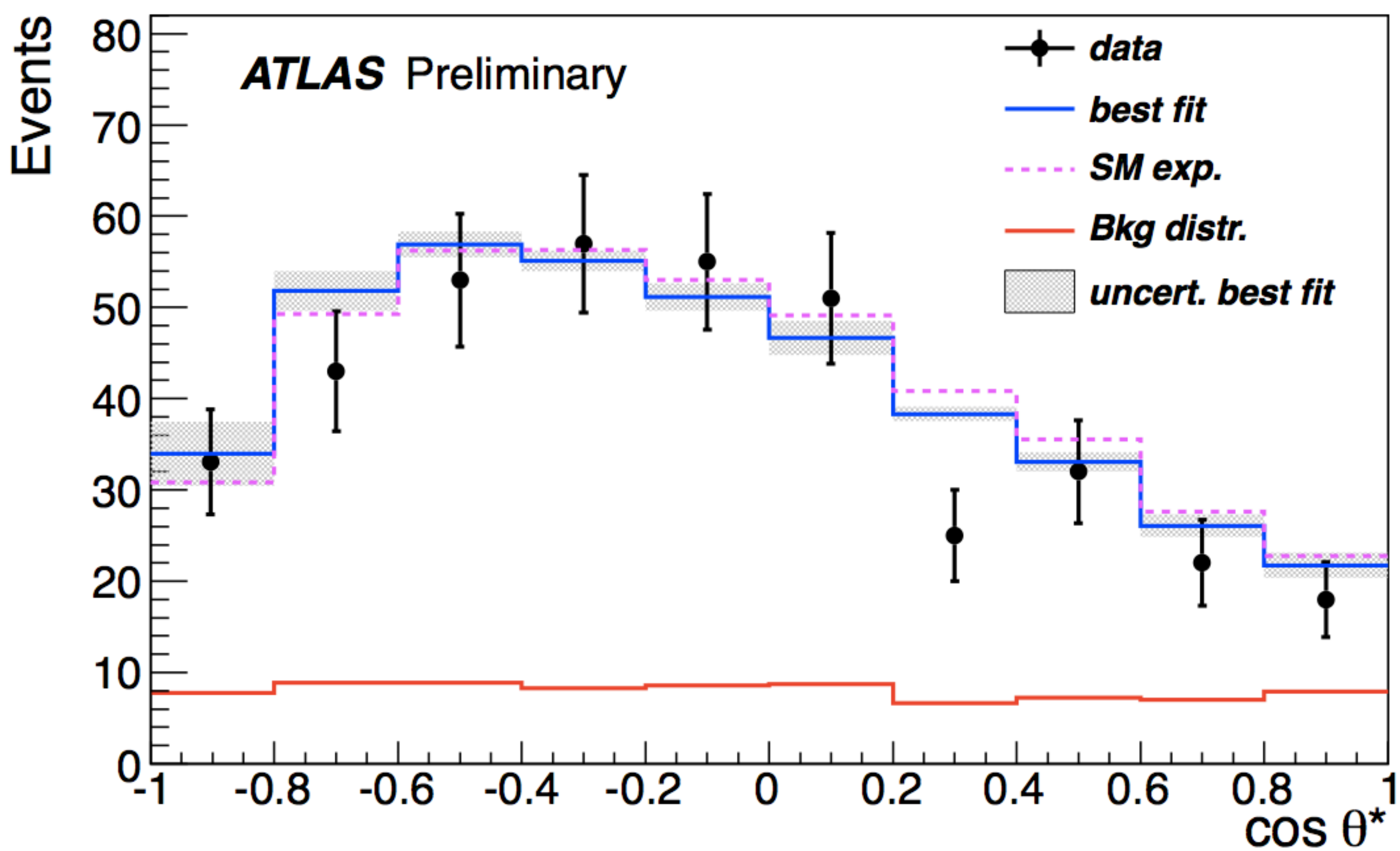
- Potential for high precision top properties measurements
  - at L = 3.5 × 10^{33} $cm^{-2}s^{-1}$, events with top(s) are produced at ~1 Hz
  - Exciting program, including
    - top mass: 175.9 +/- 0.9 (stat) +/- 2.7 (syst) — **ATLAS-CONF-2011-120**
    - top charge — **ATLAS-CONF-2011-141**
    - charge asymmetry in top-antitop pair production — **ATLAS-CONF-2011-106**
    - W helicity in top decays — **ATLAS-CONF-2011-122**
    - top-antitop spin correlation — **ATLAS-CONF-2011-117**
    - rare top decays and FCNC
    - top-antitop plus photon(s) — **ATLAS-CONF-2011-153**
    - reconstruction of boosted tops
- Many exciting searches
  - top-antitop resonances — **ATLAS-CONF-2011-123**, **ATLAS-CONF-2011-087**, **ATLAS-CONF-2011-070**
  - top-antitop + missing ransverse energy — **Submitted to PRL**
  - 4 tops, etc.

Top physics: W polarisation

- W helicities
  - one charged lepton, ETmiss, at least 4 jets (at least one is b-tagged)
  - helicity fractions F_0, F_L, F_R, where F_0 is related to the top mass!

$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta^*} = \frac{3}{8}(1+\cos\theta^*)^2 F_R + \frac{3}{8}(1-\cos\theta^*)^2 F_L + \frac{3}{4}\left(1-\cos^2\theta^*\right) F_0$$

ATLAS-CONF-2011-122



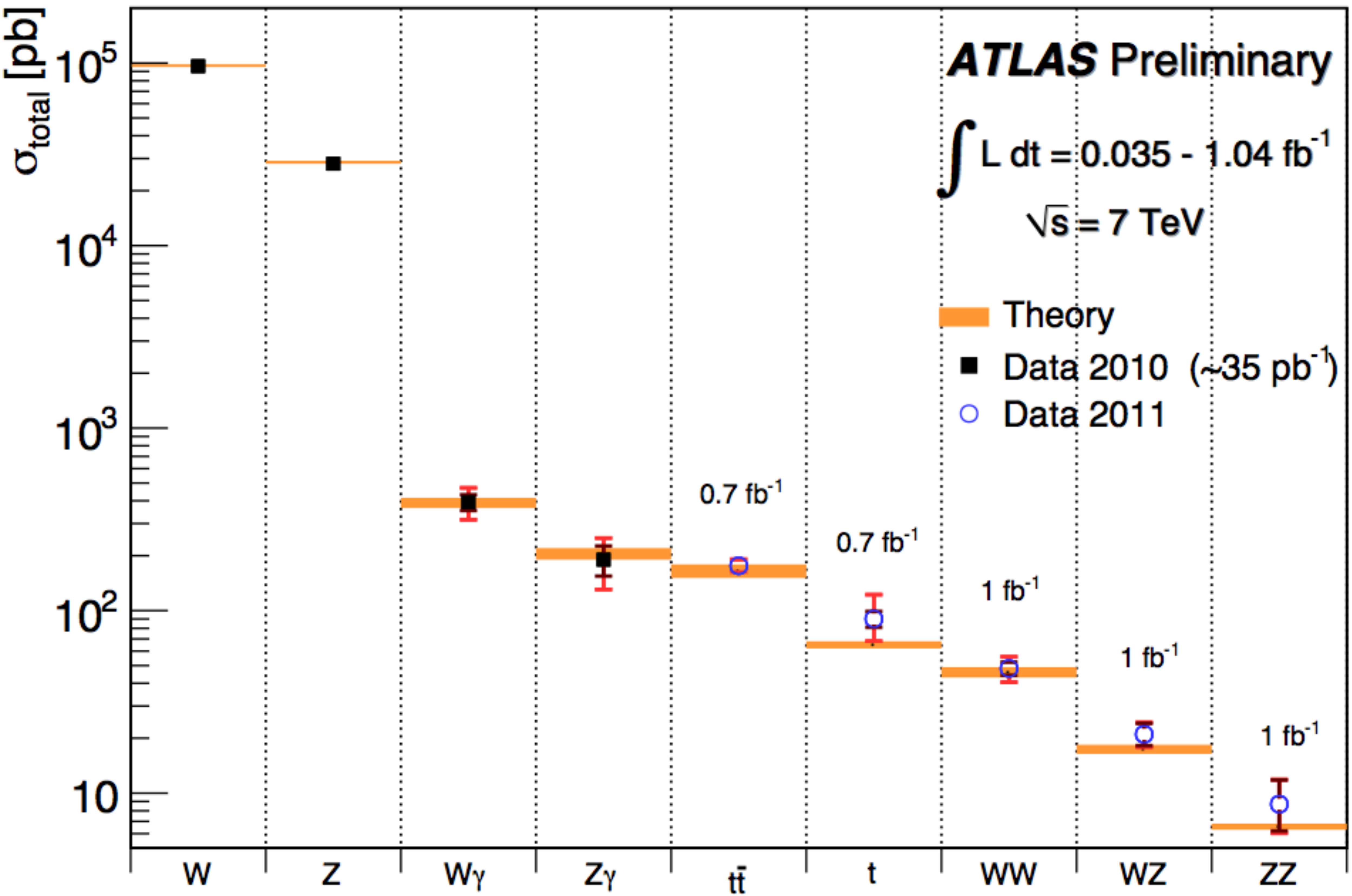
SM NNLO:
$F_0 = 0.687 \pm 0.005$
$F_L = 0.311 \pm 0.005$
$F_R = 0.0017 \pm 0.0001$

Results:

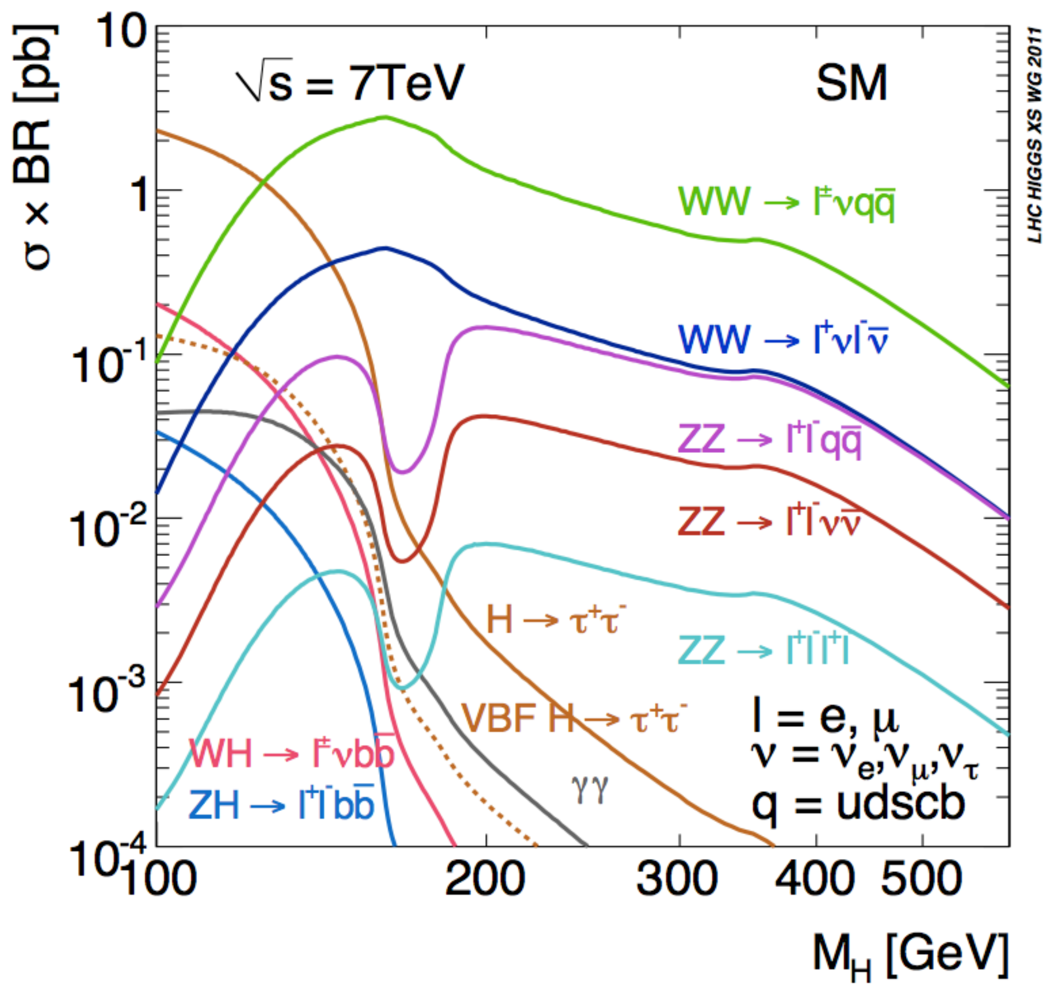
$$F_0 = 0.57 \pm 0.07\,(\text{stat.}) \pm 0.09\,(\text{syst.})$$
$$F_L = 0.35 \pm 0.04\,(\text{stat.}) \pm 0.04\,(\text{syst.})$$
$$F_R = 0.09 \pm 0.04\,(\text{stat.}) \pm 0.08\,(\text{syst.})$$

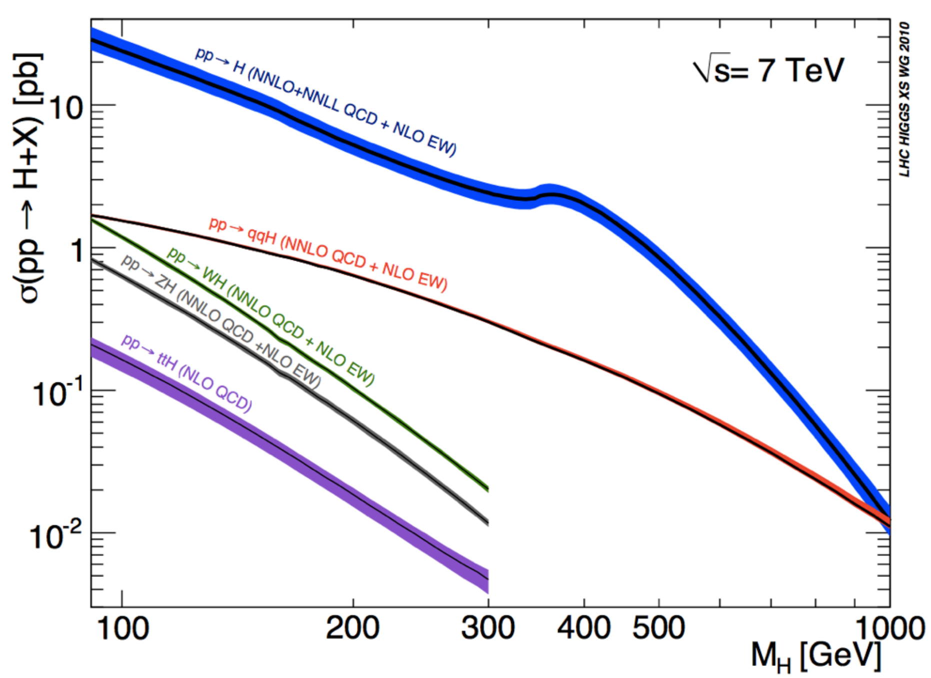
Agrees with SM V-A coupling!
Limits are set on anomalous Wtb vertex coupling

Summary of a few SM production cross section measurements

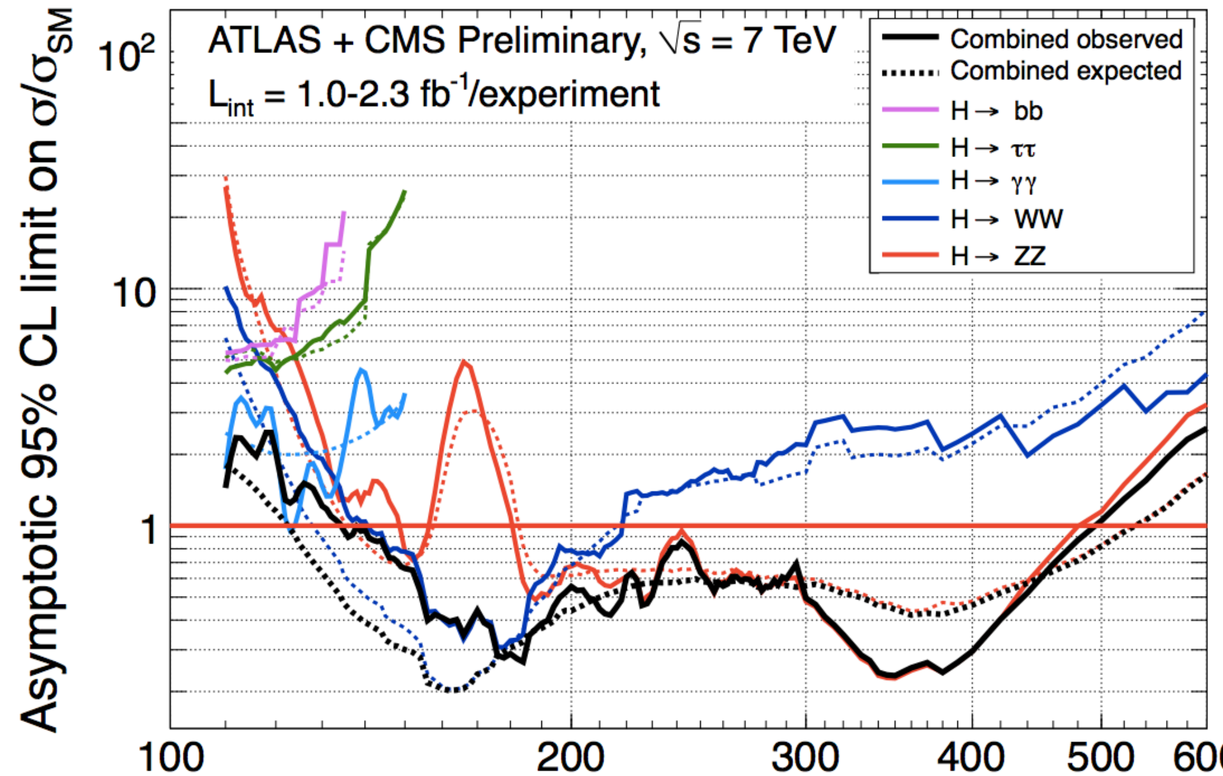


Standard Model Higgs

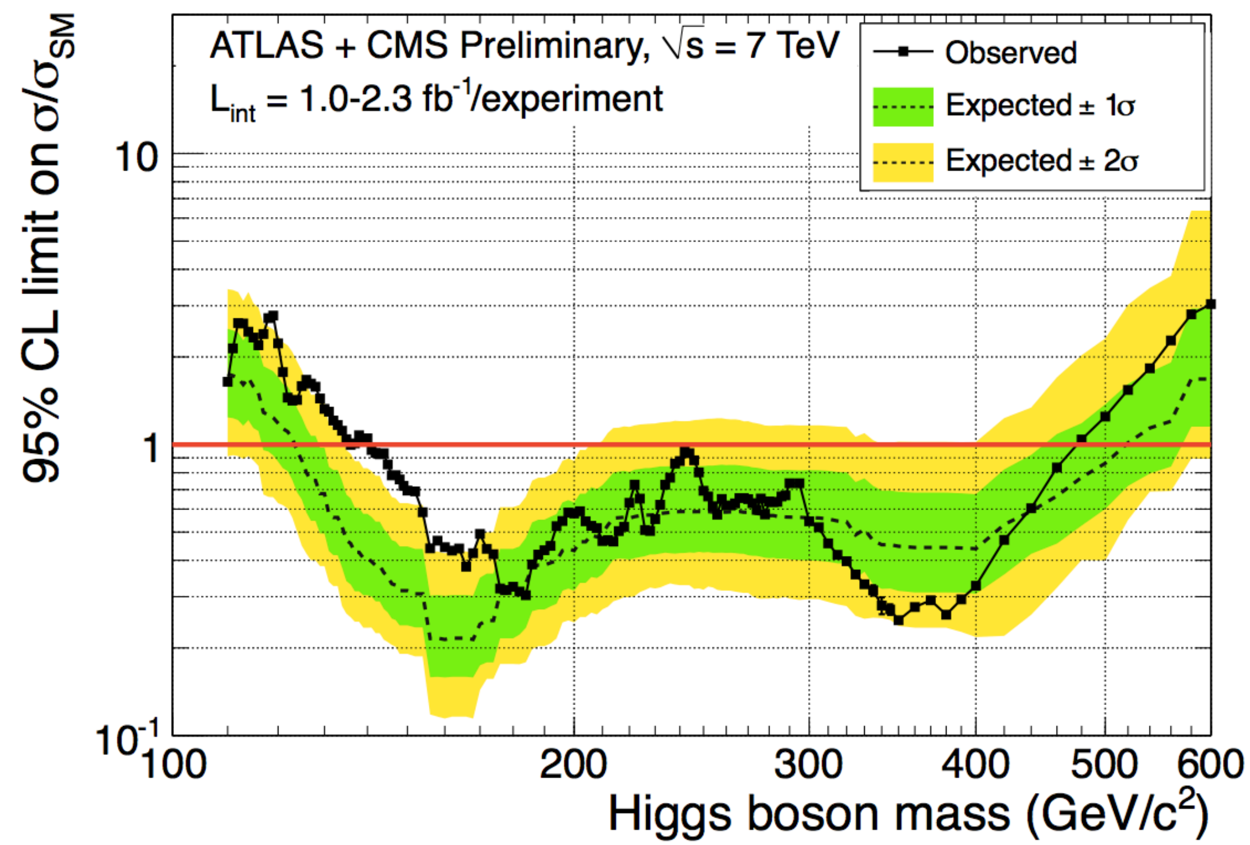




18 Nov 2011 for HCP2011

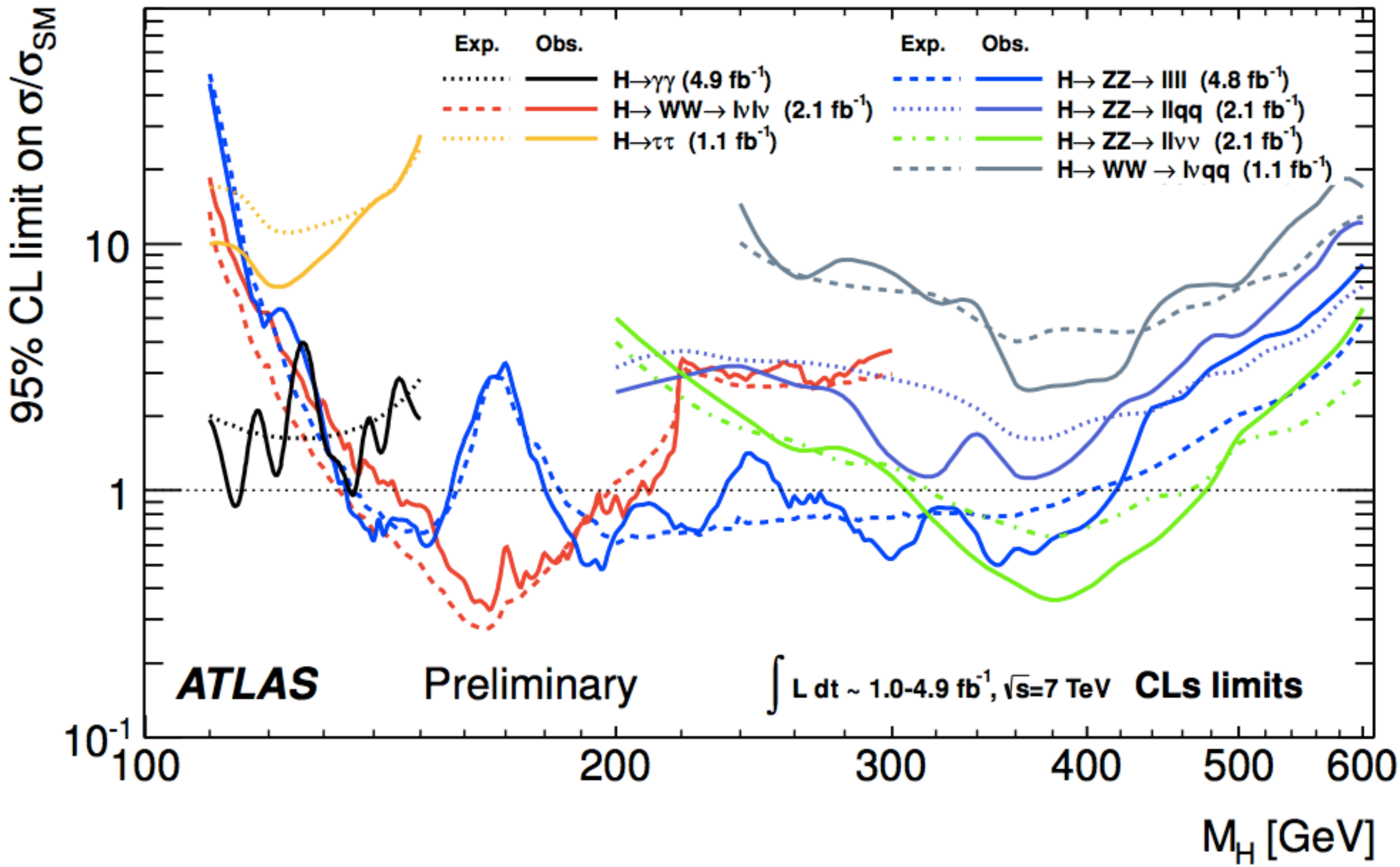


ATLAS-CONF-2011-157



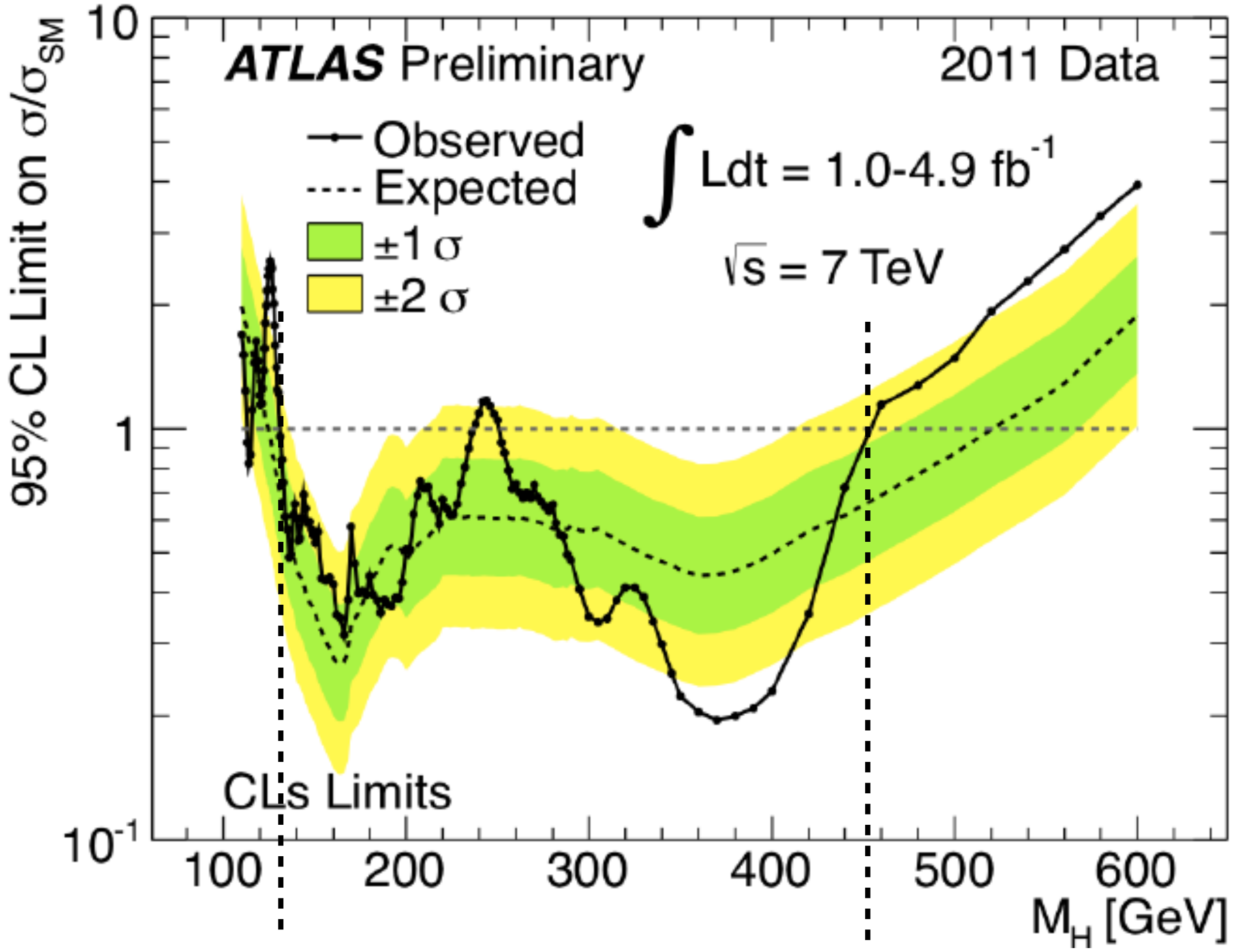
ATLAS SM Higgs Result

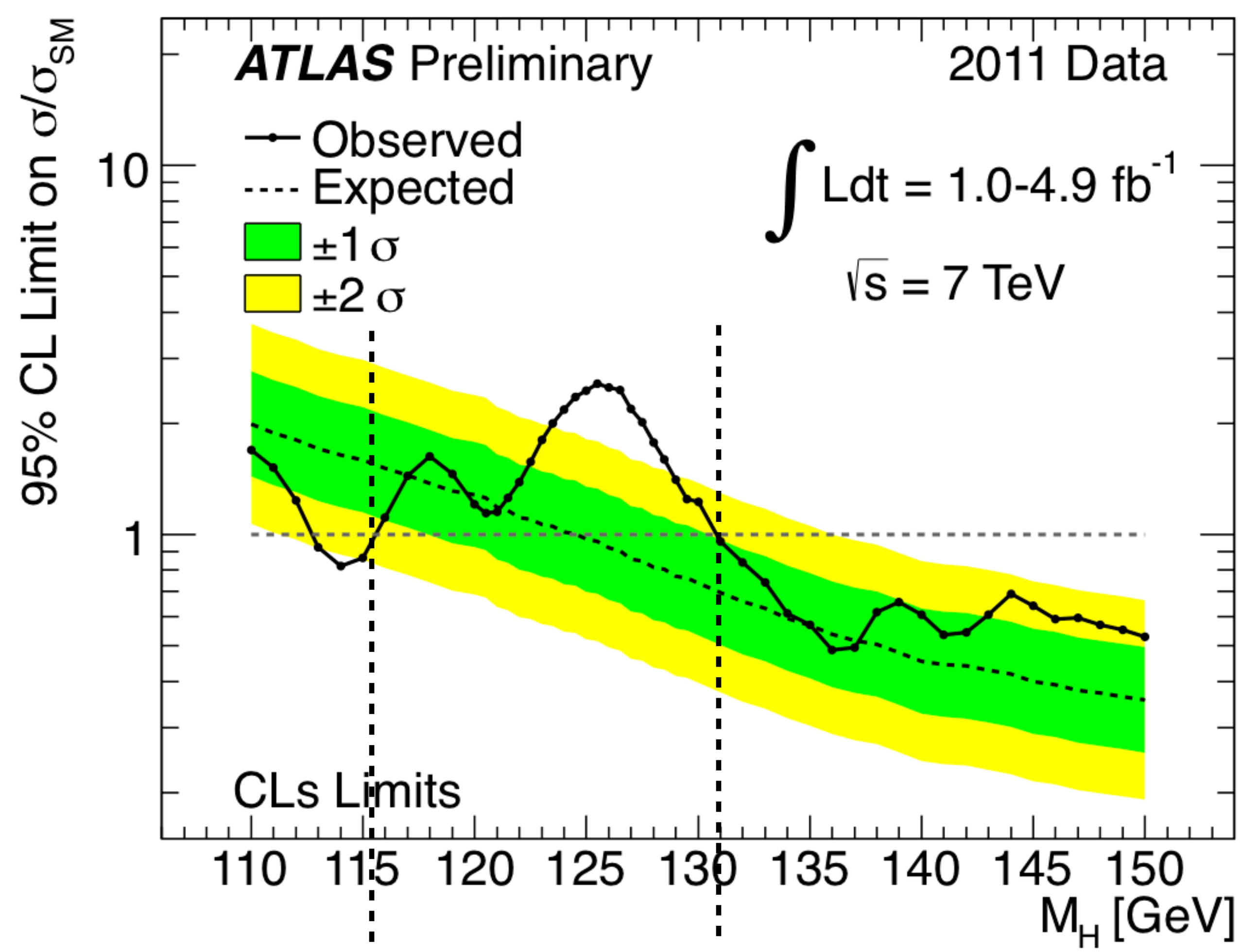
ATLAS-CONF-2011-163



SM Higgs combined channel constraints

ATLAS-CONF-2011-163





Excluded at 95% CL: $112.7 < M_H < 115.5$ GeV
$131 < M_H < 237$ GeV
$251 < M_H < 453$ GeV

Expected exclusion if no signal: $124.6 < M_H < 520$ GeV

Excluded at 99% CL: $133 < M_H < 230$ GeV
$260 < M_H < 437$ GeV

Max deviation from background-only expectation observed for $M_H \sim 126$ GeV.

Local $p_0 = 1.9 \times 10^{-4}$

- **local significance of excess = 3.6σ**
- ~2.8σ H→γγ, 2.1σ H→4l, 1.4σ H→lνlν
- expected from SM Higgs: 2.4σ

Global

- **p_0 = 0.6% → 2.5σ LEE over 110-146 GeV**
- **p_0 = 1.4% → 2.2σ LEE over 110-600 GeV**

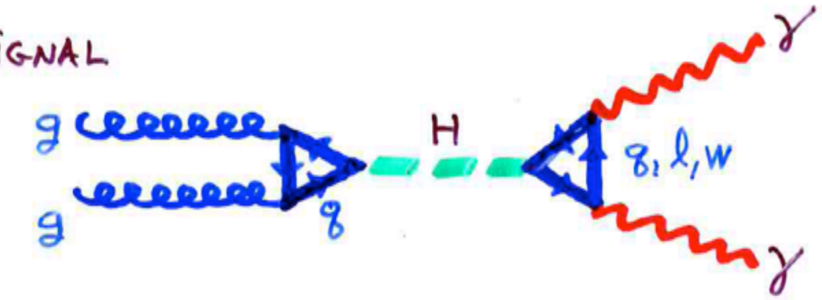
CAP June 1996

$H \rightarrow \gamma\gamma$

- BEST CHANNEL FOR $80\ GeV < M_H < 120\ GeV$

  PRESENT DIRECT LIMIT FOR SM H : $M_H > 65$ 52
  EXPECT LEP (192 GeV) : $M_H > 95$ GeV 95%

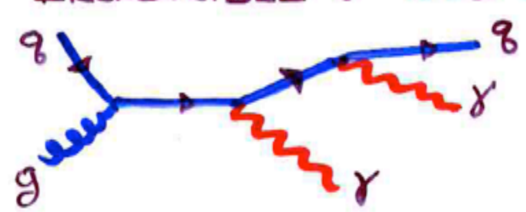
- SIGNAL



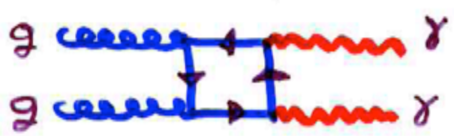
g FUSION

- BACKGROUND

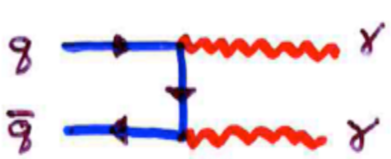
  IRREDUCIBLE : QCD PRODUCTION



q BREM



$gg \rightarrow \gamma\gamma$ (BOX)



$q\bar{q} \rightarrow \gamma\gamma$ (BORN)

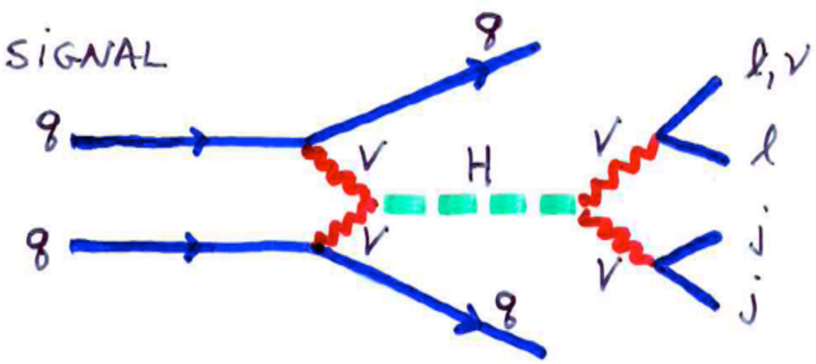
  REDUCIBLE : QCD JETS, $Z \rightarrow ee$ } WITH FAKE γ

- CHALLENGING CHANNEL

$H \rightarrow WW \rightarrow l\nu jj$
$\quad\quad\ ZZ \rightarrow lljj$

- INTERESTING BECAUSE 150× BRANCHING RATIO OF $\ell\ell$ CHANNEL

- SIGNAL



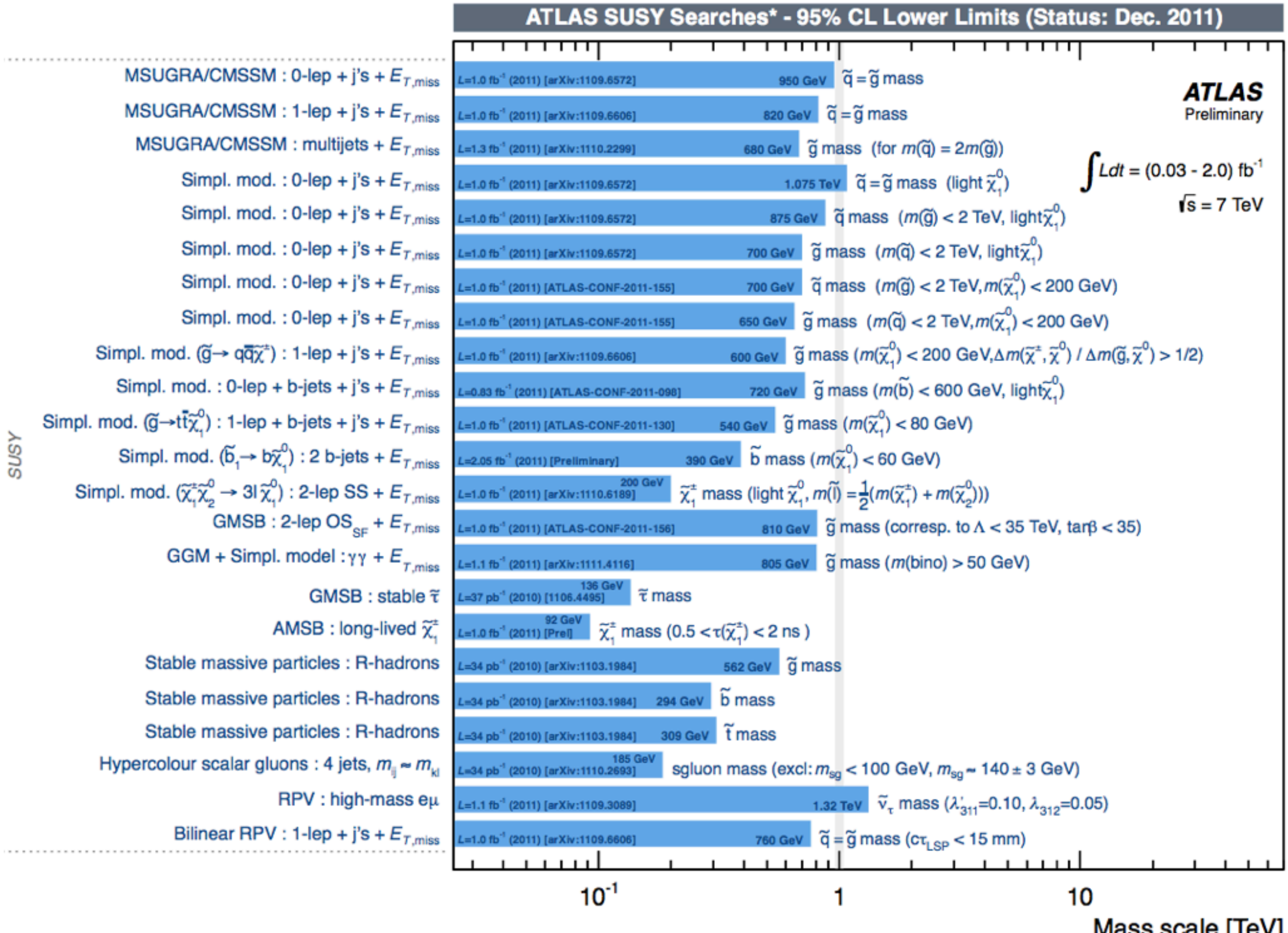
V FUSION

- BACKGROUND

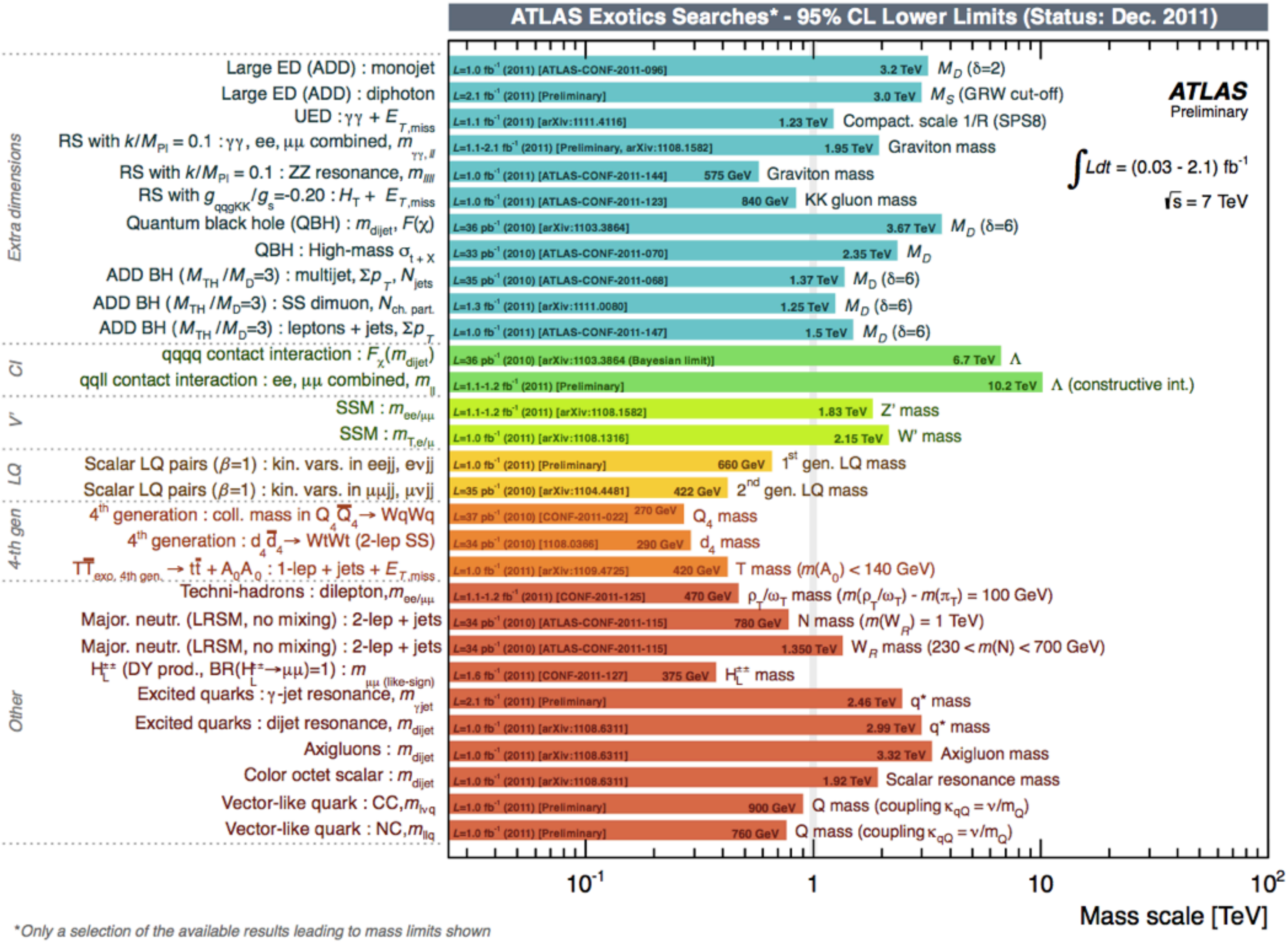
  $t\bar{t}$, W + JETS

- TO CONTROL BACKGROUND
  - NEED A GOOD $\sigma_{M_{jj}}$ FOR M_W, M_Z RECONSTRUCTION
    - → CALORIMETER GRANULARITY
    - → PILEUP CONTROL
  - FORWARD JET TAGGING $2 < |\eta| < 5$
  - CENTRAL JET VETO

→ TALK P. SAVARD

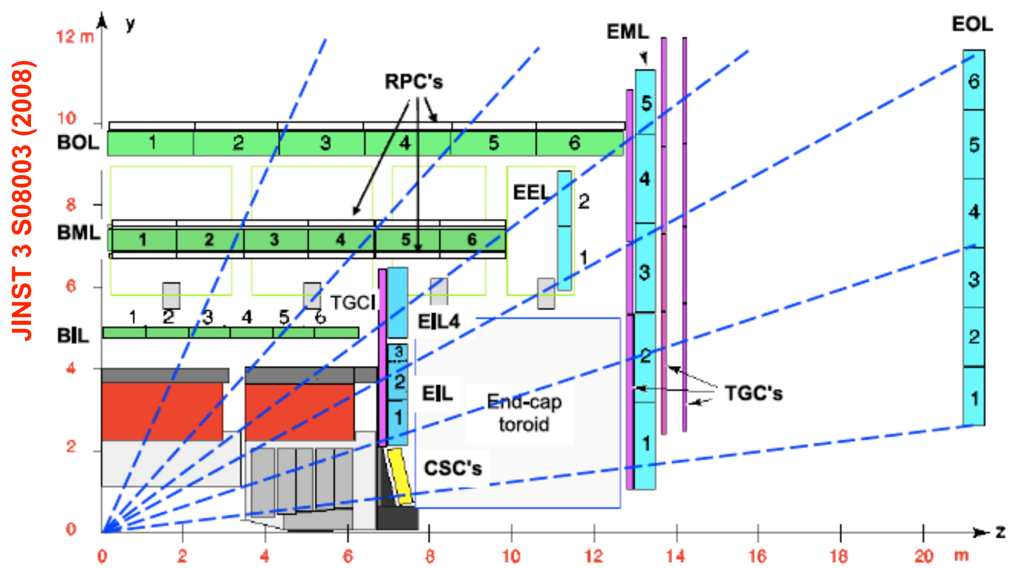


*Only a selection of the available results leading to mass limits shown

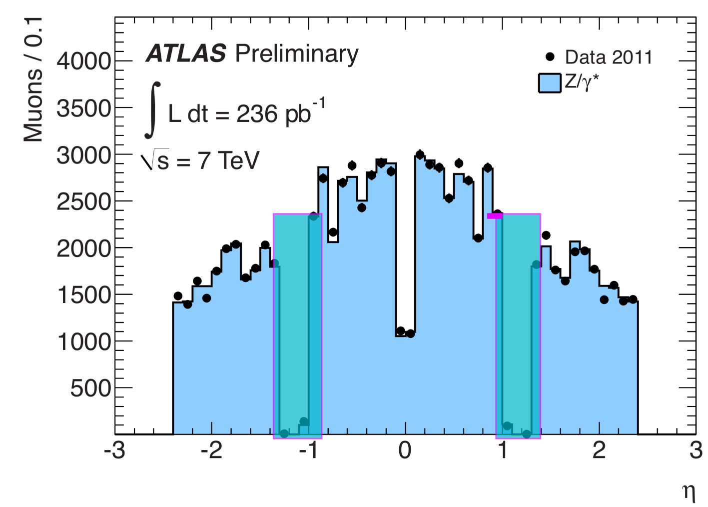


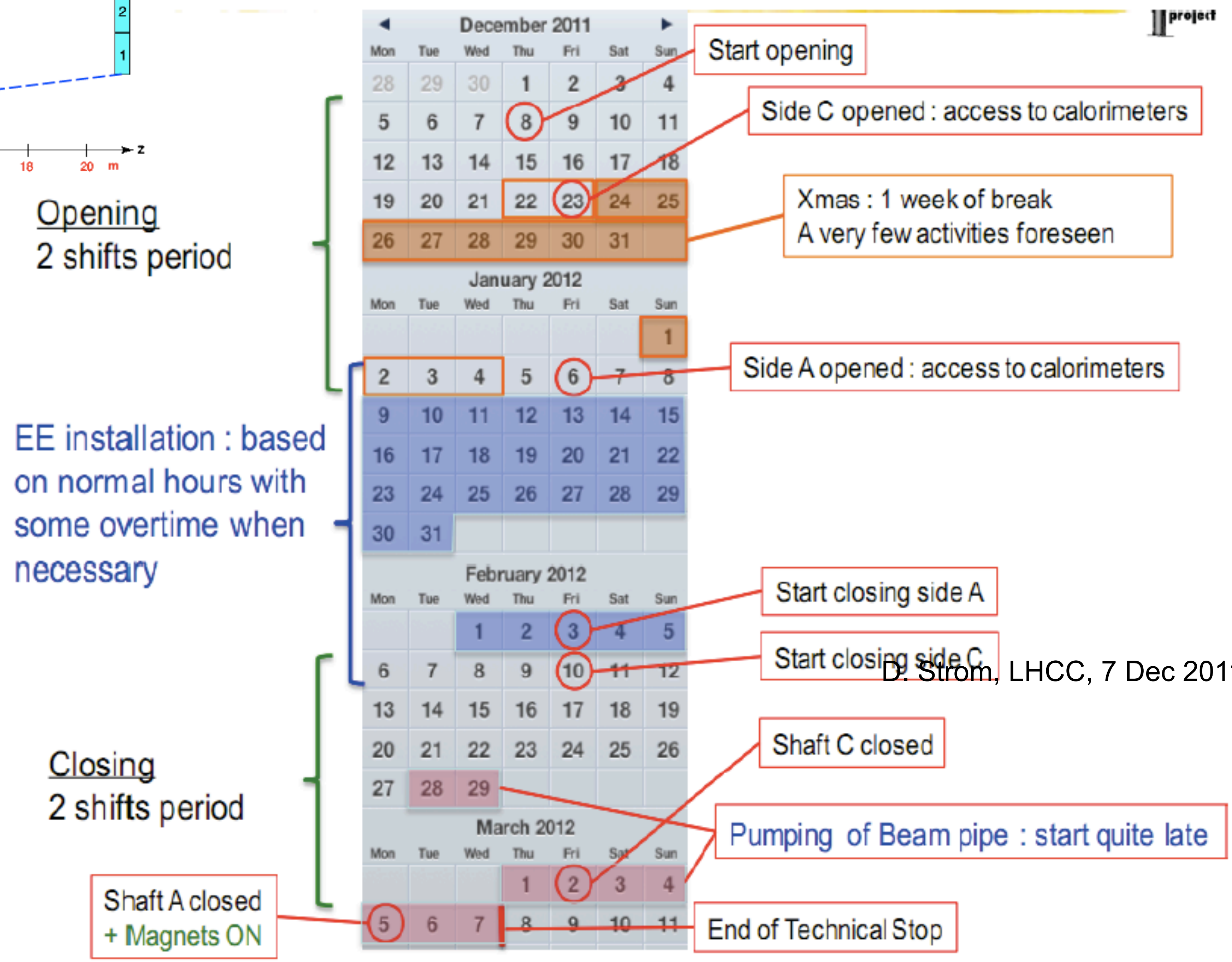
ATLAS Exotics Searches* - 95% CL Lower Limits (Status: Dec. 2011)
ATLAS
Preliminary
$\int Ldt = (0.03 - 2.1)\ fb^{-1}$
$\sqrt{s} = 7$ TeV
Extra dimensions
Large ED (ADD) : monojet
L=1.0 fb-1 (2011) [ATLAS-CONF-2011-096] 3.2 TeV M_D (δ=2)
Large ED (ADD) : diphoton
L=2.1 fb-1 (2011) [Preliminary] 3.0 TeV M_S (GRW cut-off)
UED : γγ + $E_{T,miss}$
L=1.1 fb-1 (2011) [arXiv:1111.4116] 1.23 TeV Compact. scale 1/R (SPS8)
RS with k/M_{Pl} = 0.1 : γγ, ee, μμ combined, $m_{\gamma\gamma,ll}$
L=1.1-2.1 fb-1 (2011) [Preliminary, arXiv:1108.1582] 1.95 TeV Graviton mass
RS with k/M_{Pl} = 0.1 : ZZ resonance, m_{llll}
L=1.0 fb-1 (2011) [ATLAS-CONF-2011-144] 575 GeV Graviton mass
RS with g_{qqgKK}/g_s=-0.20 : H_T + $E_{T,miss}$
L=1.0 fb-1 (2011) [ATLAS-CONF-2011-123] 840 GeV KK gluon mass
Quantum black hole (QBH) : m_{dijet}, F(χ)
L=36 pb-1 (2010) [arXiv:1103.3864] 3.67 TeV M_D (δ=6)
QBH : High-mass σ_{t+X}
L=33 pb-1 (2010) [ATLAS-CONF-2011-070] 2.35 TeV M_D
ADD BH (M_{TH}/M_D=3) : multijet, Σp_T, N_{jets}
L=35 pb-1 (2010) [ATLAS-CONF-2011-068] 1.37 TeV M_D (δ=6)
ADD BH (M_{TH}/M_D=3) : SS dimuon, $N_{ch.\ part.}$
L=1.3 fb-1 (2011) [arXiv:1111.0080] 1.25 TeV M_D (δ=6)
ADD BH (M_{TH}/M_D=3) : leptons + jets, Σp_T
L=1.0 fb-1 (2011) [ATLAS-CONF-2011-147] 1.5 TeV M_D (δ=6)
CI
qqqq contact interaction : $F_\chi(m_{dijet})$
L=36 pb-1 (2010) [arXiv:1103.3864 (Bayesian limit)] 6.7 TeV Λ
qqll contact interaction : ee, μμ combined, m_{ll}
L=1.1-1.2 fb-1 (2011) [Preliminary] 10.2 TeV Λ (constructive int.)
V'
SSM : $m_{ee/\mu\mu}$
L=1.1-1.2 fb-1 (2011) [arXiv:1108.1582] 1.83 TeV Z' mass
SSM : $m_{T,e/\mu}$
L=1.0 fb-1 (2011) [arXiv:1108.1316] 2.15 TeV W' mass
LQ
Scalar LQ pairs (β=1) : kin. vars. in eejj, evjj
L=1.0 fb-1 (2011) [Preliminary] 660 GeV 1st gen. LQ mass
Scalar LQ pairs (β=1) : kin. vars. in μμjj, μvjj
L=35 pb-1 (2010) [arXiv:1104.4481] 422 GeV 2nd gen. LQ mass
4-th gen
4th generation : coll. mass in $Q_4\bar{Q}_4 \rightarrow WqWq$
L=37 pb-1 (2010) [CONF-2011-022] 270 GeV Q_4 mass
4th generation : $d_4\bar{d}_4 \rightarrow WtWt$ (2-lep SS)
L=34 pb-1 (2010) [1108.0366] 290 GeV d_4 mass
$T\bar{T}_{exo,\ 4th\ gen.} \rightarrow t\bar{t} + A_0A_0$: 1-lep + jets + $E_{T,miss}$
L=1.0 fb-1 (2011) [arXiv:1109.4725] 420 GeV T mass ($m(A_0)$ < 140 GeV)
Other
Techni-hadrons : dilepton, $m_{ee/\mu\mu}$
L=1.1-1.2 fb-1 (2011) [CONF-2011-125] 470 GeV ρ_T/ω_T mass ($m(\rho_T/\omega_T) - m(\pi_T)$ = 100 GeV)
Major. neutr. (LRSM, no mixing) : 2-lep + jets
L=34 pb-1 (2010) [ATLAS-CONF-2011-115] 780 GeV N mass ($m(W_R)$ = 1 TeV)
Major. neutr. (LRSM, no mixing) : 2-lep + jets
L=34 pb-1 (2010) [ATLAS-CONF-2011-115] 1.350 TeV W_R mass (230 < m(N) < 700 GeV)
$H_L^{\pm\pm}$ (DY prod., BR($H_L^{\pm\pm}\rightarrow\mu\mu$)=1) : $m_{\mu\mu\ (like\text{-}sign)}$
L=1.6 fb-1 (2011) [CONF-2011-127] 375 GeV $H_L^{\pm\pm}$ mass
Excited quarks : γ-jet resonance, $m_{\gamma jet}$
L=2.1 fb-1 (2011) [Preliminary] 2.46 TeV q* mass
Excited quarks : dijet resonance, m_{dijet}
L=1.0 fb-1 (2011) [arXiv:1108.6311] 2.99 TeV q* mass
Axigluons : m_{dijet}
L=1.0 fb-1 (2011) [arXiv:1108.6311] 3.32 TeV Axigluon mass
Color octet scalar : m_{dijet}
L=1.0 fb-1 (2011) [arXiv:1108.6311] 1.92 TeV Scalar resonance mass
Vector-like quark : CC, m_{lvq}
L=1.0 fb-1 (2011) [Preliminary] 900 GeV Q mass (coupling $\kappa_{qQ} = v/m_Q$)
Vector-like quark : NC, m_{llq}
L=1.0 fb-1 (2011) [Preliminary] 760 GeV Q mass (coupling $\kappa_{qQ} = v/m_Q$)
10^{-1}
1
10
10^2
Mass scale [TeV]
*Only a selection of the available results leading to mass limits shown

ATLAS 2011/2012 technical stop



- Fix some calorimeter readout problems
- Install staged EE muon chambers on one side (C), remaining ones in the next shutdown
- Yearly maintenance of the infrastructure





LHC in 2012

- First discussion at LHC Machine Committee (LMC) on 26 Nov
- ... to be followed by an LHC meeting in Evian 12-14 December
- ... and finalized in Chamonix in February 2012

- Machine parameters
  - which energy? 3.5 TeV, 4 TeV per beam?
  - which bunch spacing? 50 ns, 25 ns?
  - which β* at ATLAS and CMS? 0.7 m, 1 m?
- Considerations for the experiments
  - pile-up
  - background limitations?
  - physics priorities?
    - required integrated luminosity
    - impact of energy choice
    - luminosity calibration
    - ...

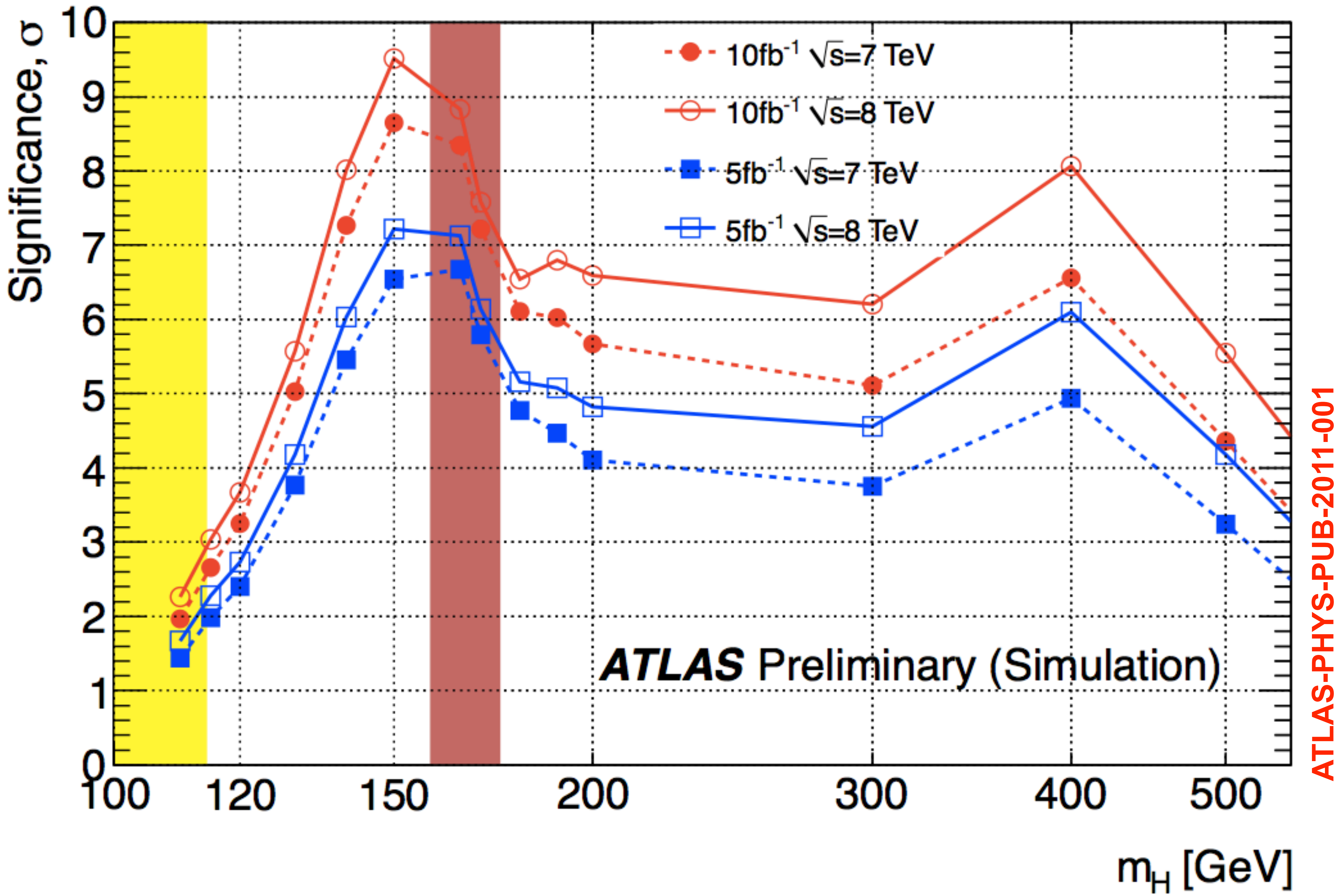
Assumptions

E=4TeV: beta* = 0.7m: 148 days of physics: no intensity limit for 25ns

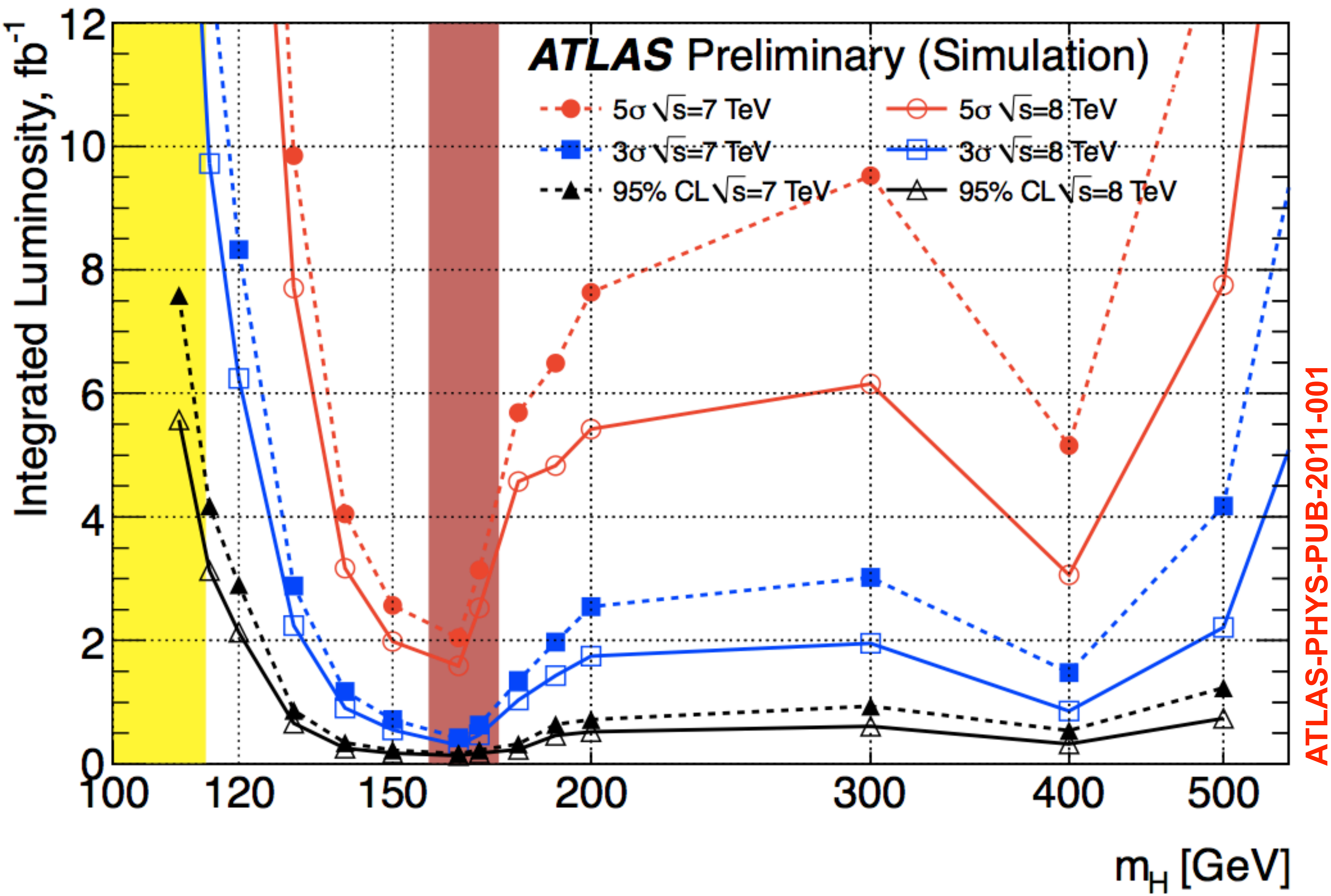
Bunch Spacing	Peak Luminosity	Integrated Luminosity (fb-1)	Pile Up	N max
50ns	5.80E+33	~16	~27	1.55E+11
25ns	3.80E+33	~10	~9	1.15E+11

S. Meyers, LHCC, 7 Dec 2011
Also, Bertolucci, HCP2011

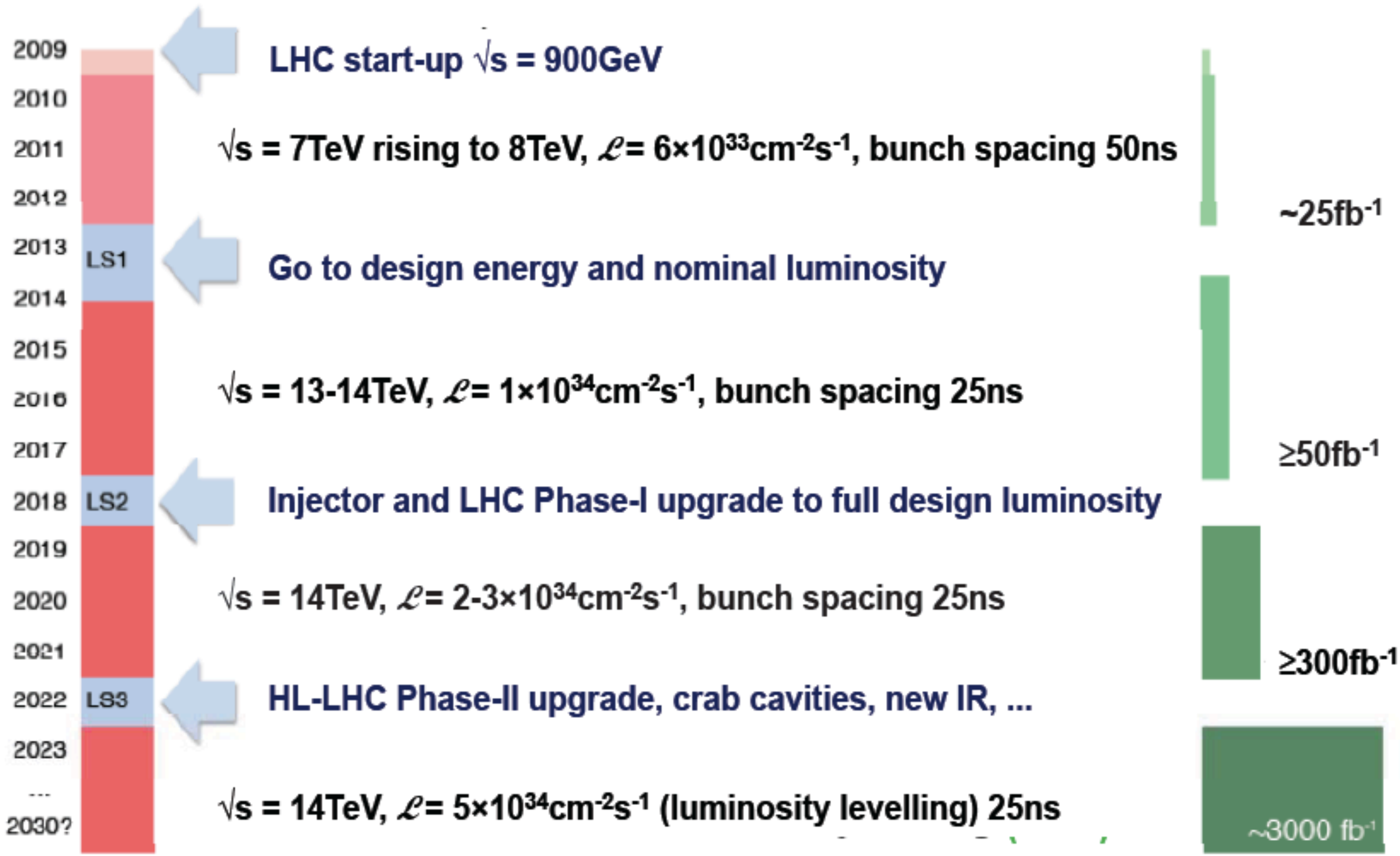
Higgs expected level of significance



Higgs exclusion, evidence, discovery



LHC schedule assumptions



ILC, HE-LHC, ... ?

D. Strom, LHCC, 7 Dec 2011
Also, Bertolucci, HCP2011

Phase-0 (installation 2013-14) ATLAS

Major Improvements to Physics Capabilities

- New insertable pixel b-layer (IBL) (drives shutdown schedule)
- Finish the installation of the EE muon chambers staged in 2003 +additional chambers in the feet (new electronics) and elevators region
- New small Be pipe

Consolidation and maintenance to preserve present performance

- New Aluminum beam pipes to prevent activation problem and reduce BG
- New pixel services (nSQP) (→ pending decision by mid 2012)
- New evaporative cooling plant for Pixel and SCT + IBL CO_2 cooling plant
- Replace all calorimeter Low Voltage Power Supplies
- Exchange all broken TGCs where possible
- Consolidate part of the LUCID system
- Upgrade the magnets cryogenics with a new spare main compressor and decouple toroid and solenoid cryogenics
- Add specific neutron shielding (behind end-cap toroid, USA15)
- Revisit the entire electricity supply network (UPS,…)
- Repairs and maintenance work in general !!!
- Preparations for Phase I upgrade (moveable b-pipe, AFP prototypes,…
- MBTS removal and possible replacement

D. Strom, LHCC, 7 Dec 2011

Phase-I (installation in or before 2018) ATLAS

Major Projects

1. New muon small wheels with more trigger granularity and trigger track vector information
2. Fast track processor (FTK) using SCT and pixel hits (input to LVL2) expected installation before 2018
3. Higher-granularity calorimeter LVL1 trigger and associated front-end electronic
4. New forward physics detection station at 220 m for new diffractive physics (full 3D edgeless and timing detectors, target 2017)
5. Topological trigger processors combining LVL1 information from different regions of interest (improvements starting well before 2018)

Supporting Projects

1. Adapt central LVL1 trigger electronics to new needs
2. New Tiles crack-gap scintillators and some new trigger electronics
3. Adapt if proven necessary HLT (in particular network) to the new needs/ conditions

D. Strom, LHCC, 7 Dec 2011

Phase-II (installation 2022-23)

ATLAS

1. New Inner Detector (strips and pixels)
   Very substantial progress in many R&D areas
2. New LAr front-end and back-end electronics
3. New Tiles front-end and back-end electronics
4. TDAQ upgrade
5. TAS and shielding upgrade
6. Various infrastructure upgrades
7. Common activities (installation, safety, …)

Under study:

1. LAr new FCAL
2. LAr HEC cold electronics consolidation
3. Muon Barrel and Large Wheel system upgrade
4. L1 track trigger
5. LUCID upgrade

D. Strom, LHCC, 7 Dec 2011

Conclusion

- The LHC has performed superbly. Thank you LHC!!
- ATLAS has recorded high quality data
  - hard work by ATLAS members to ensure high data quality and high data taking efficiency
- Trigger, data reconstruction, computing and data analysis are meeting the challenge of increase pile-up
- Physics results from the 2011 data set are very promising
  - solid understanding of SM signatures essential to searches for new physics
    - in some cases, SM measurements reach theoretical prediction precision
    - still many analyses to update with full data set
  - **the Higgs does not have many places to hide anymore...**
  - large array of searches for new physics
    - **BSM: if it is within the LHC's reach, ATLAS will see it!**
- ATLAS is preparing for 2012 and beyond

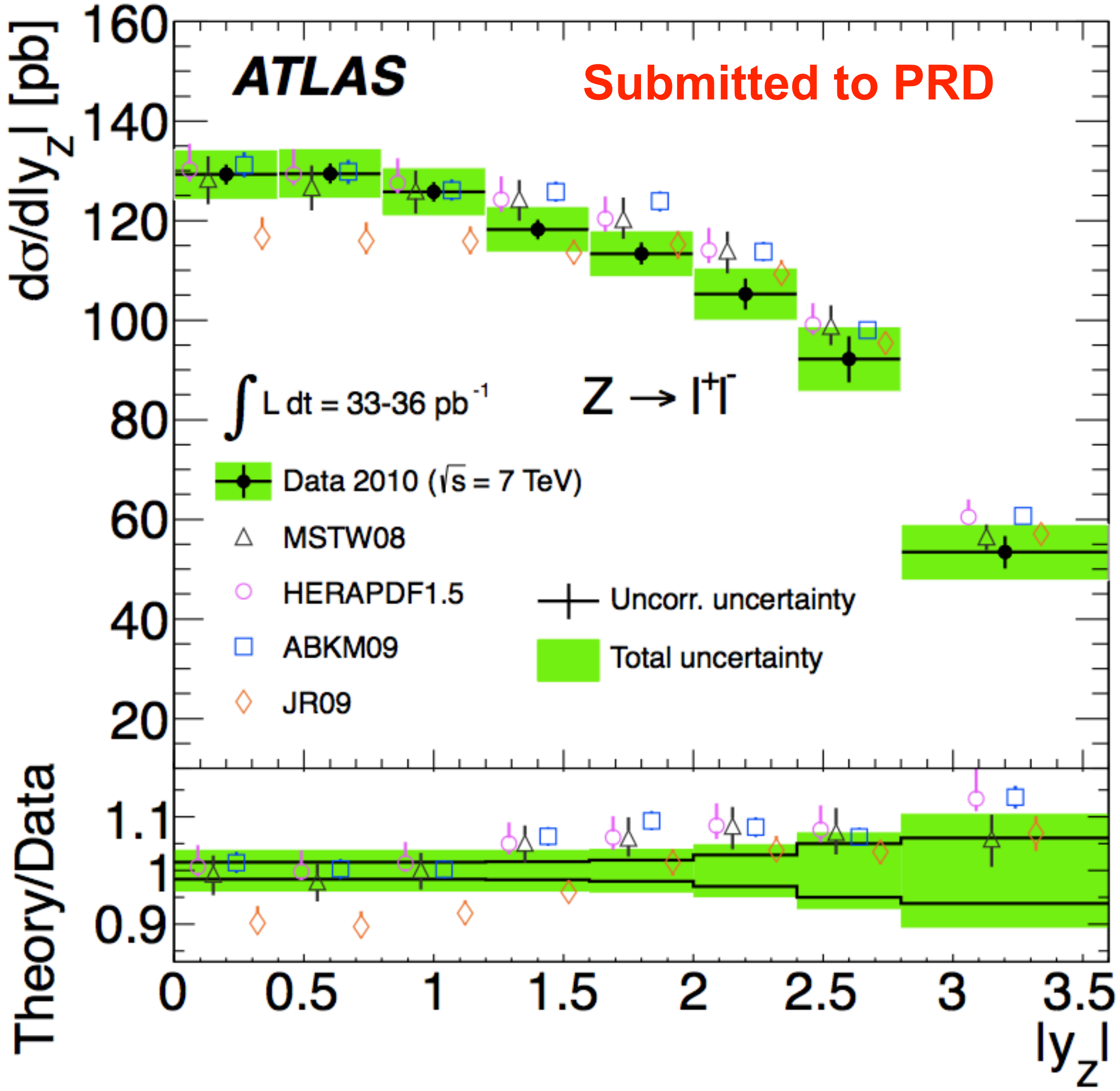
Entering a very exciting period...
with excellent prospects!

- **Acknowledgements (Canada): NSERC, CFI, NRC**

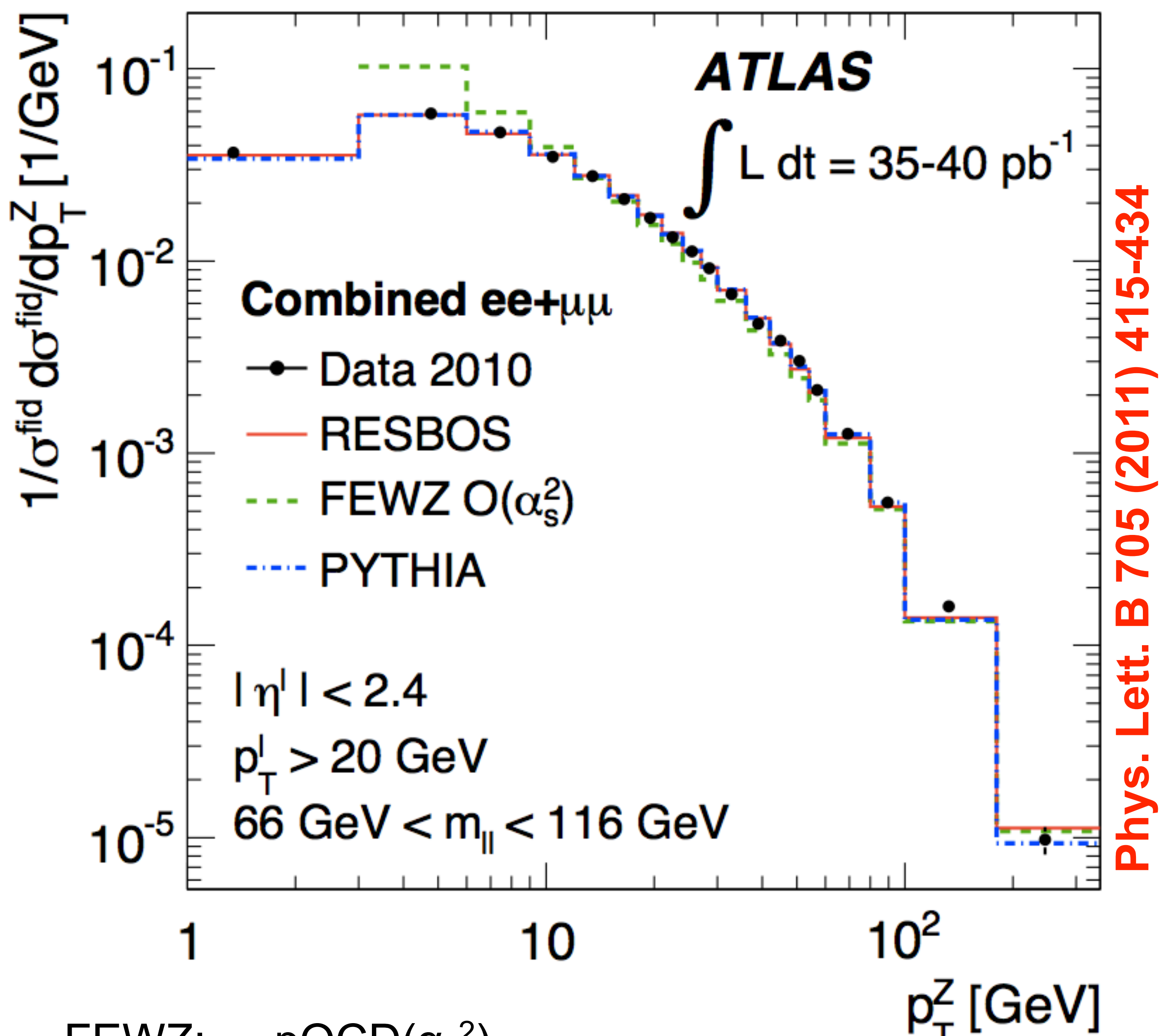
Extra slides

W/Z physics

- Production cross section vs W/Z rapidity and p_T
  - constraints on PDF and input to QCD calculations
    - NLO parton emissions, resummation models, NNLO cross section



Comparison with NNLO for various PDF sets
$66 < M_{ll} < 116$ GeV and $p_T(l) > 20$ GeV

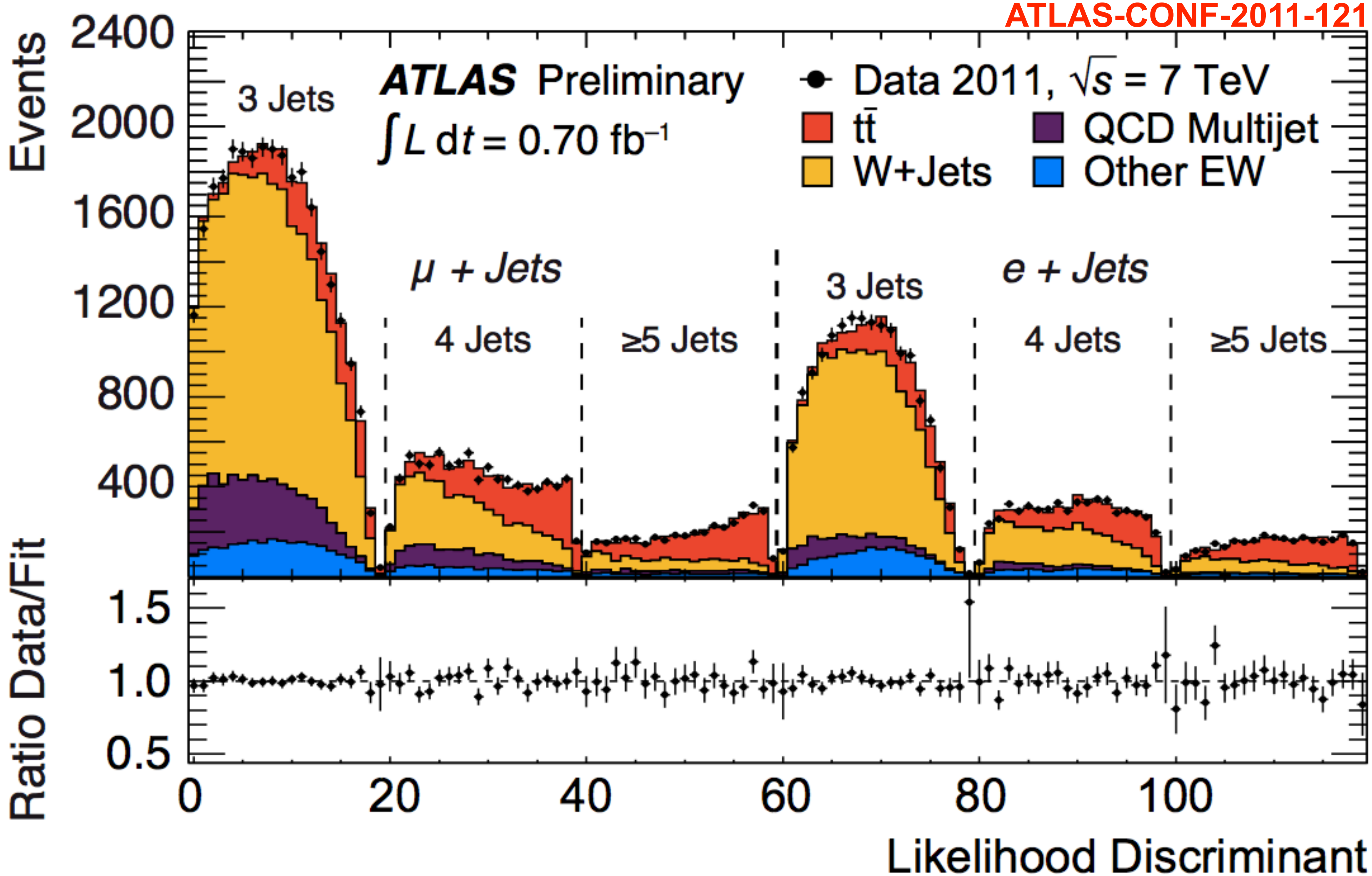


FEWZ: pQCD(α_s^2)
RESBOS: soft g resummation + pQCD (α_s and K)
PYTHIA: LO parton shower +match of pQCD(α_s)

Top-antiTop pair production cross section

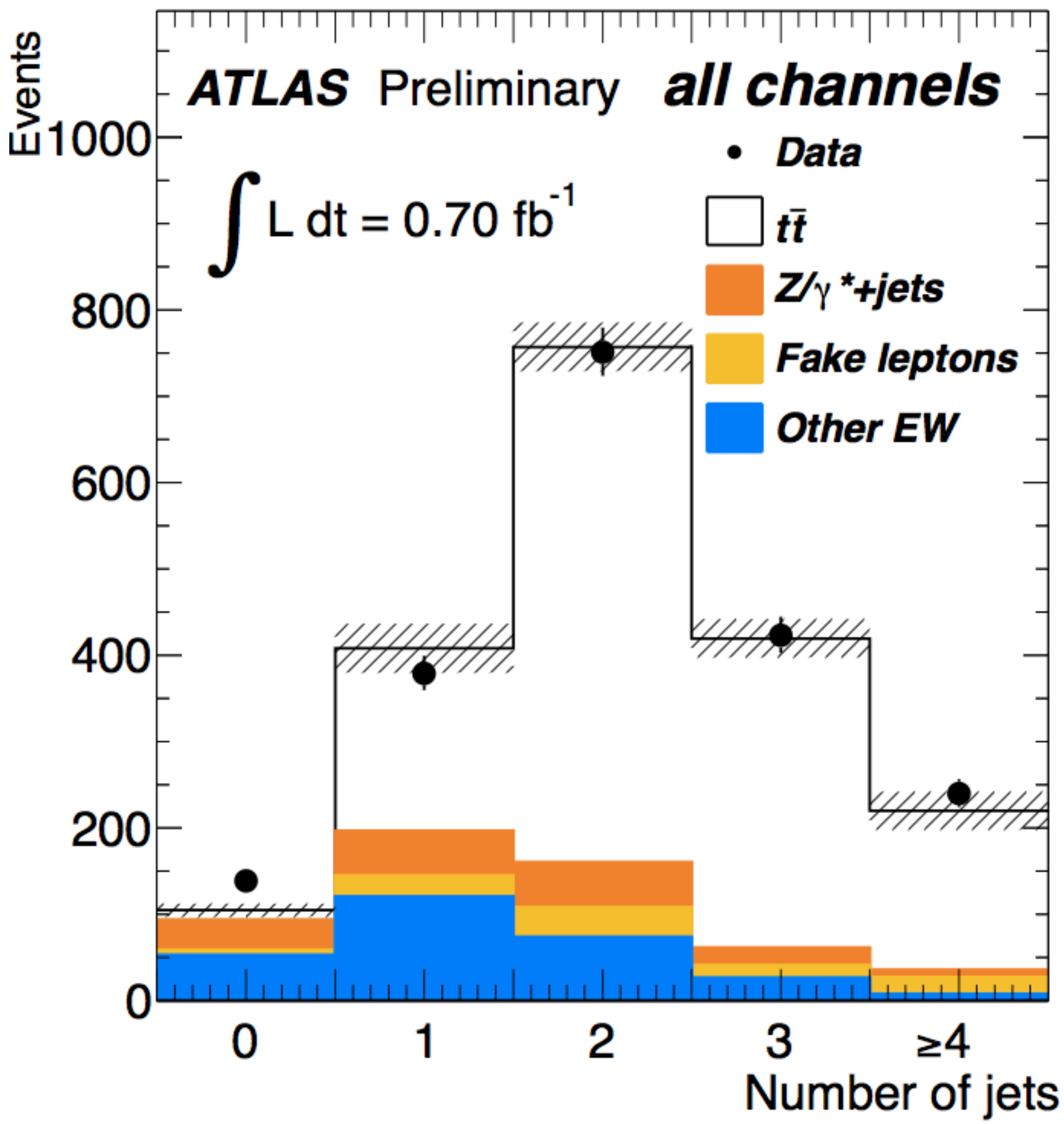
- Leptons + jets without b-tagging
  - results of combined fit with data: 179 ± 10 (stat+syst) ± 7 (lumi) pb

ATLAS-CONF-2011-121

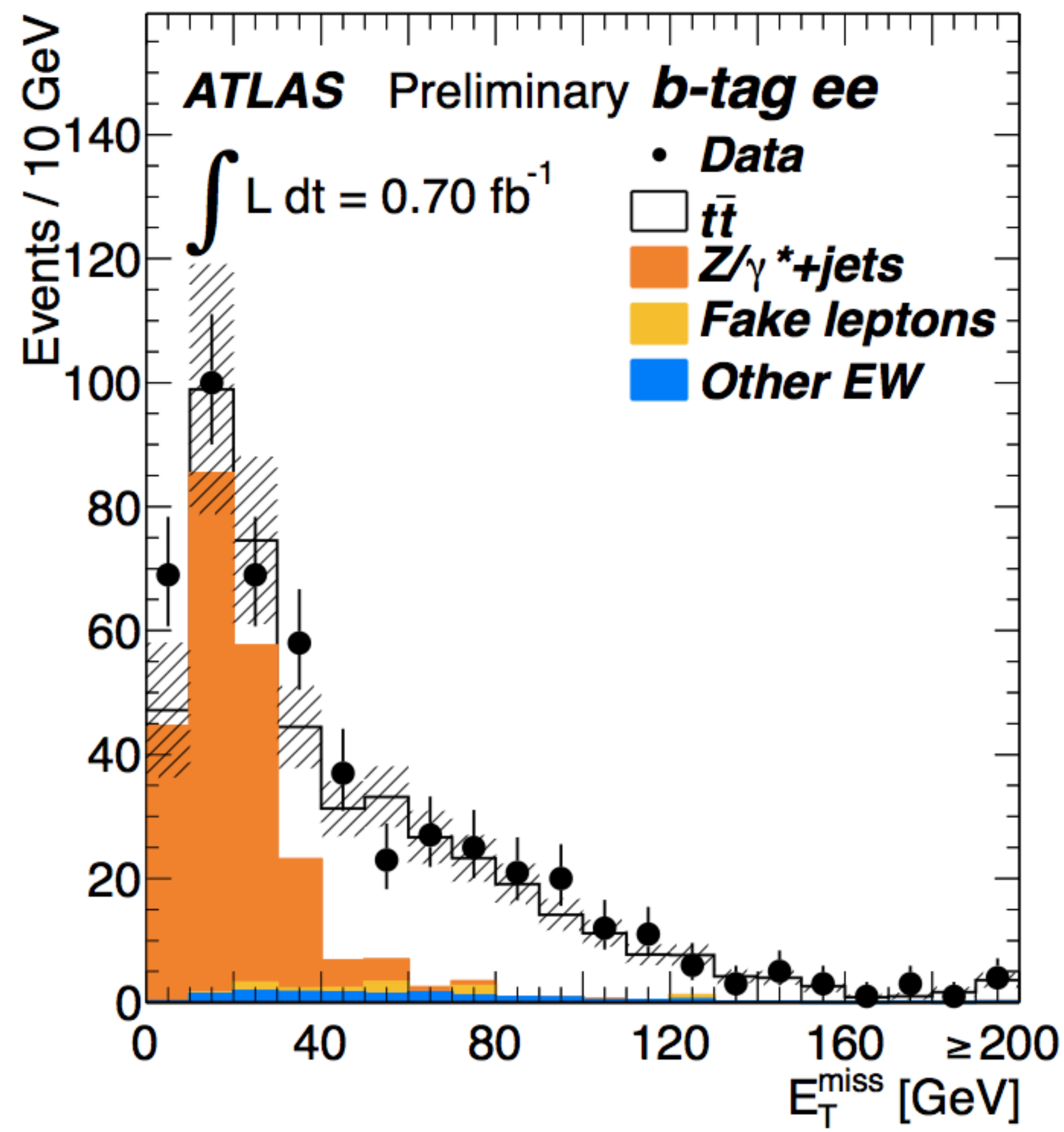


Top-antiTop pair production cross section

- Dileptons without b-tagging
  - 177 ± 6 (stat) ± 17/14 (syst) ± 8 (lumi) pb
- Dileptons with >= 1 b-tagged jet
  - 183 ± 6 (stat) ± 18/14 (syst) ± 8/7 (lumi) pb



ATLAS-CONF-2011-100



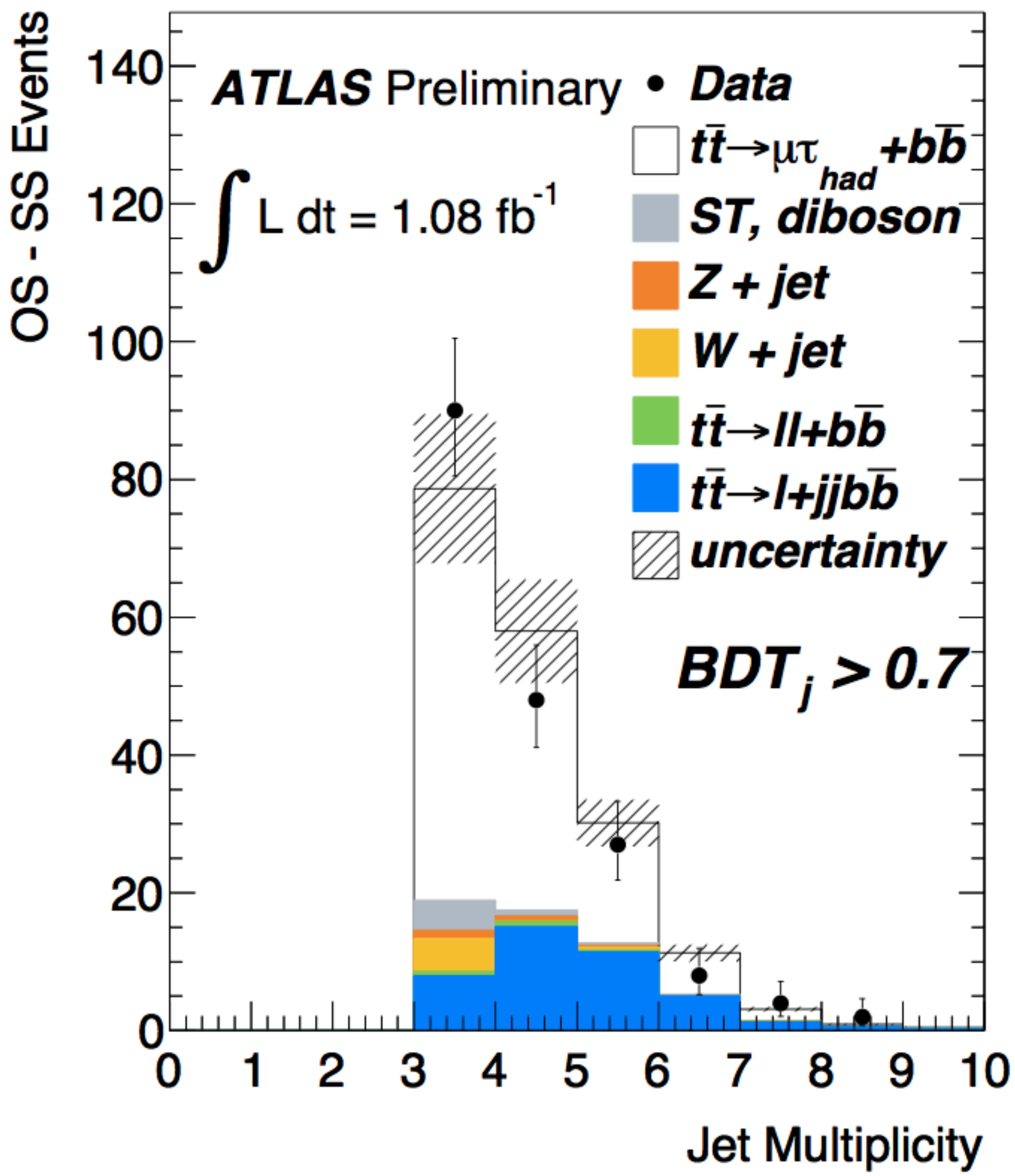
"Other EW": diboson and single top

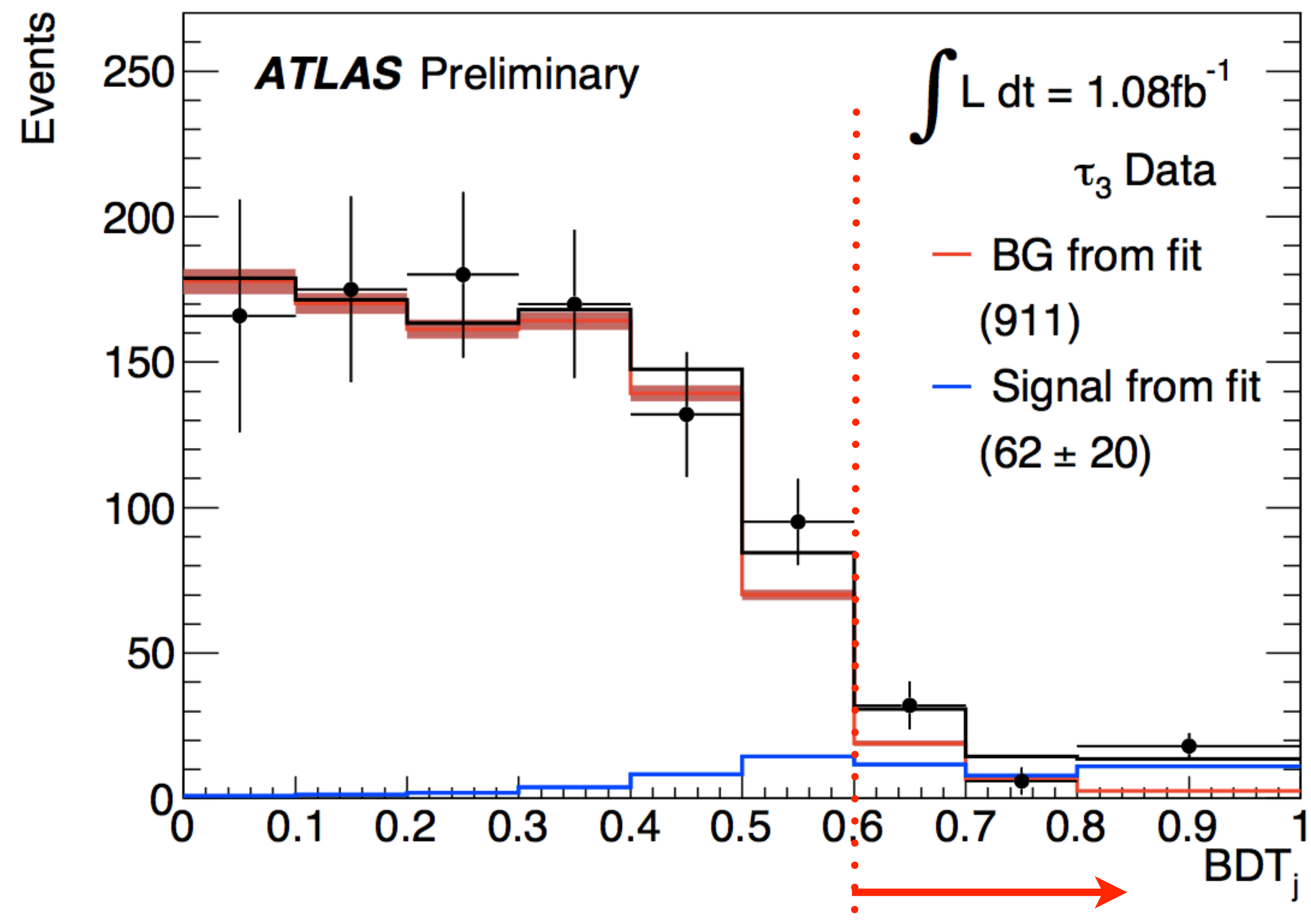
without the ETmiss > 40 GeV cut

Top-antiTop pair production cross section

- μ + tau(h) + jets
  - using boosted decision tree to identify taus

ATLAS-CONF-2011-119

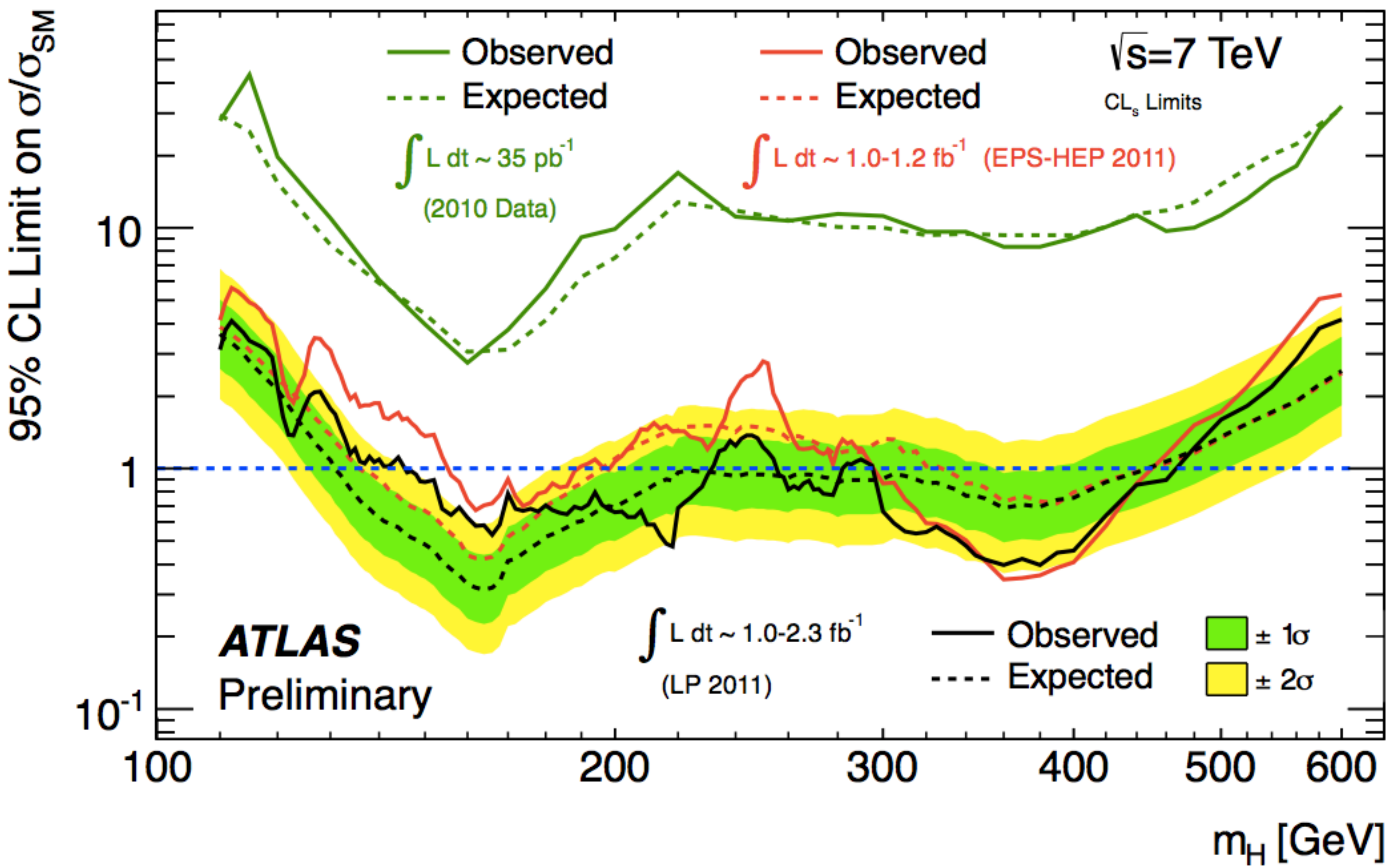




142 ± 21 (stat) ± 20/16 (syst) ± 5 (lumi) pb

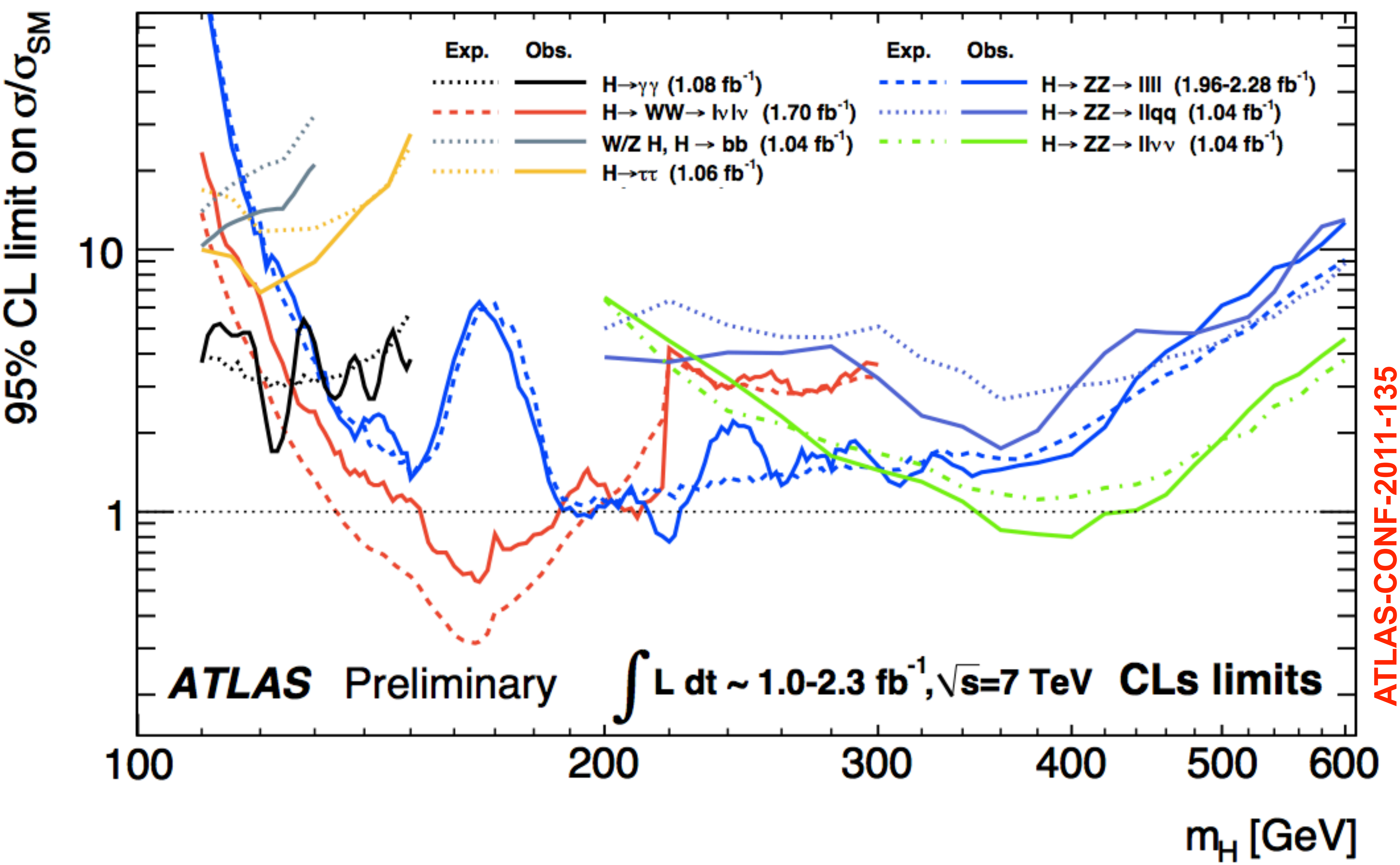
ATLAS SM Higgs searches

LPCC combination Oct 2011



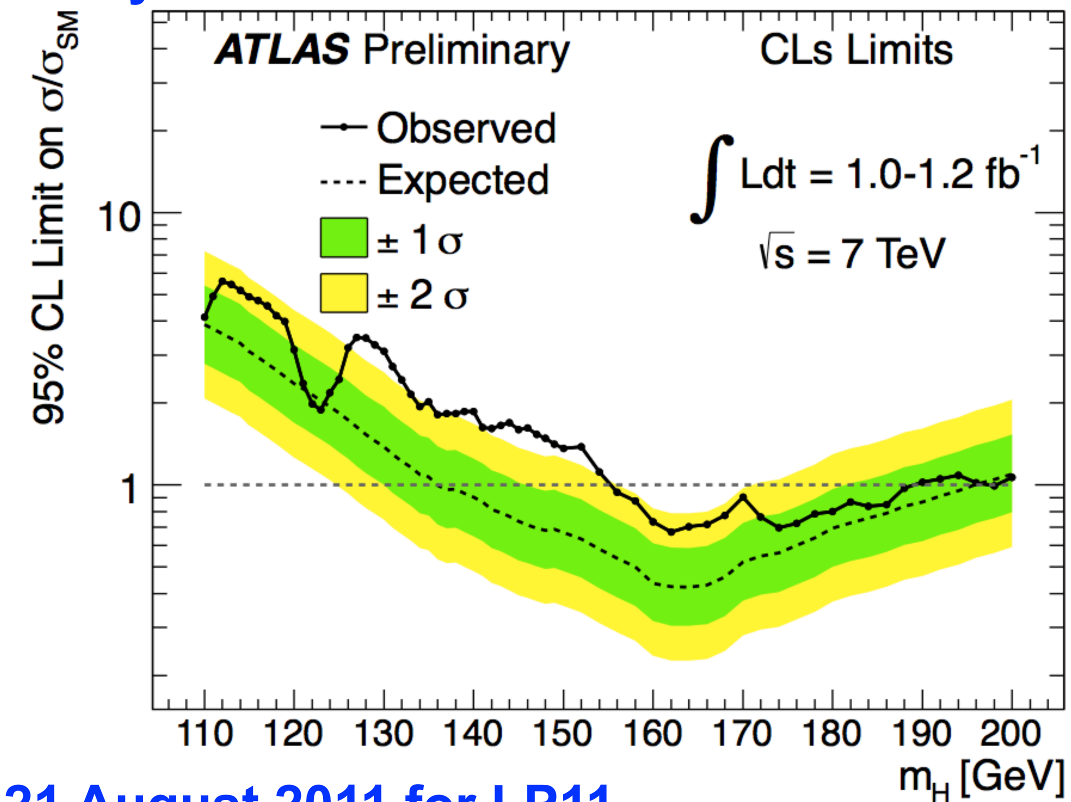
ATLAS SM Higgs searches

21 August 2011 for LP11

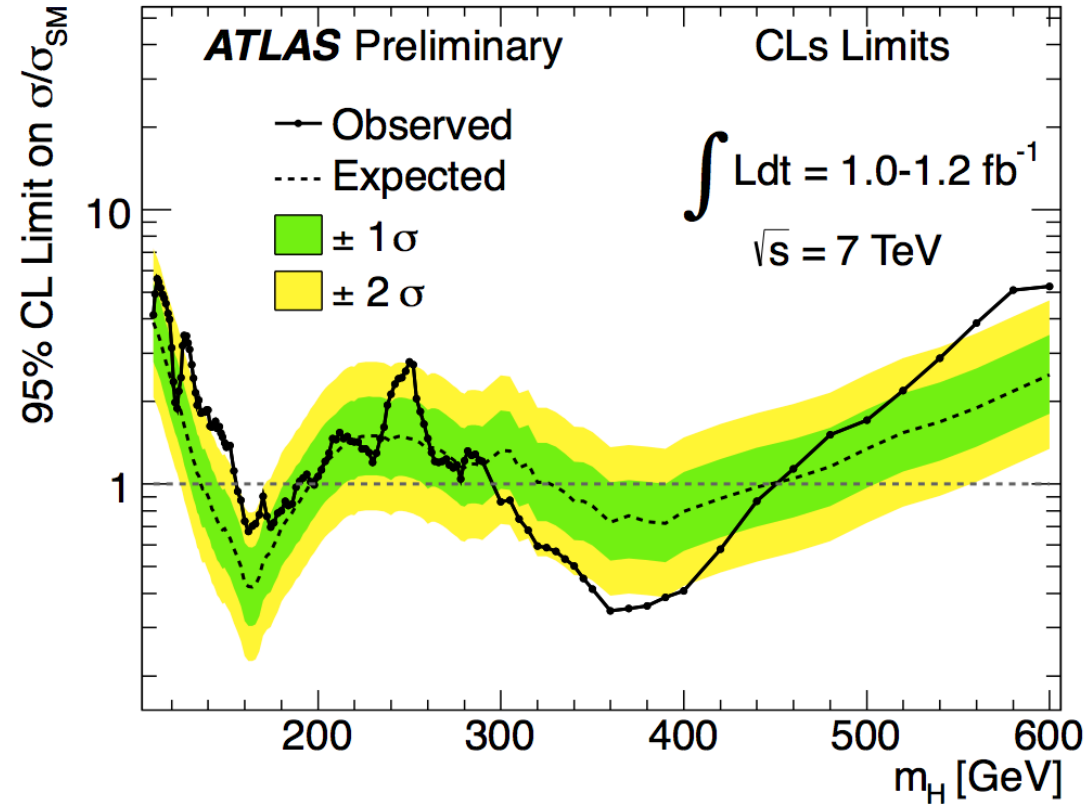


ATLAS SM Higgs searches

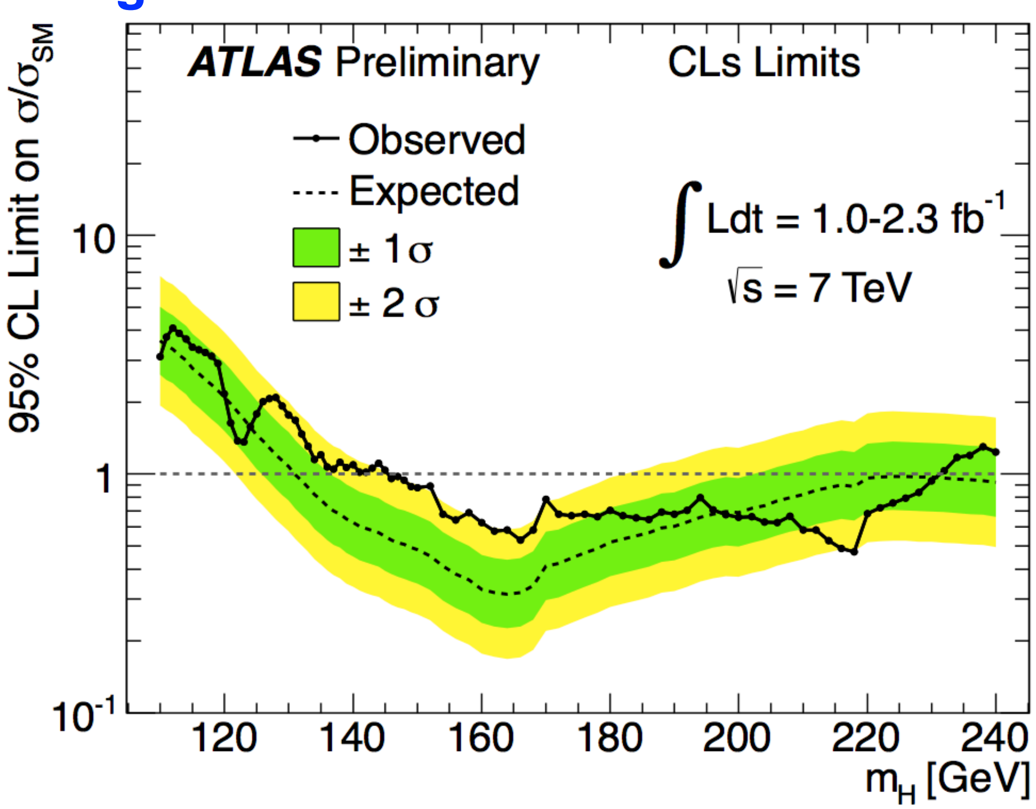
24 July 2011 for EPS



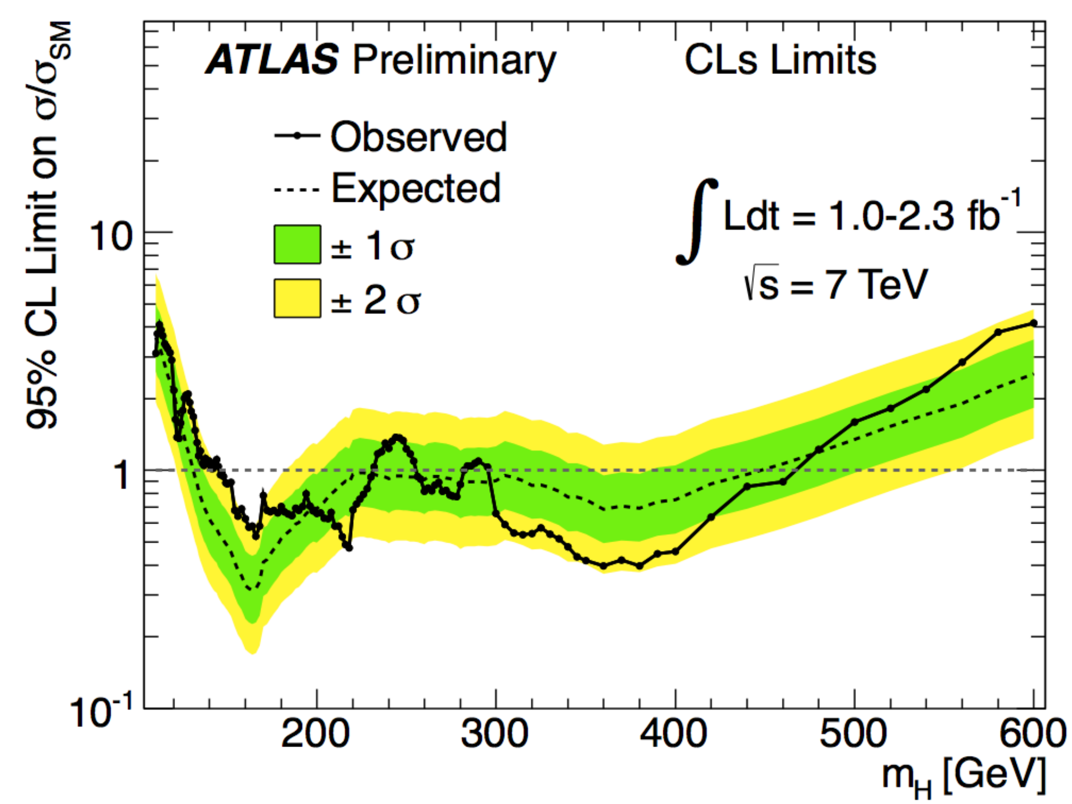
ATLAS-CONF-2011-112



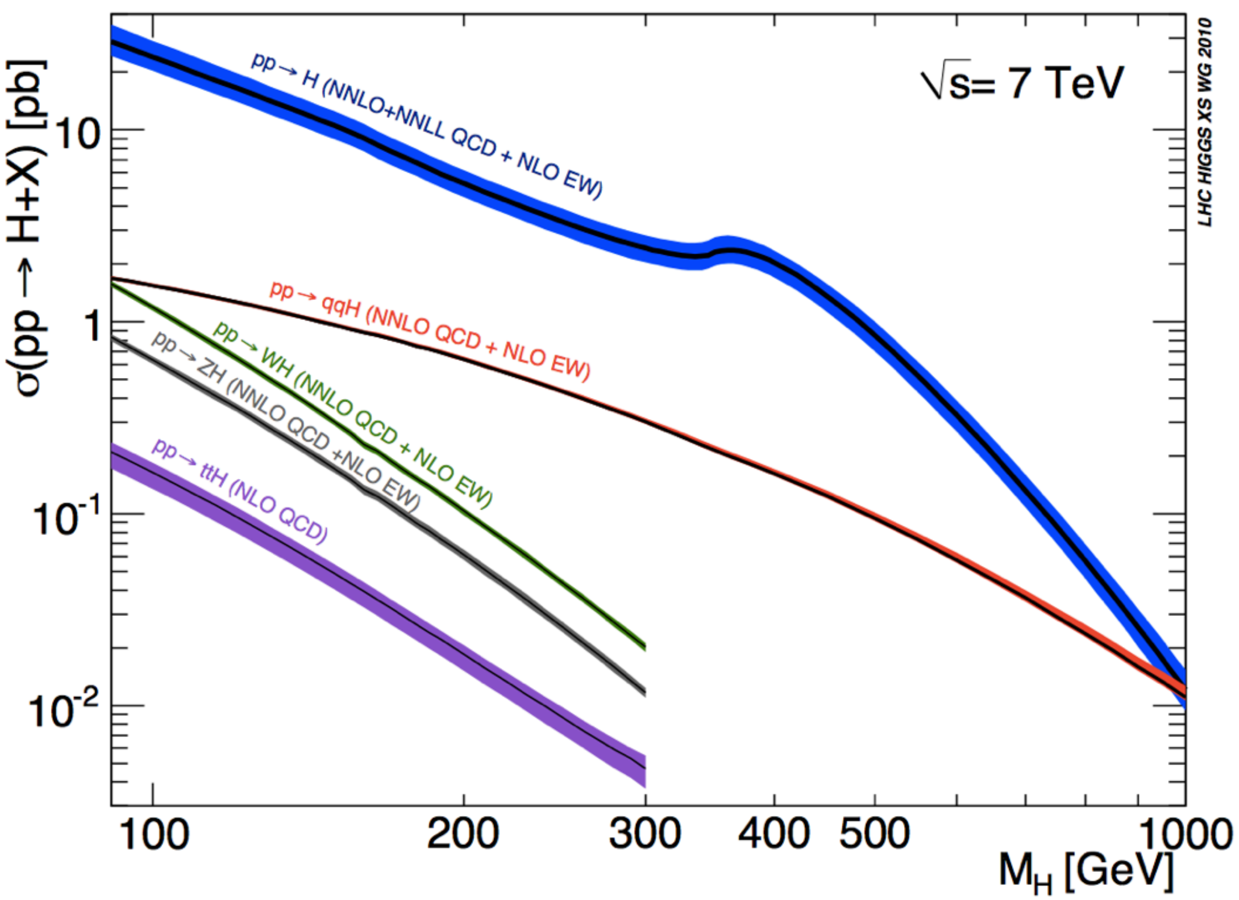
21 August 2011 for LP11

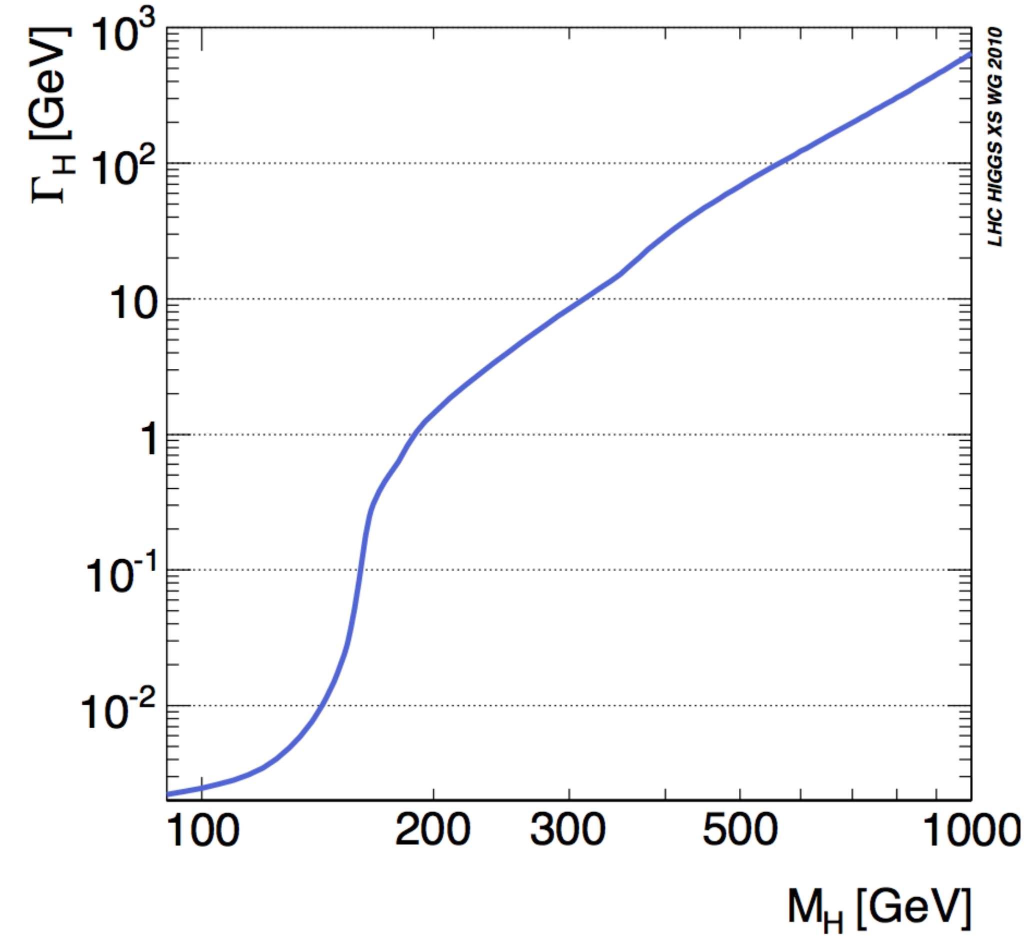


ATLAS-CONF-2011-135

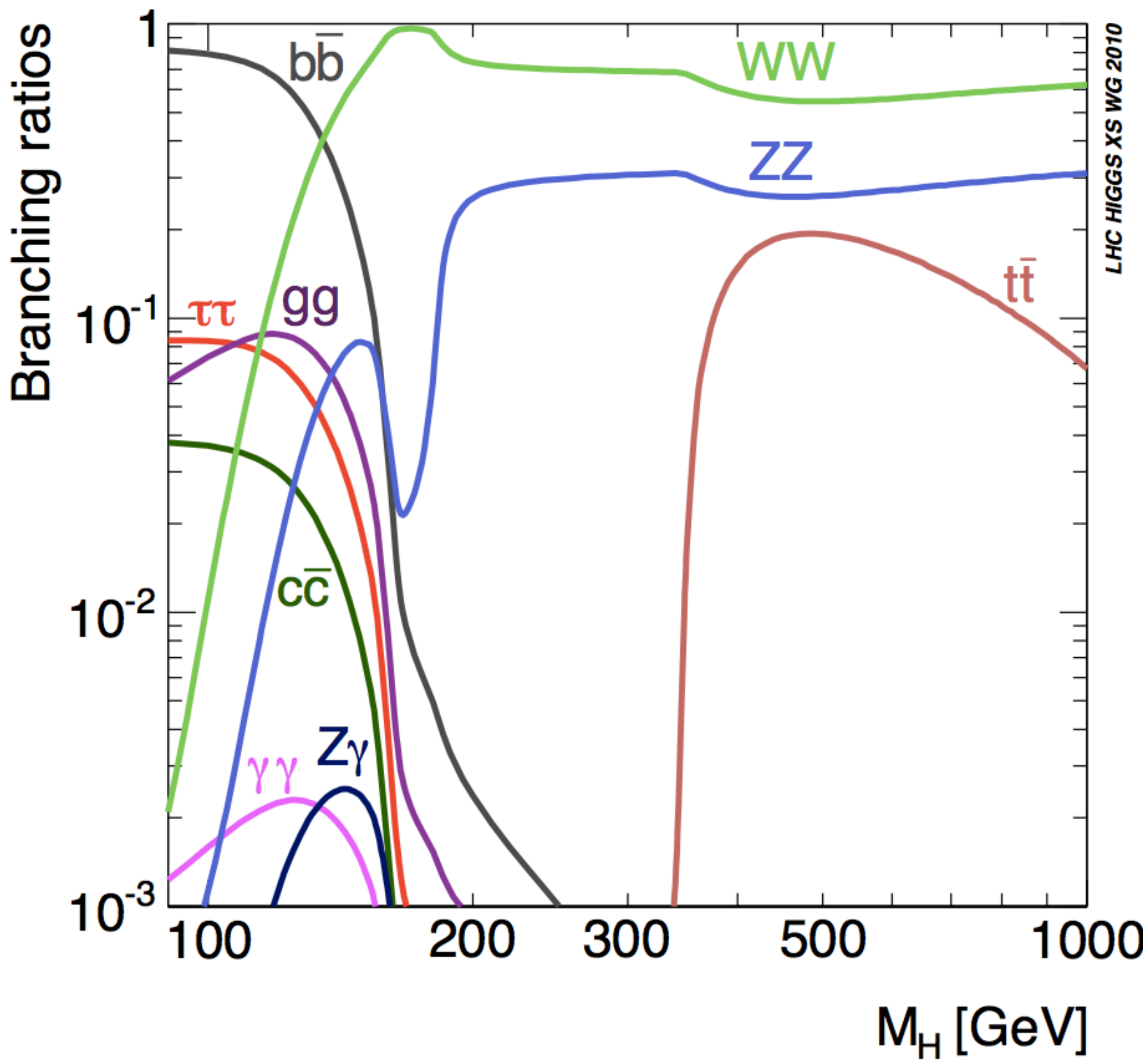


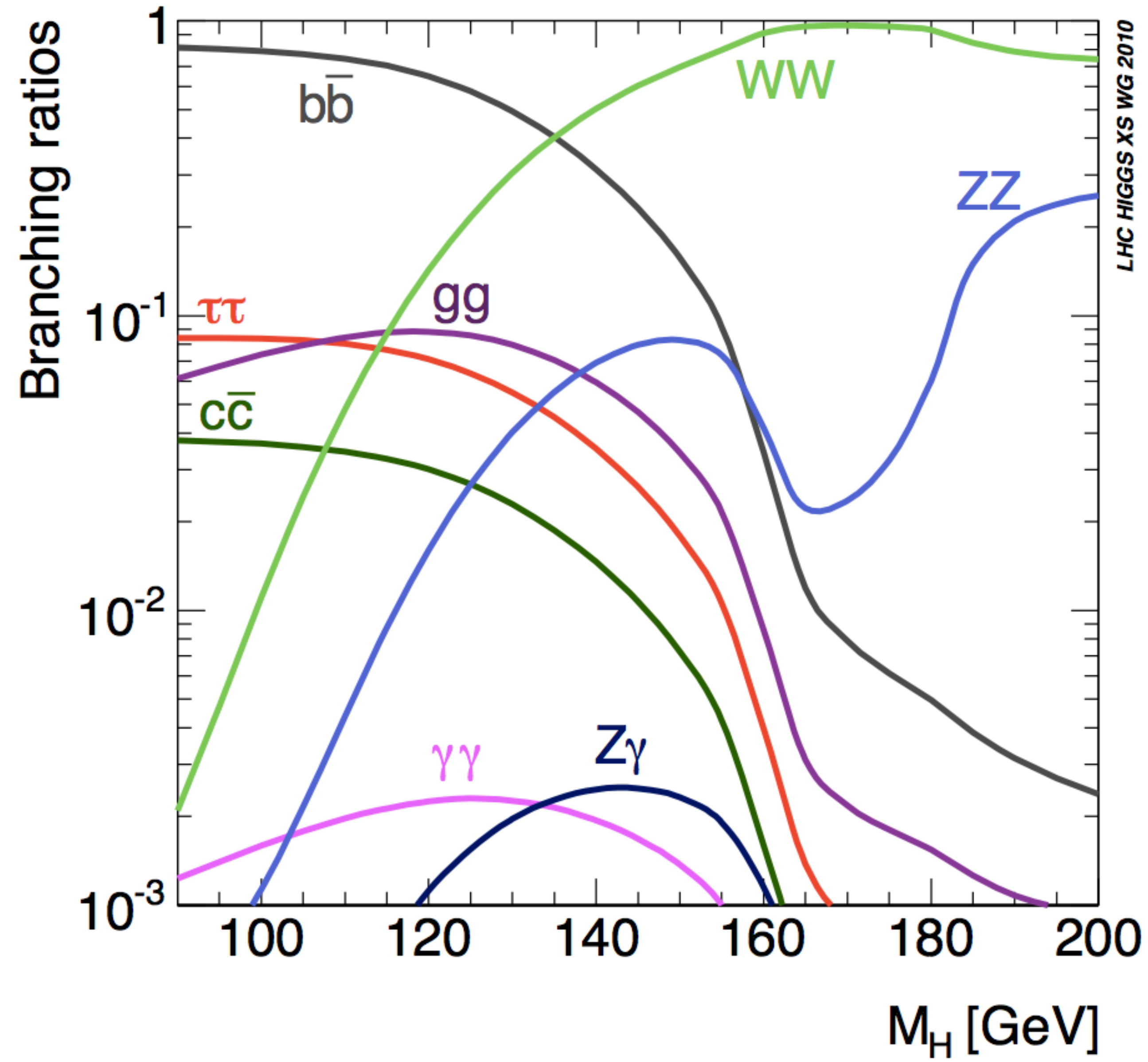
Standard Model Higgs



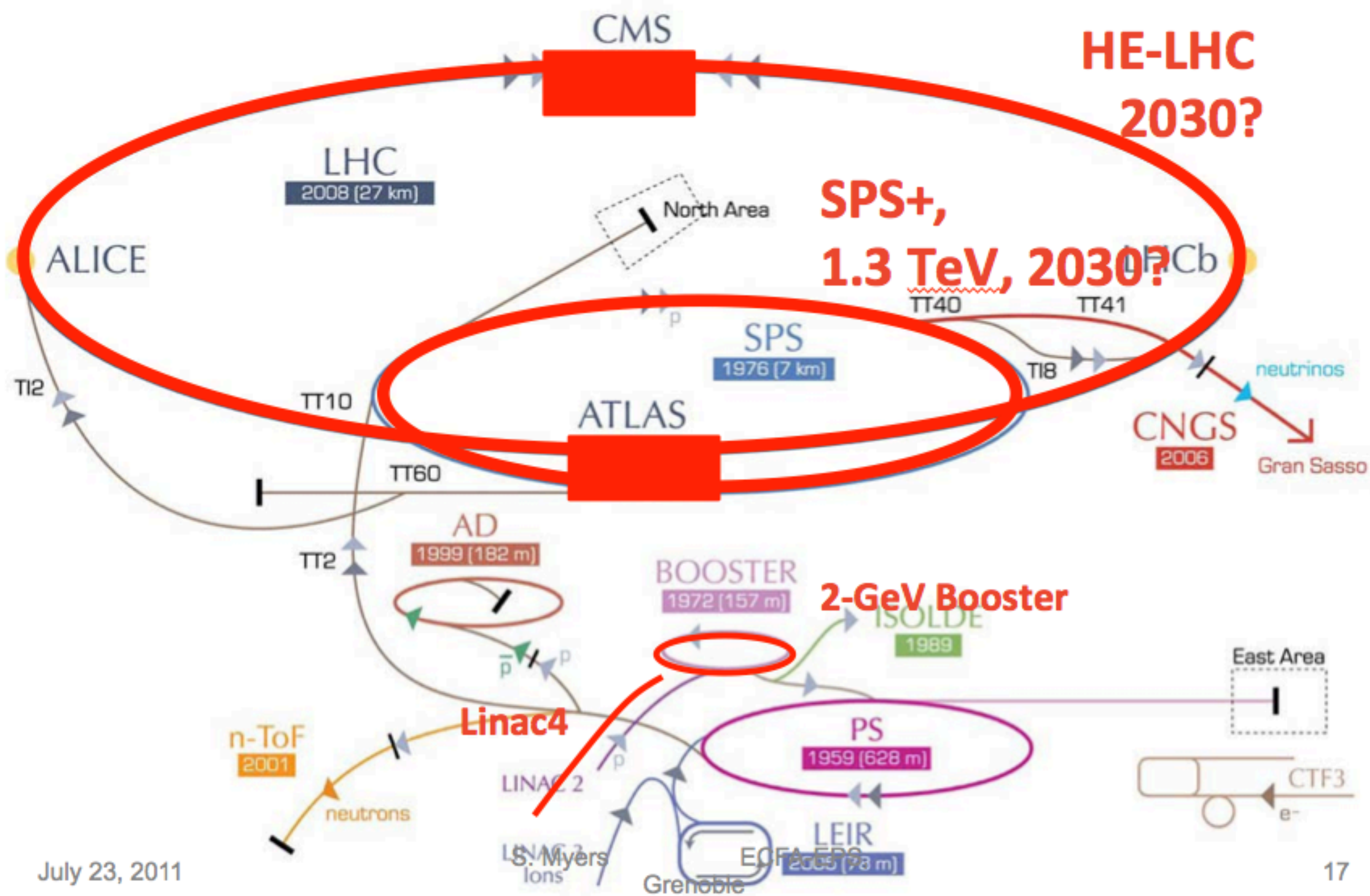


Standard Model Higgs





HE-LHC – LHC modifications



High Energy-LHC (HE-LHC)

CERN working group since April 2010

EuCARD AccNet workshop HE-LHC'10 ,
14-16 October 2010, Proc. CERN-2011-003

<u>key topics</u>

beam energy 16.5 TeV; 20-T magnets

cryogenics: **synchrotron-radiation heat**

radiation damping & emittance control

vacuum system: synchrotron radiation

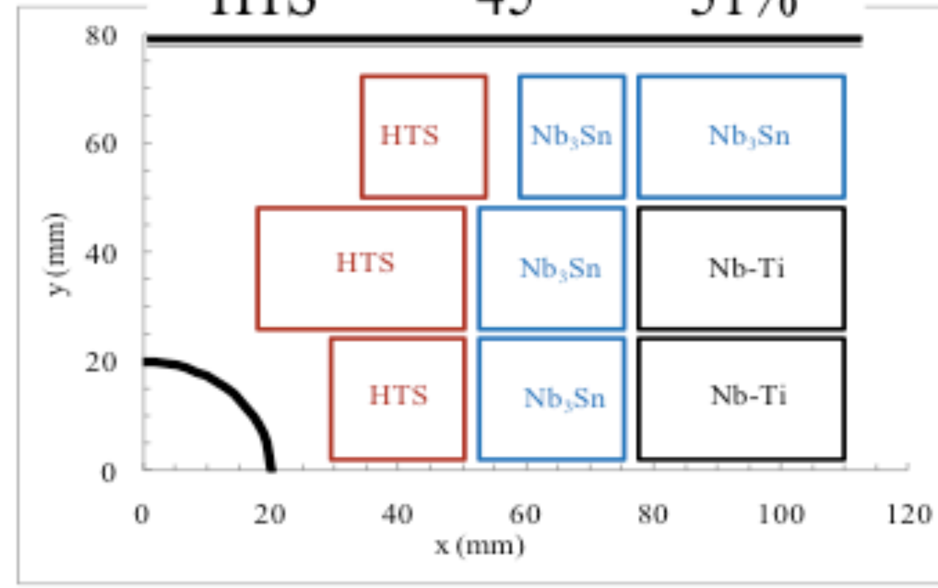
new injector: energy > 1 TeV

parameters

	LHC	HE-LHC
beam energy [TeV]	7	16.5
dipole field [T]	8.33	20
dipole coil aperture [mm]	56	40
#bunches	2808	1404
IP beta function [m]	0.55	1 (x), 0.43 (y)
number of IPs	3	2
beam current [A]	0.584	0.328
SR power per ring [kW]	3.6	65.7
arc SR heat load dW/ds [W/m/ap]	0.21	2.8
peak luminosity [10^{34} cm^{-2}s^{-1}]	1.0	2.0
events per crossing	19	76

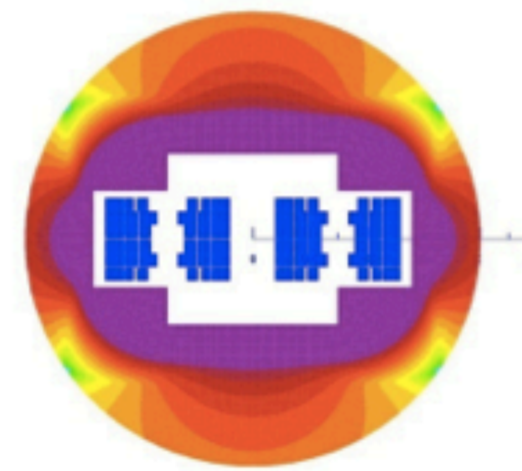
July 25, 2011 S. Myers ECFA-EPS, Grenoble

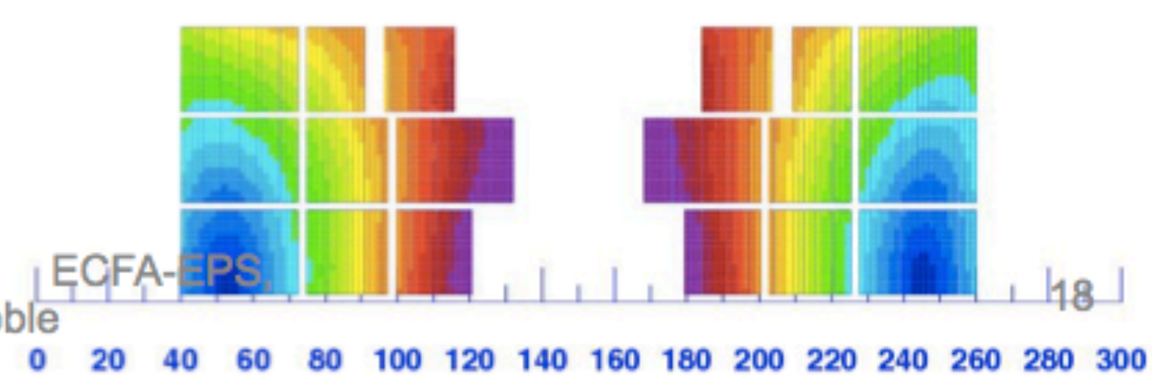
	Turns	%
Nb-Ti	40	28%
Nb_3Sn	58	41%
HTS	45	31%



E. Todesco

hybrid magnet





HE-LHC – main issues and R&D

- ***high-field 20-T dipole*** *magnets based on Nb_3Sn, Nb_3Al, and HTS*
- ***high-gradient quadrupole magnets*** *for arc and IR*
- ***fast cycling SC magnets*** *for 1-TeV injector*
- ***emittance control*** *in regime of strong SR damping and IBS*
- *cryogenic handling of* ***SR heat load*** *(first analysis; looks manageable)*
- *dynamic* ***vacuum***