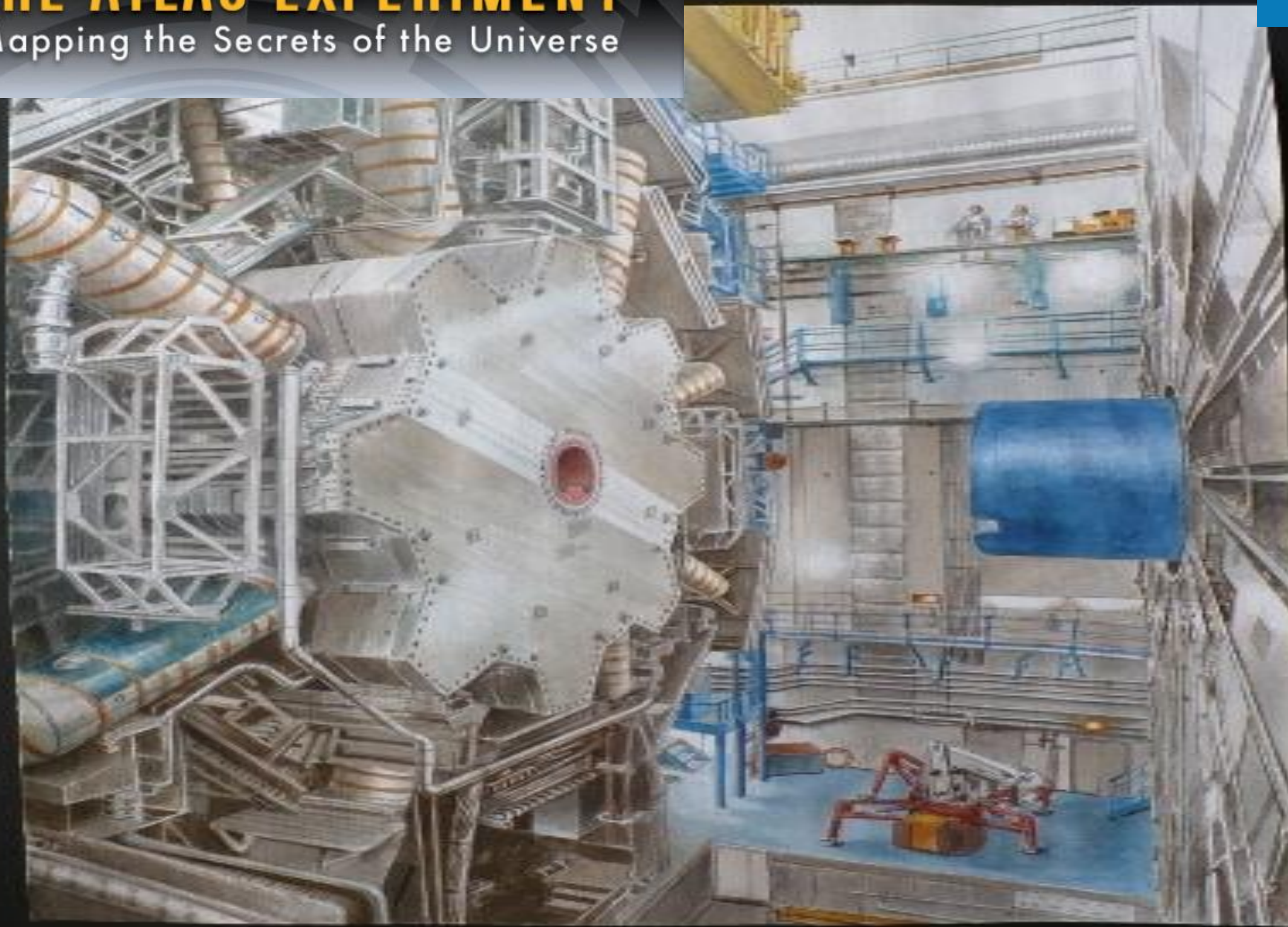
THE ATLAS EXPERIMENT
Mapping the Secrets of the Universe

CERN

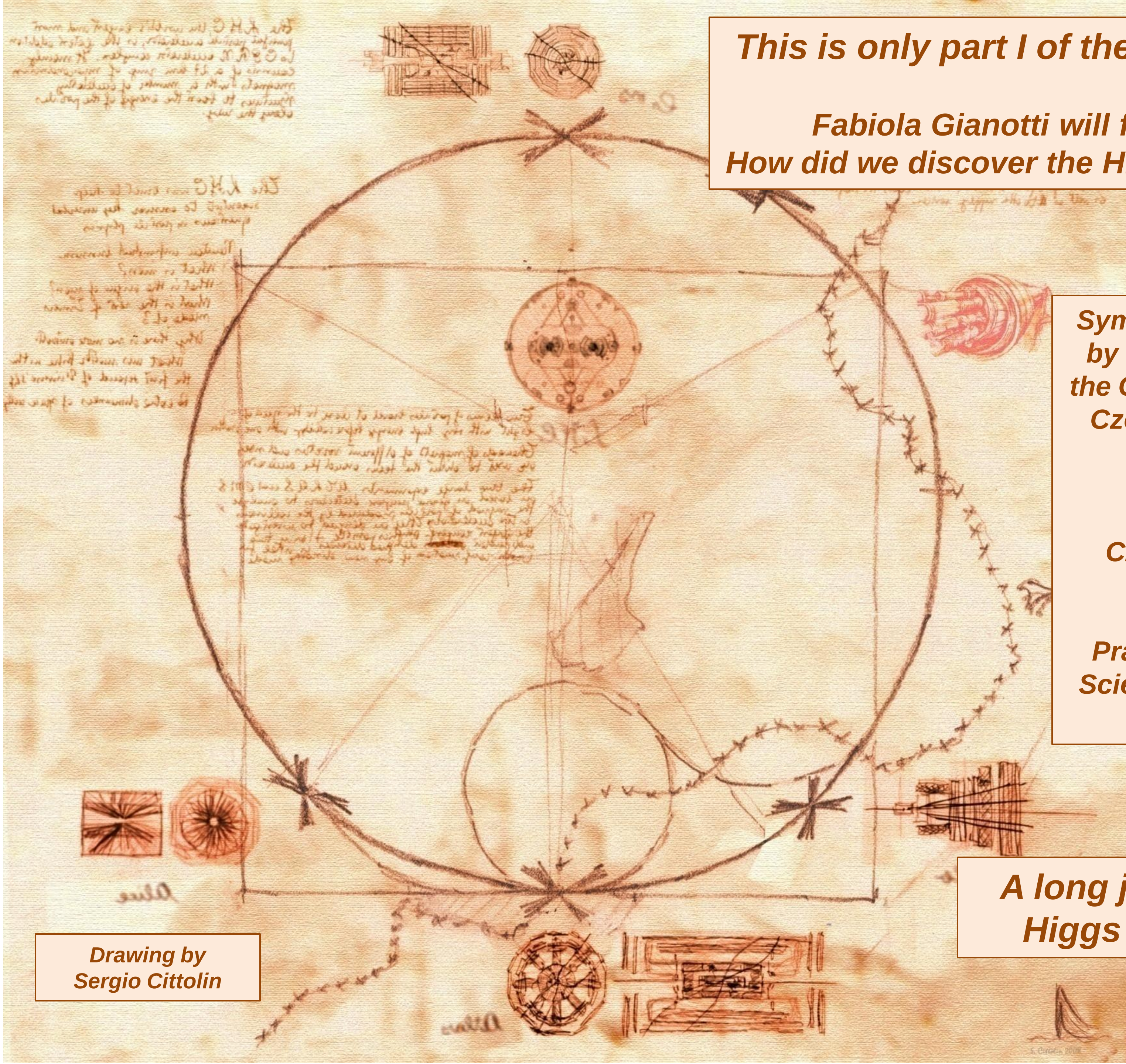


A long journey to the Higgs and beyond

Prague, 26th Oct 2012
Peter Jenni, CERN

This is only part I of the ATLAS report

Fabiola Gianotti will follow with:
How did we discover the Higgs-like Boson?



Symposium organized by the Committee for the Collaboration of the Czech Republic with CERN

20 years of the Czech Republic at CERN

Prague, Academy of Sciences of the Czech Republic

A long journey to the Higgs and beyond

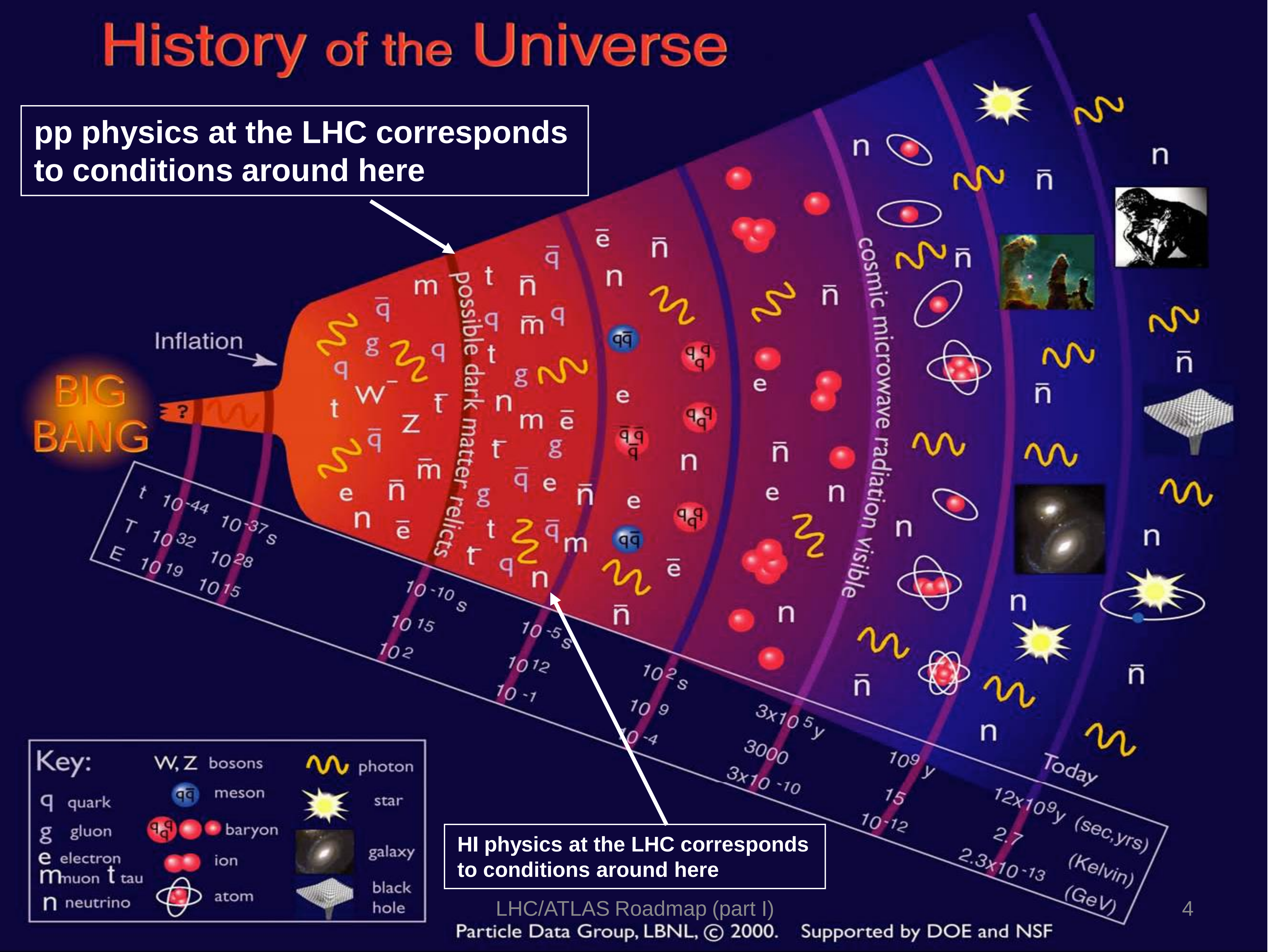
Drawing by Sergio Cittolin

Peter Jenni (CERN)
26th October 2012

The Large Hadron Collider project is a global scientific adventure, combining the accelerator, a worldwide computing grid and the experiments, initiated more than 20 years ago

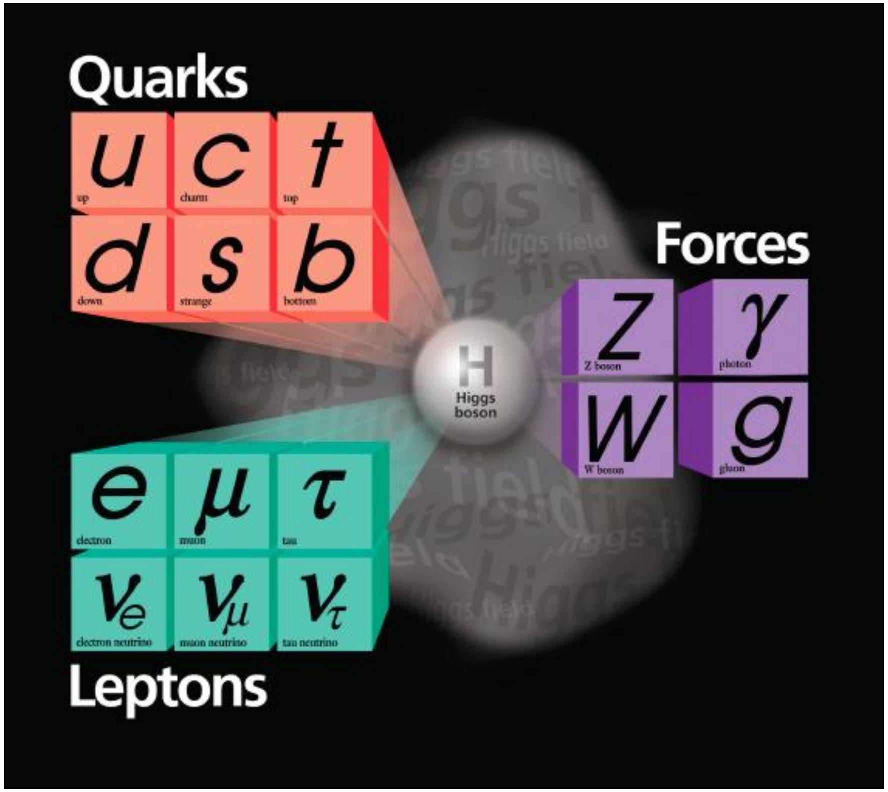
It is a great privilege and pleasure to present now first physics results

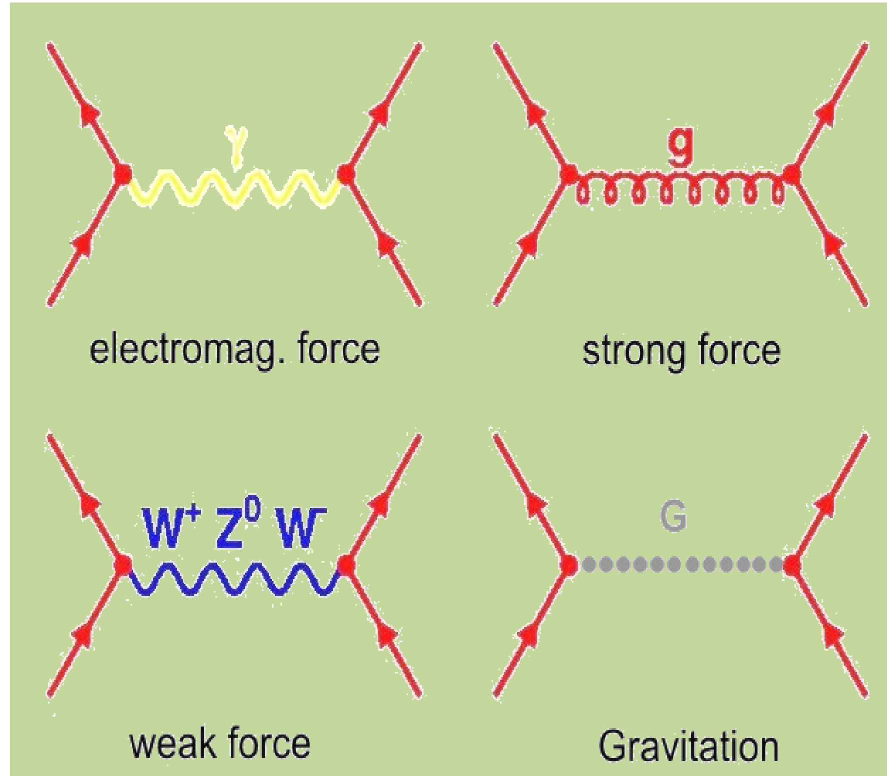
pp physics at the LHC corresponds to conditions around here



HI physics at the LHC corresponds to conditions around here

The Standard Model of Particle Physics





(i) Constituents of matter: quarks and leptons

(ii) Four fundamental forces
(described by quantum field theories, except gravitation)

(iii) The Higgs field (problem of mass)

How the LHC came to be …

(see a nice article by Chris Llewellyn Smith in Nature 448, p281)

Some early key dates

1977 **The community talked about the LEP project, and it was already mentioned that a new tunnel could also house a hadron collider in the far future**

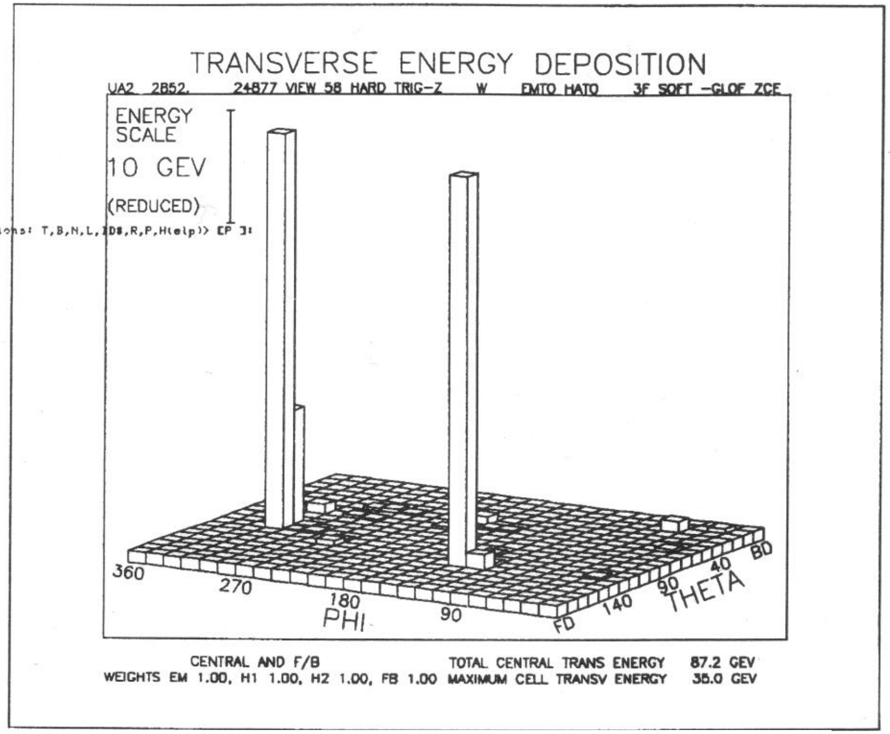
1981 **LEP was approved with a large and long (27 km) tunnel**

1983 **The early 1980s were crucial:**

The real belief that a 'dirty' hadron collider can actually do great discovery physics came from UA1 and UA2 with their W and Z boson discoveries at CERN

This also triggered a famous quote from a 1983 New York Times editorial:

'Europe: 3 - US Not Even Z-Zero'



A very early Z → ee online display from one of the detectors (UA2)

ATLAS was borne with the Letter of Intent (LoI), submitted on 1st October 1992, 20 years ago

Spokesperson Fabiola Gianotti, celebrating 20 years of ATLAS on 1st October 2012

1991 December CERN Council:
'LHC is the right machine for advance of the subject and the future of CERN'
(thanks to the great push by DG C Rubbia)

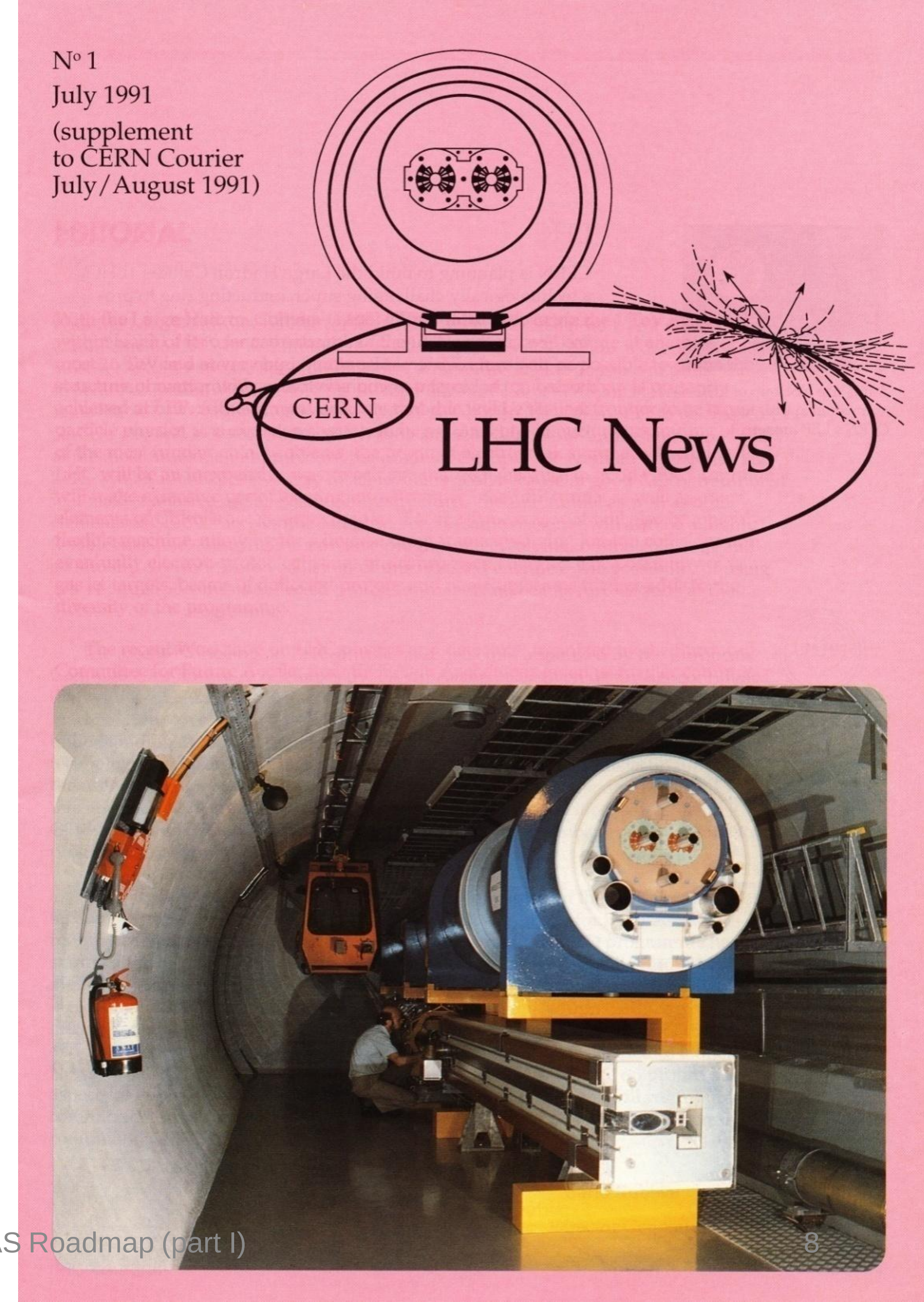
1993 December proposal of LHC with commissioning in 2002

1994 June Council:

Staged construction was proposed, but some countries could not yet agree, so the Council session vote was suspended until

16 December 1994 Council:

(Two-stage) construction of LHC was approved



The two-stage approval of LHC was understood to be modified in case sufficient CERN non-member state contributions would become available

A lot of LHC campaigns and negotiations took place in the years 1995 - 1997, including also the experiments

Japan, Russia, India, Canada and the USA were agreeing in that phase to contribute to the LHC

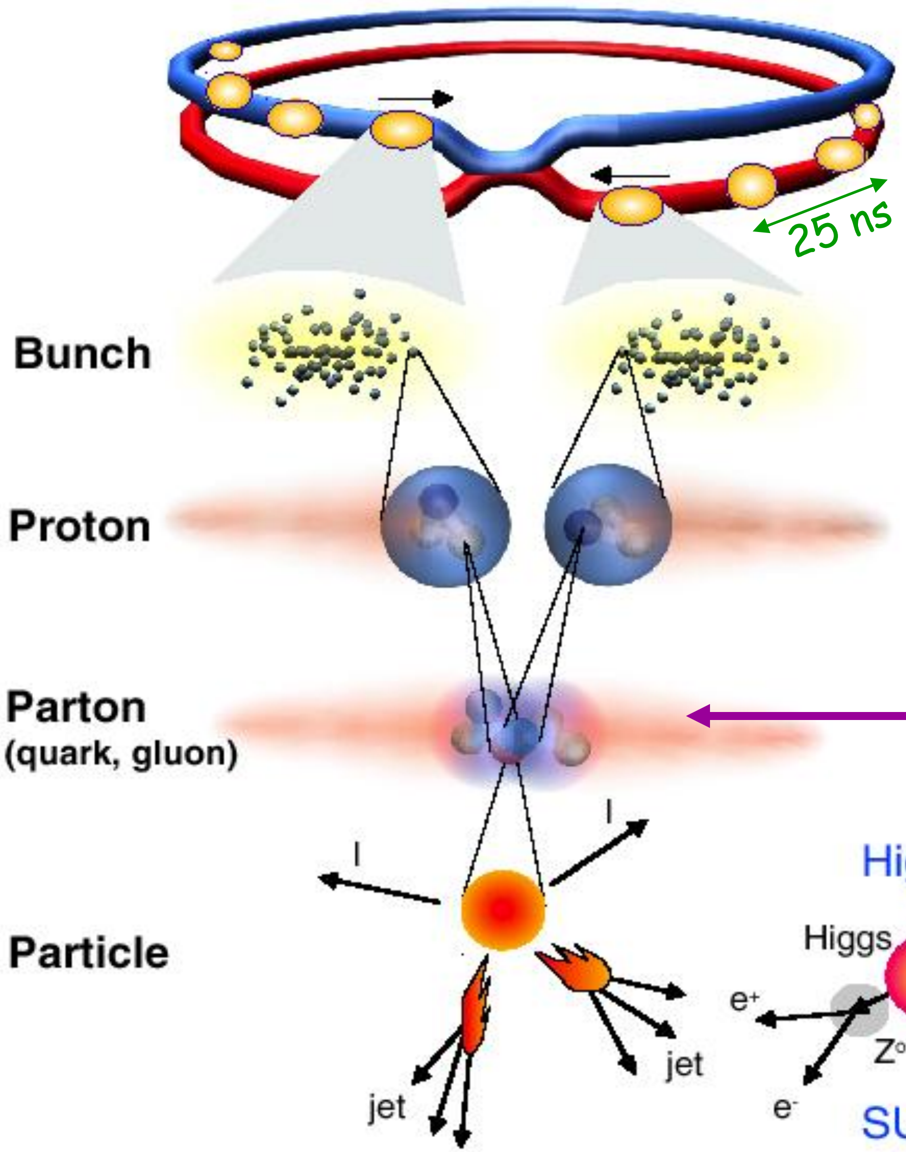
(Israel contributed all along to the full CERN programme and LHC)

1997

December Council approved finally the single-stage 14 TeV LHC for completion in 2005

Signature of the US-CERN agreement in December 1997:
R Eisenstein (NSF), C Llewellyn Smith (CERN DG), M Krebs (DOE)

Collisions at LHC



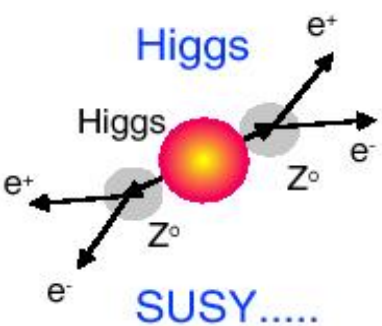
Proton-Proton	
Protons/bunch	10^{11}
Beam energy	7 TeV ($7x10^{12}$ eV)
Luminosity	10^{34} cm^{-2} s^{-1}

Event rate:

N = L x σ (pp) ≈ 10^9 interactions/s

Mostly soft (low p_T) events

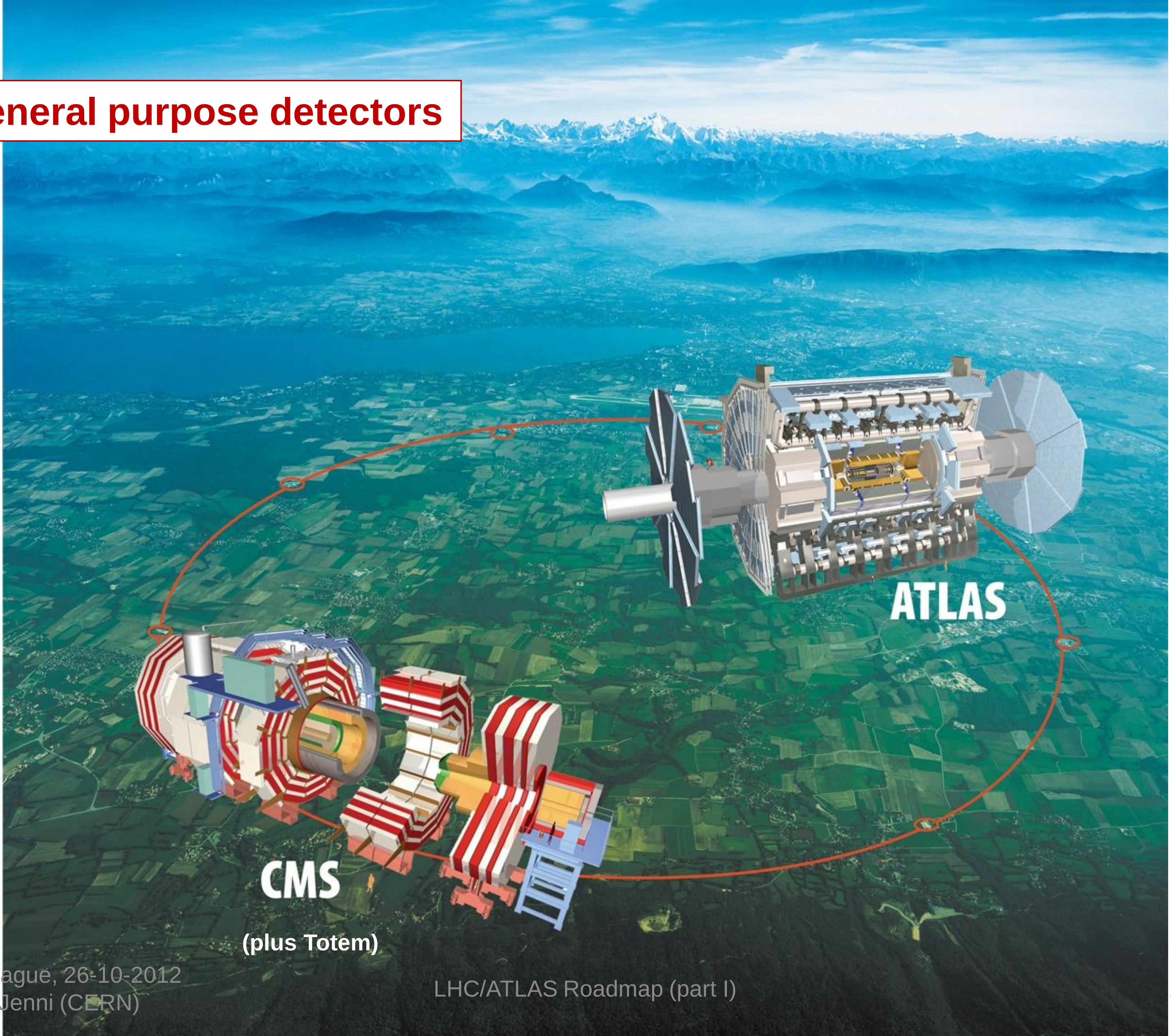
Interesting hard (high-p_T) events are rare



Selection of 1 in 10,000,000,000,000

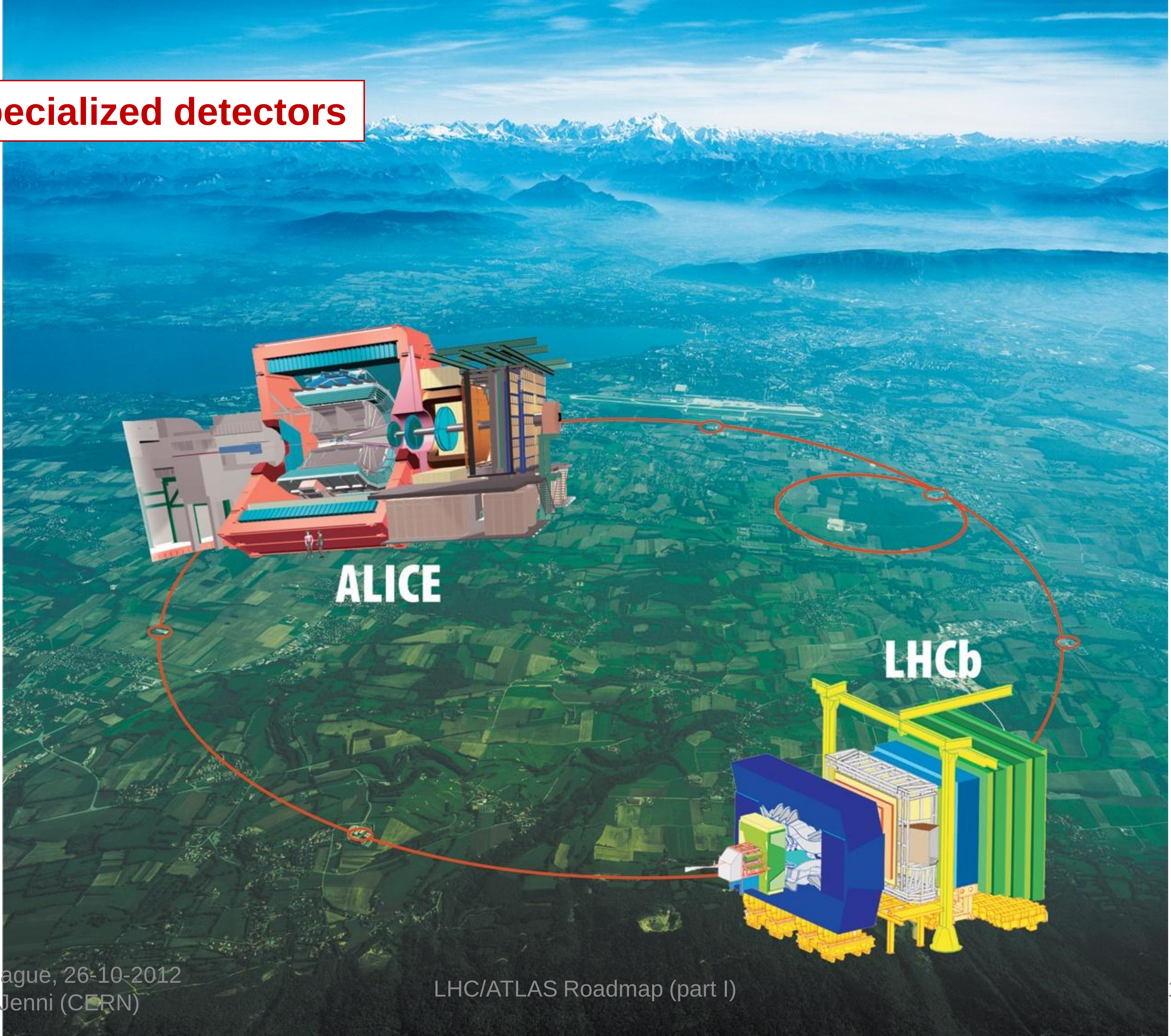
→ very powerful detectors needed

General purpose detectors



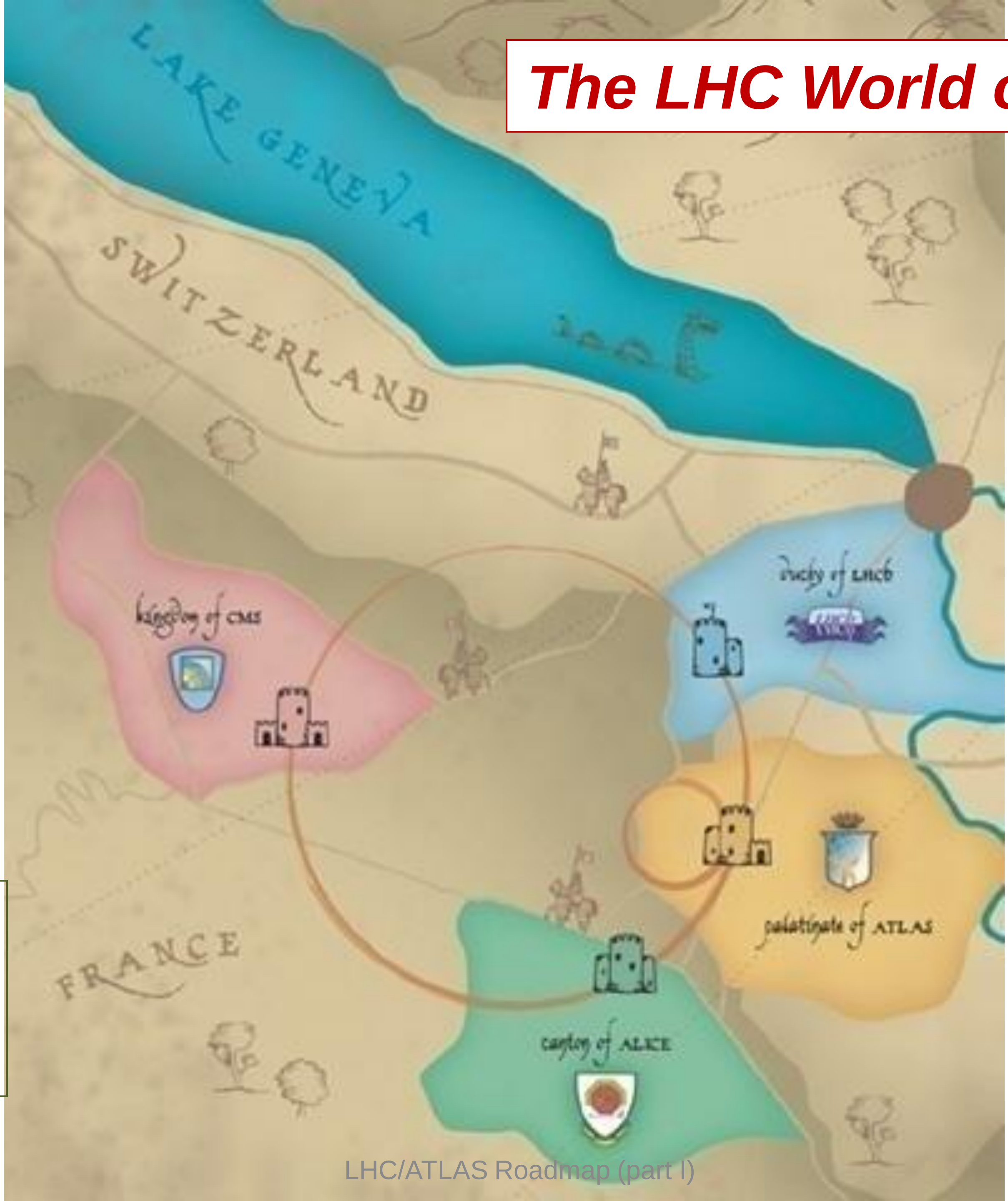
(plus Totem)

Specialized detectors



The LHC World of CERN

Plus smaller local earldoms
LHCf (point-1)
TOTEM (point-5)
Moedal (point-8)



CMS
2900 Physicists
184 Institutions
38 countries
550 MCHF

LHCb
730 Physicists
54 Institutions
15 countries
75 MCHF

ATLAS
3000 Physicists
176 Institutions
38 countries
550 MCHF

ALICE
1000 Physicists
105 Institutions
30 countries
150 MCHF

ATLAS Collaboration

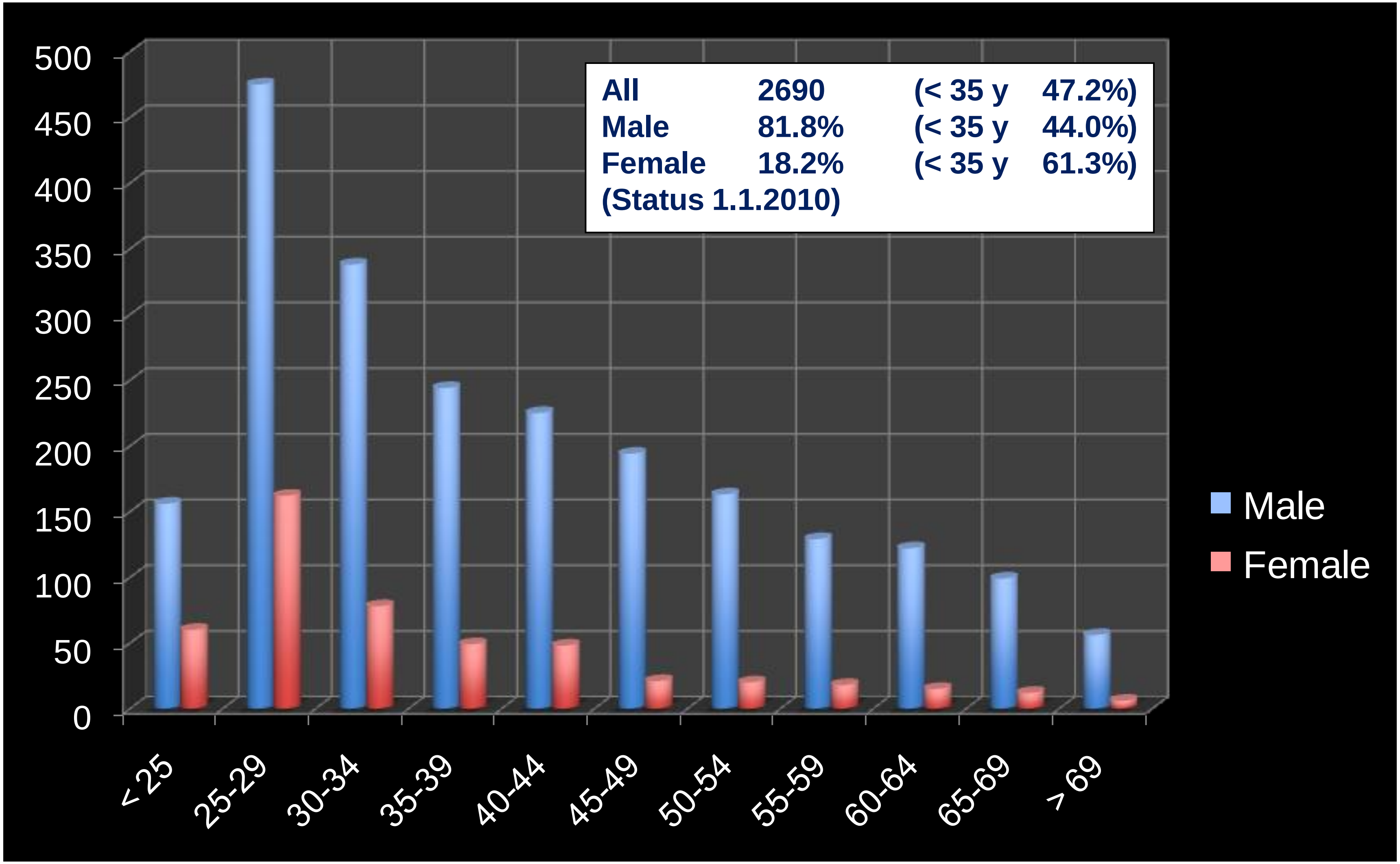
(Status June 2012)

38 Countries
176 Institutions
3000 Scientific participants total
(1000 Students)

ATLAS enjoys a longstanding and very fruitful partnership with the Czech groups since the very first days

Adelaide, Albany, Alberta, NIKHEF Amsterdam, Ankara, LAPP Annecy, Argonne NL, Arizona, UT Arlington, Athens, NTU Athens, Baku, IFAE Barcelona, Belgrade, Bergen, Berkeley LBL and UC, HU Berlin, Bern, Birmingham, UAN Bogota, Bologna, Bonn, Boston, Brandeis, Brasil Cluster, Bratislava/SAS Kosice, Brookhaven NL, Buenos Aires, Bucharest, Cambridge, Carleton, CERN, Chinese Cluster, Chicago, Chile, Clermont-Ferrand, Columbia, NBI Copenhagen, Cosenza, AGH UST Cracow, IFJ PAN Cracow, SMU Dallas, UT Dallas, DESY, Dortmund, TU Dresden, JINR Dubna, Duke, Edinburgh, Frascati, Freiburg, Geneva, Genoa, Giessen, Glasgow, Göttingen, LPSC Grenoble, Technion Haifa, Hampton, Harvard, Heidelberg, Hiroshima IT, Indiana, Innsbruck, Iowa SU, Iowa, UC Irvine, Istanbul Bogazici, KEK, Kobe, Kyoto, Kyoto UE, Kyushu, Lancaster, UN La Plata, Lecce, Lisbon LIP, Liverpool, Ljubljana, QMW London, RHBNC London, UC London, Lund, UA Madrid, Mainz, Manchester, CPPM Marseille, Massachusetts, MIT, Melbourne, Michigan, Michigan SU, Milano, Minsk NAS, Minsk NCPHEP, Montreal, McGill Montreal, RUPHE Morocco, FIAN Moscow, ITEP Moscow, MEPhI Moscow, MSU Moscow, LMU Munich, MPI Munich, Nagasaki IAS, Nagoya, Naples, New Mexico, New York, Nijmegen, Northern Illinois, BINP Novosibirsk, Ohio SU, Okayama, Oklahoma, Oklahoma SU, **Olomouc,** Oregon, LAL Orsay, Osaka, Oslo, Oxford, Paris VI and VII, Pavia, Pennsylvania, NPI Petersburg, Pisa, Pittsburgh, **CAS Prague, CU Prague, TU Prague**, IHEP Protvino, Rome I, Rome II, Rome III, Rutherford Appleton Laboratory, DAPNIA Saclay, Santa Cruz UC, Sheffield, Shinshu, Siegen, Simon Fraser Burnaby, SLAC, South Africa, Stockholm, KTH Stockholm, Stony Brook, Sydney, Sussex, AS Taipei, Tbilisi, Tel Aviv, Thessaloniki, Tokyo ICEPP, Tokyo MU, Tokyo Tech, Toronto, TRIUMF, Tsukuba, Tufts, Udine/ICTP, Uppsala, UI Urbana, Valencia, UBC Vancouver, Victoria, Warwick, Waseda, Washington, Weizmann Rehovot, FH Wiener Neustadt, Wisconsin, Wuppertal, Würzburg, Yale, Yerevan

Age distribution of the ATLAS population



All	**2690**	**(< 35 y**	**47.2%)**
Male	**81.8%**	**(< 35 y**	**44.0%)**
Female	**18.2%**	**(< 35 y**	**61.3%)**
(Status 1.1.2010)			

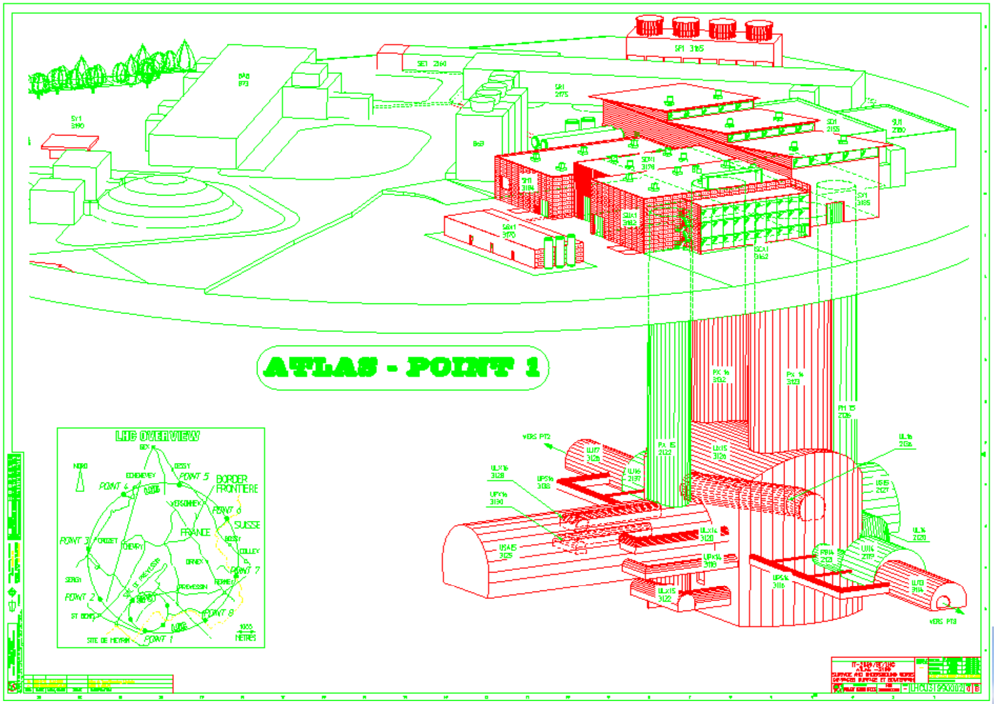
ATLAS Overview Week

A meeting of the world-wide ATLAS Collaboration building a detector for the near future of particle physics at the Large Hadron Collider at CERN. 13 –19 September 2003, Prague, Czech Republic

ATLAS has a long-standing, excellent, cooperation with the Czech teams, since the official start of the project in 1992

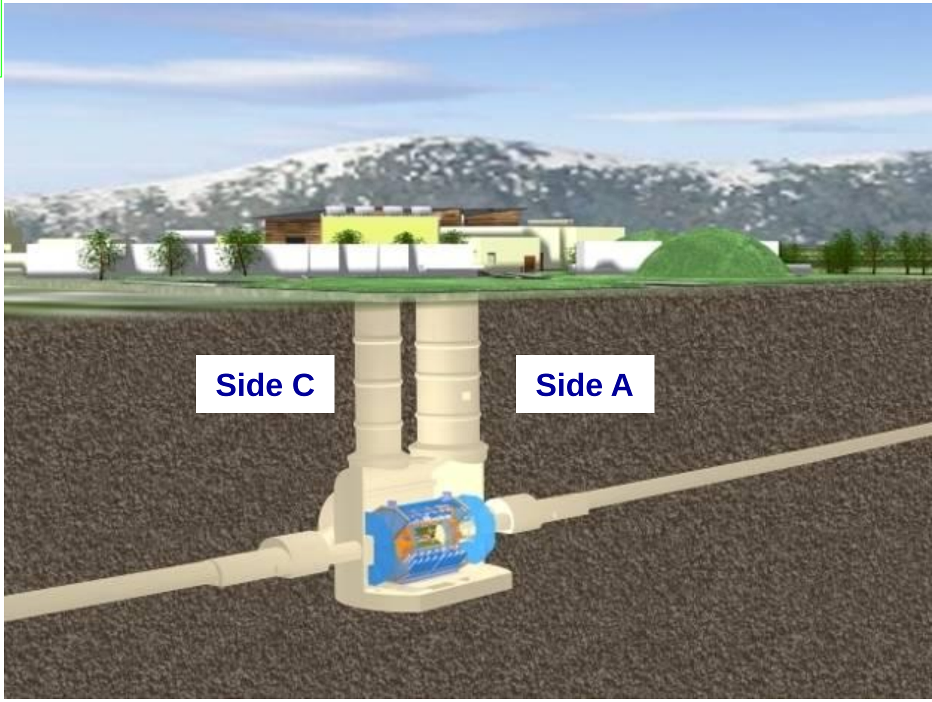
An important milestone was the ATLAS Collaboration meeting in Prague 2003, just before we started installing the detector

Professor J Niederle (1939-2010) opening the ATLAS Overview Week in Prague



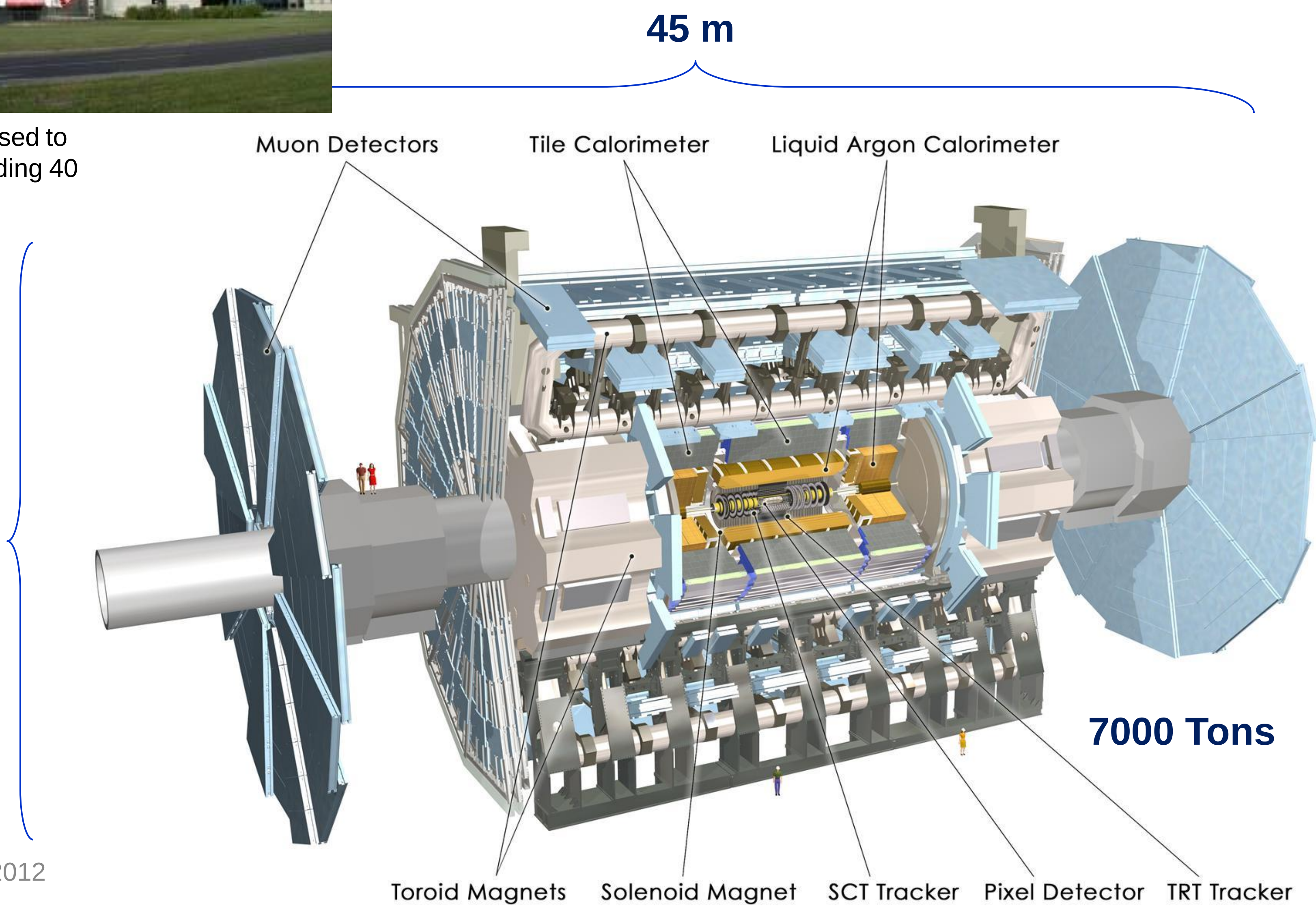
The Underground Cavern at Point-1 for the ATLAS Detector

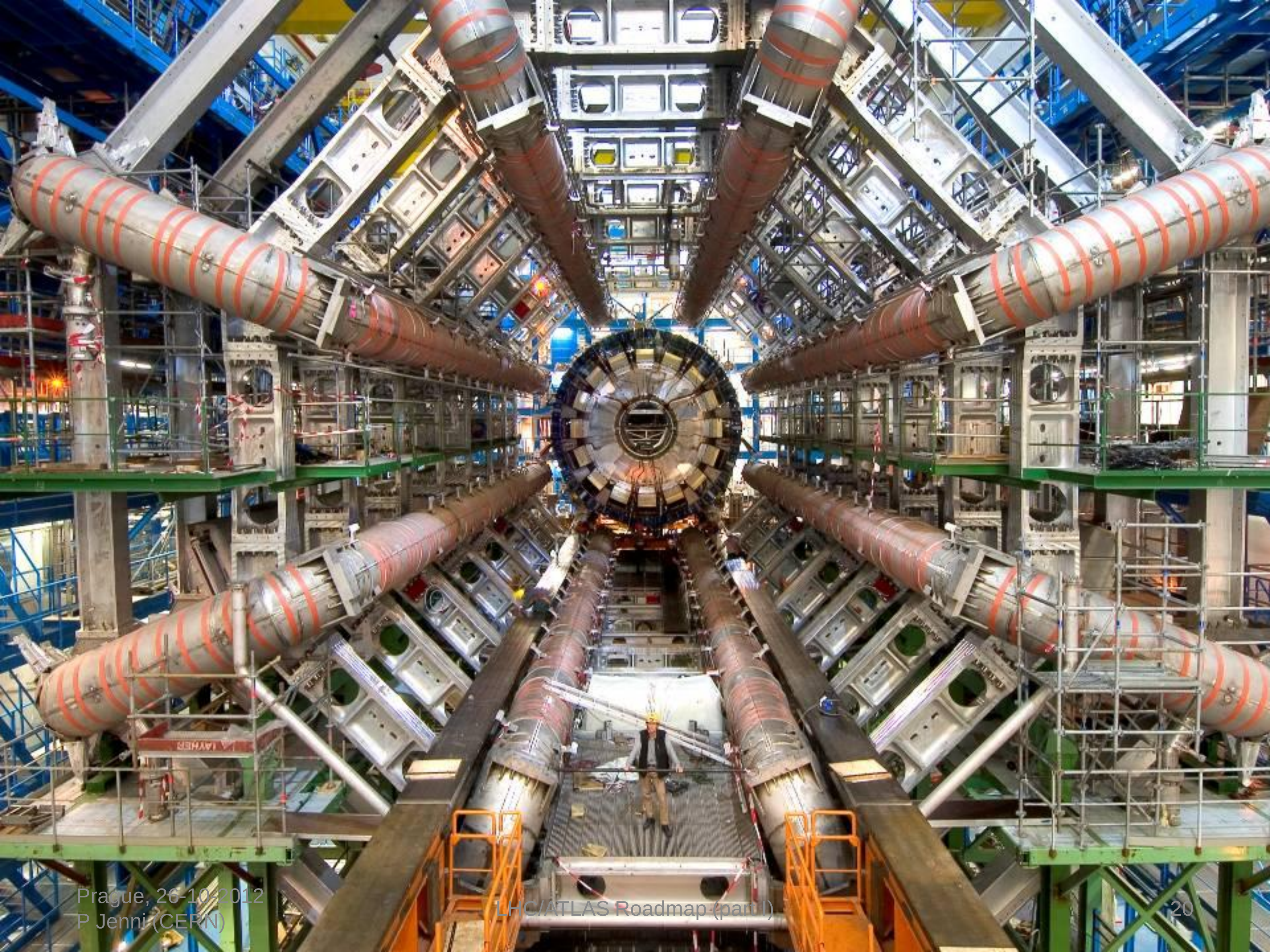
Length = 55 m
Width = 32 m
Height = 35 m



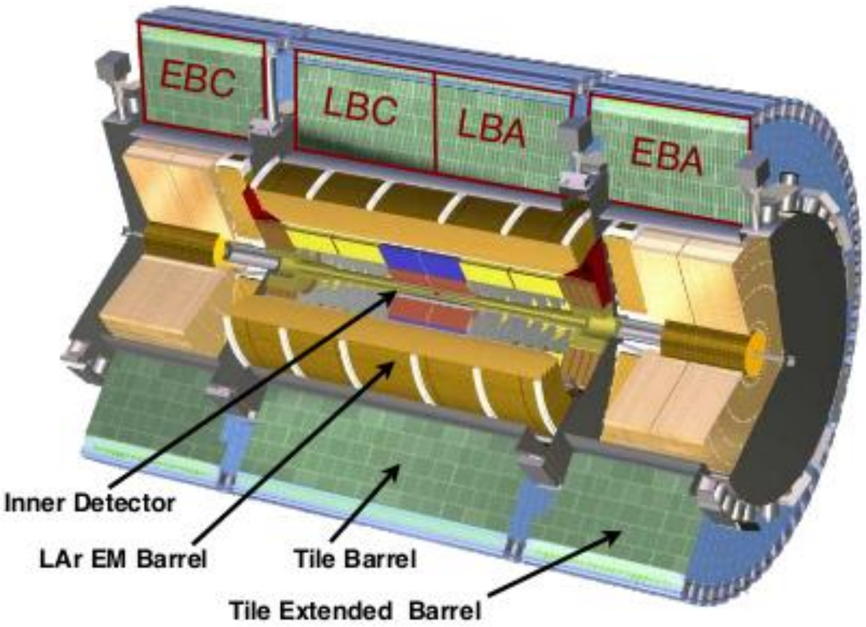
ATLAS Detector

ATLAS superimposed to the 5 floors of building 40

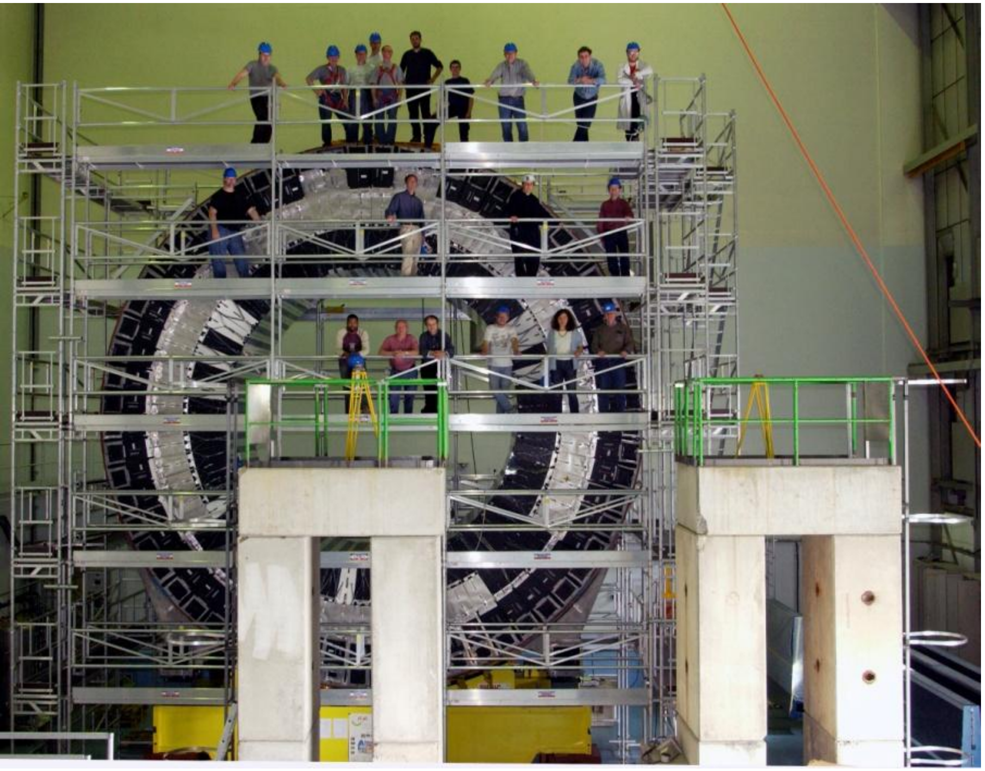




Tile Calorimeter



EBC pre-assembly on the surface, April 2003



Rupert Leitner Project Leader 2001-2004

Tile Calorimeter sub-module construction in Prague 1999

Czech Deputy Prime Minister Petr Mares visiting the Tile Calorimeter pre-assembly (Dec 2003)

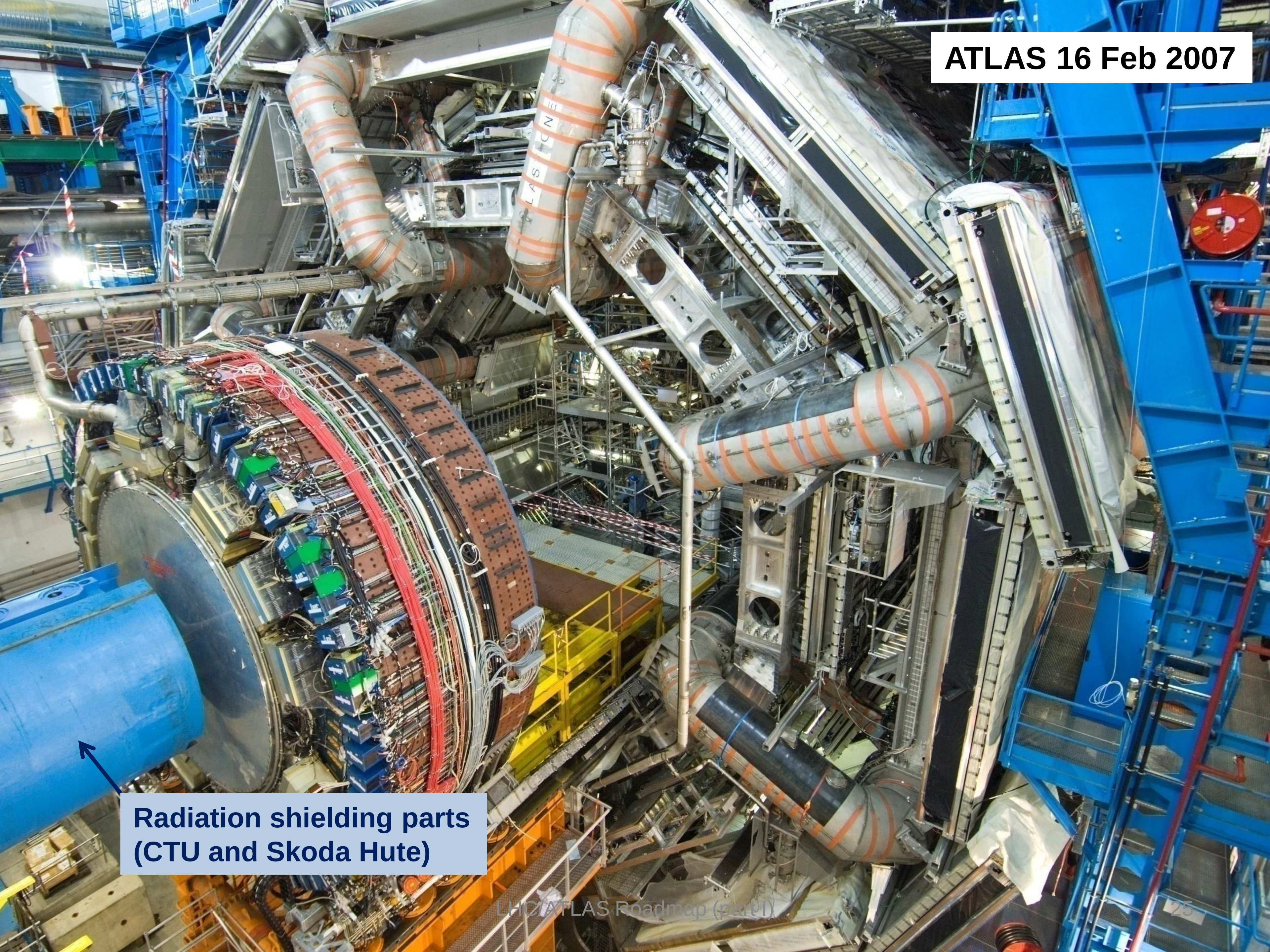
Transport of part of the Barrel Tile Calorimeter to the experimental area Point-1 (Sep 2004)

EBA assembly 24 May 2006

The Prague groups (and Czech industry) are also important collaborators on the semiconductor tracking system (SCT and Pixels)

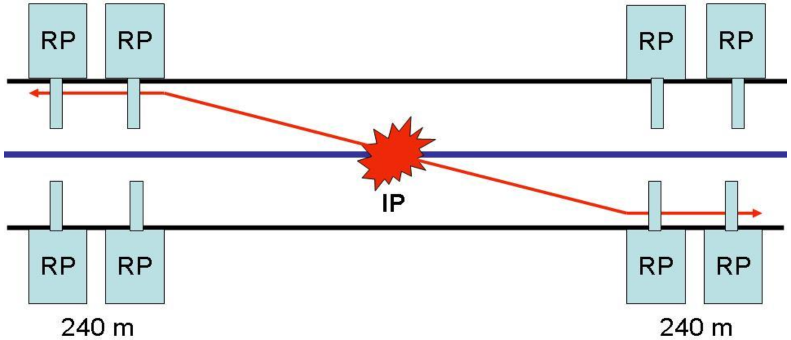
ATLAS Supplier Award ceremony for 'On Semiconductor' (ex 'Tesla') in 2007

(Also 'Skoda Hute' received the same award in 2004 for their shielding work)


ATLAS 16 Feb 2007
Radiation shielding parts
(CTU and Skoda Hute)

ATLAS Roman Pots (ALFA)

There is also a strong involvement of Czech colleagues and industry in ALFA since the Palacky University in Olomouc joined ATLAS in 2008

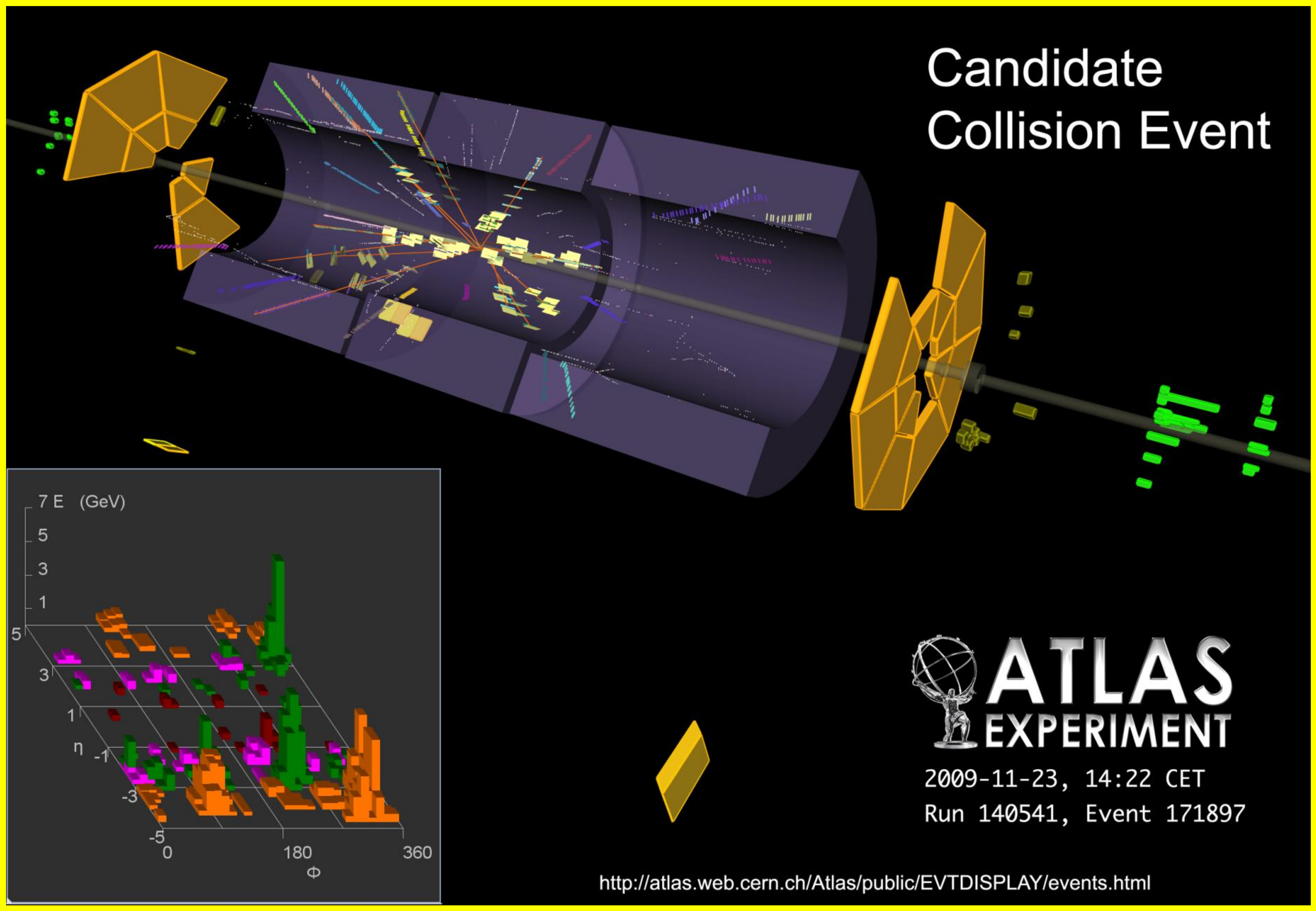


Absolute
Luminosity
For
ATLAS

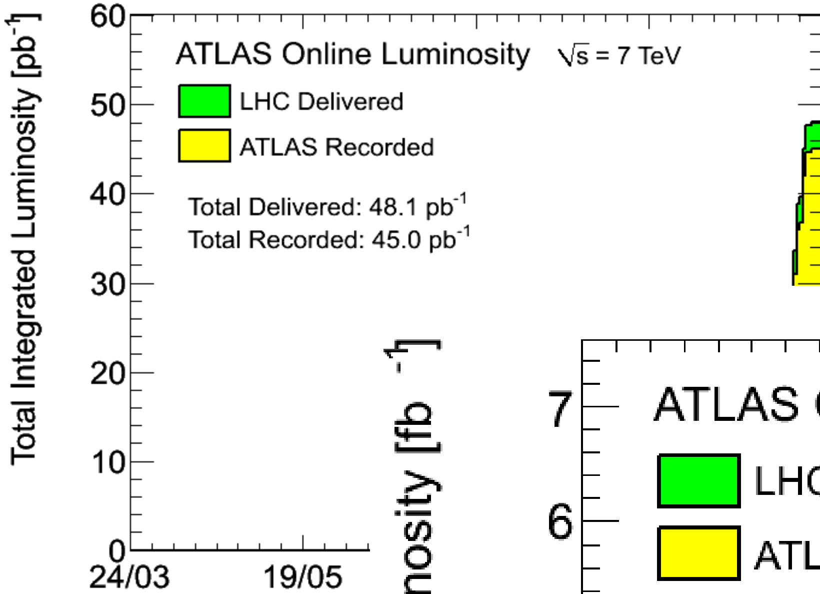
Roman Pots mechanics, based on Czech work in the Totem experiment

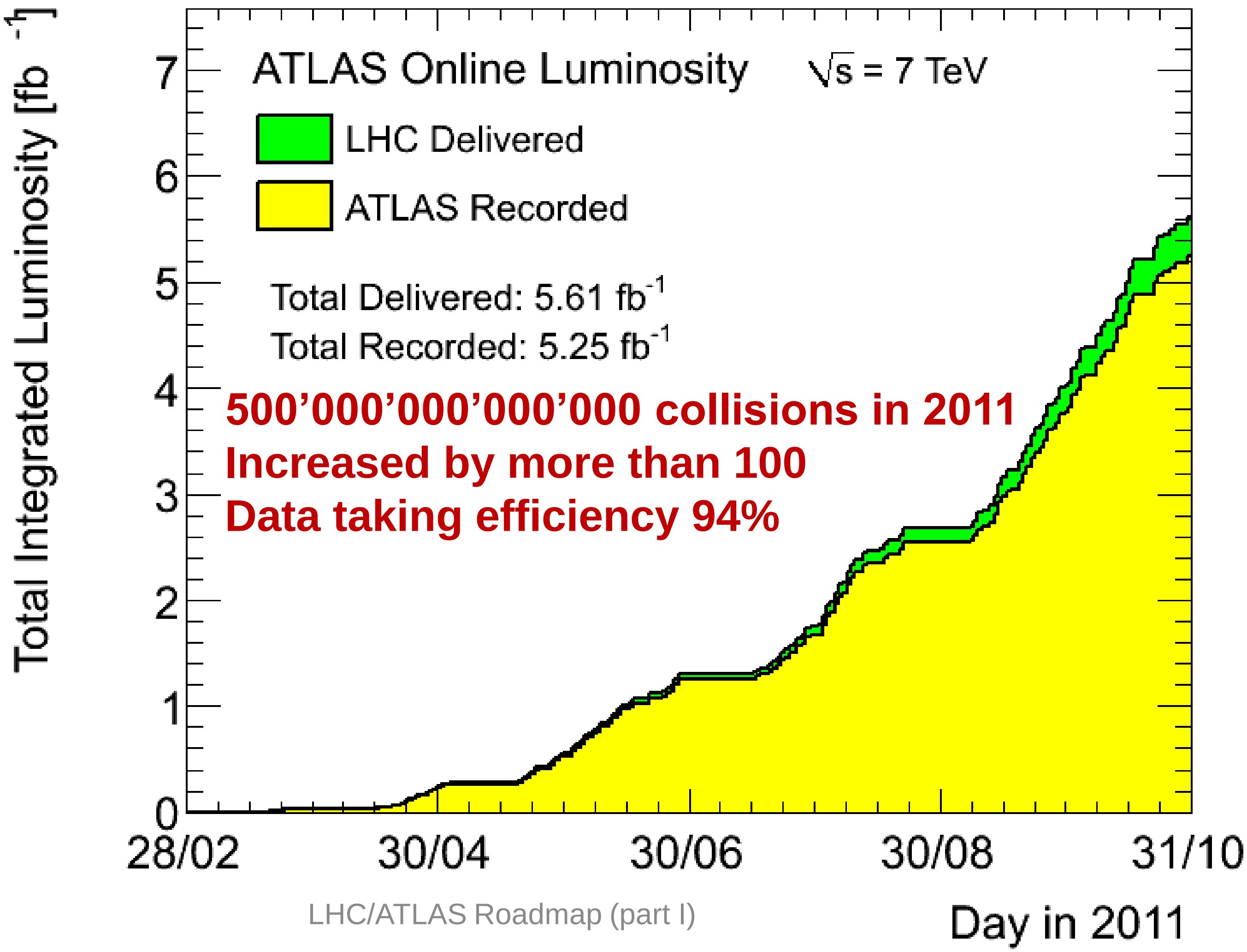
The joy in the ATLAS Control Room when the first LHC beam collided on November 23rd, 2009....

First collisions at the LHC end of November 2009 with beams at the injection energy of 450 GeV



A lot of exciting physics results were already possible thanks to the superb LHC performance in 2011

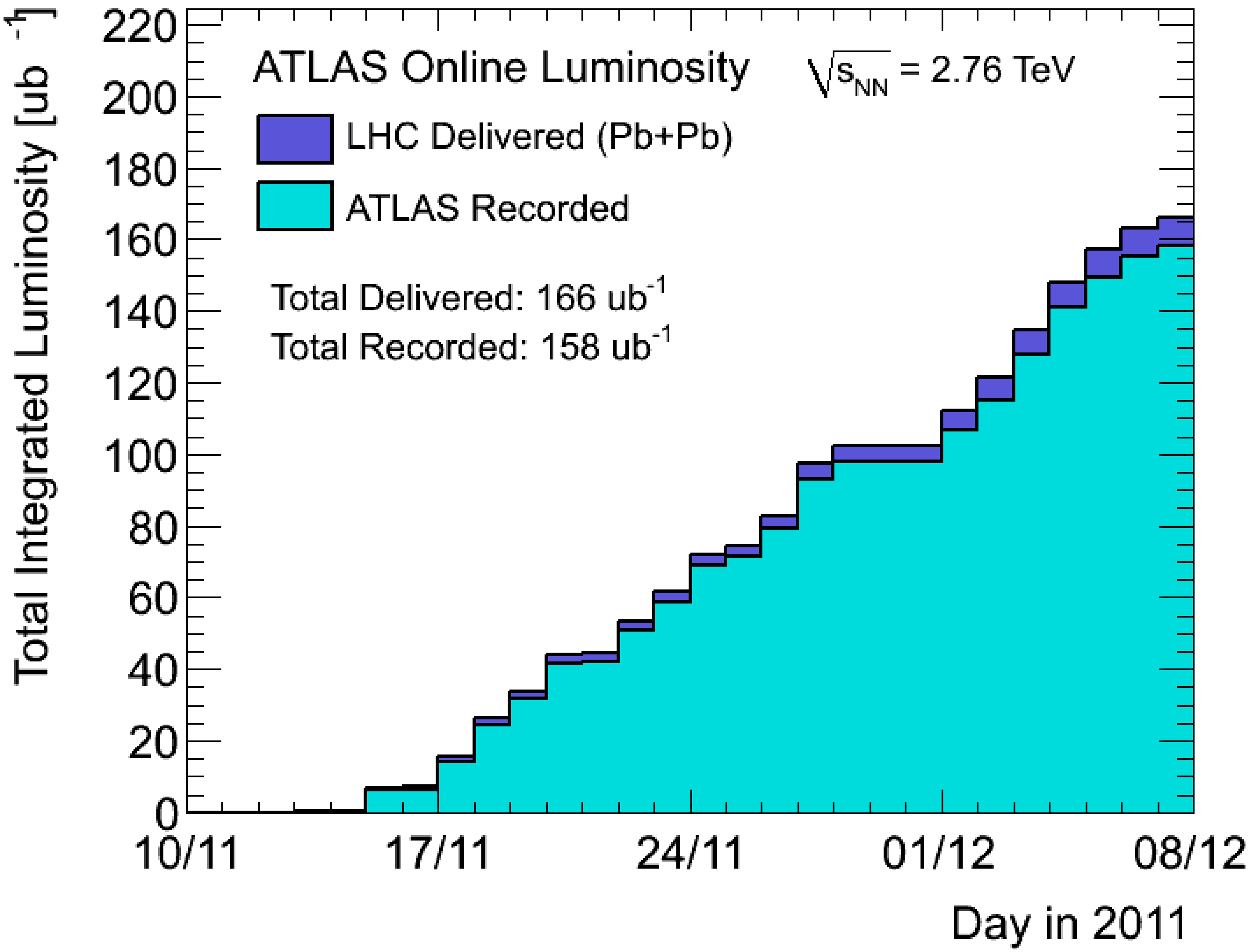




500’000’000’000’000 collisions in 2011
Increased by more than 100
Data taking efficiency 94%

$$N_{events} = \sigma \int L\, dt$$

Heavy Ion Running in 2011



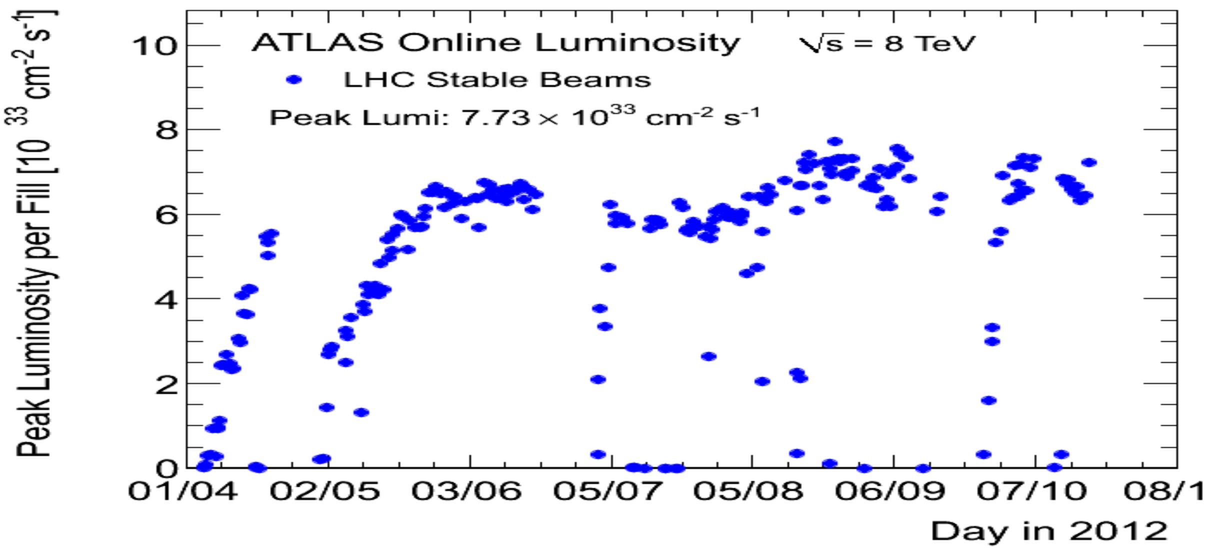
During the short Winter shut-down on 8 March 2012: Visit of the Deputy Minister Ivan Wilhelm in ATLAS

Current LHC Operation:

1380 bunches per beam

50 ns bunch spacing

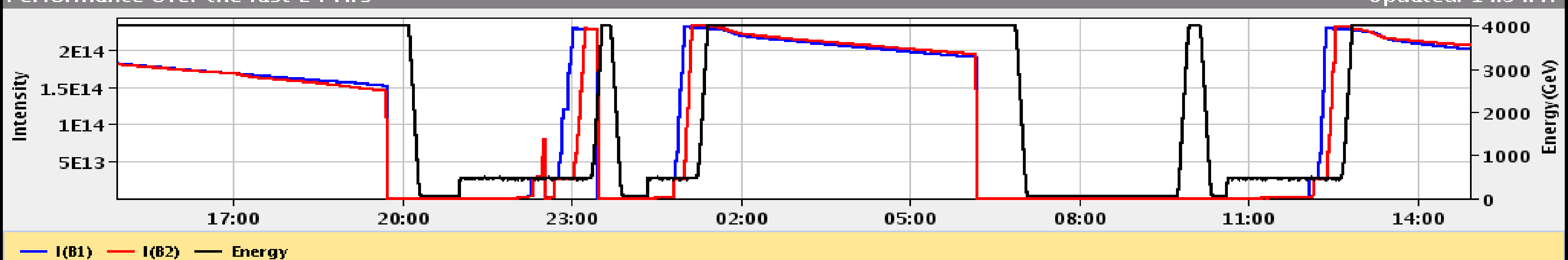
1.5 x 10^{11} protons / bunch



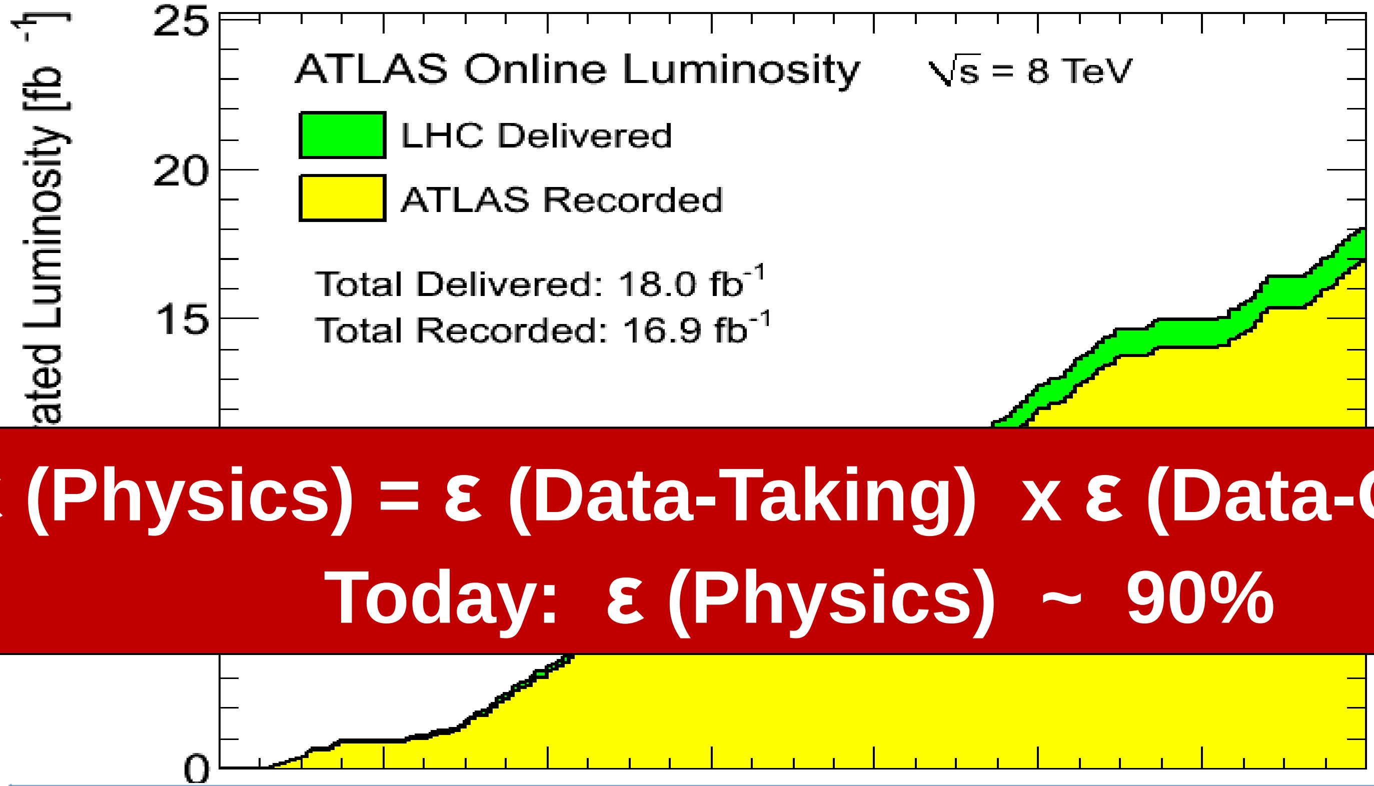
22-Oct-2012 14:54:48	Fill #: 3208	Energy: 4000 GeV	I(B1): 2.02e+14	I(B2): 2.07e+14
	ATLAS	ALICE	CMS	LHCb
Experiment Status	PHYSICS	PHYSICS	PHYSICS	PHYSICS
Instantaneous Lumi [(ub.s)^-1]	5394.2	5.976	5253.7	398.0
BRAN Luminosity [(ub.s)^-1]	5351.2	3.943	4618.0	240.2
Fill Luminosity (nb)^-1	28330.6	30.5	24854.2	1727.9
BKGD 1	0.724	0.834	2.375	0.911
BKGD 2	104.642	0.000	3.854	27.452
BKGD 3	1.855	9.490	18.651	1.334

LHCb VELO Position IN Gap: -0.0 mm | STABLE BEAMS | TOTEM: STANDBY

Performance over the last 24 Hrs Updated: 14:54:47



But the LHC (at 8 TeV) and ATLAS performances are even more fantastic this year



ε (Physics) = ε (Data-Taking) x ε (Data-Quality)

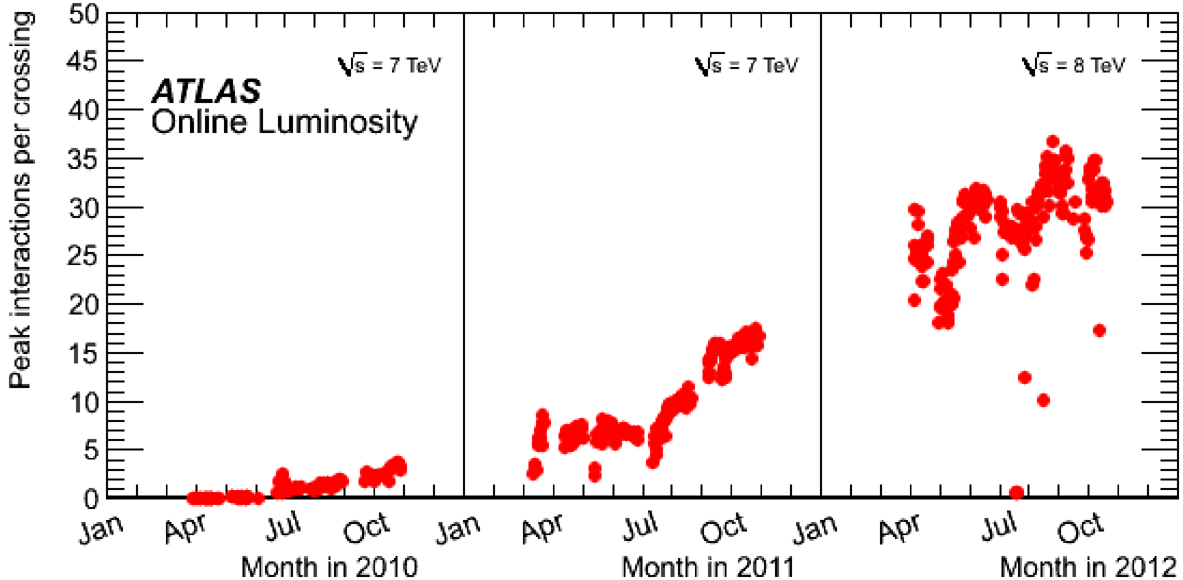
Today: ε (Physics) ~ 90%

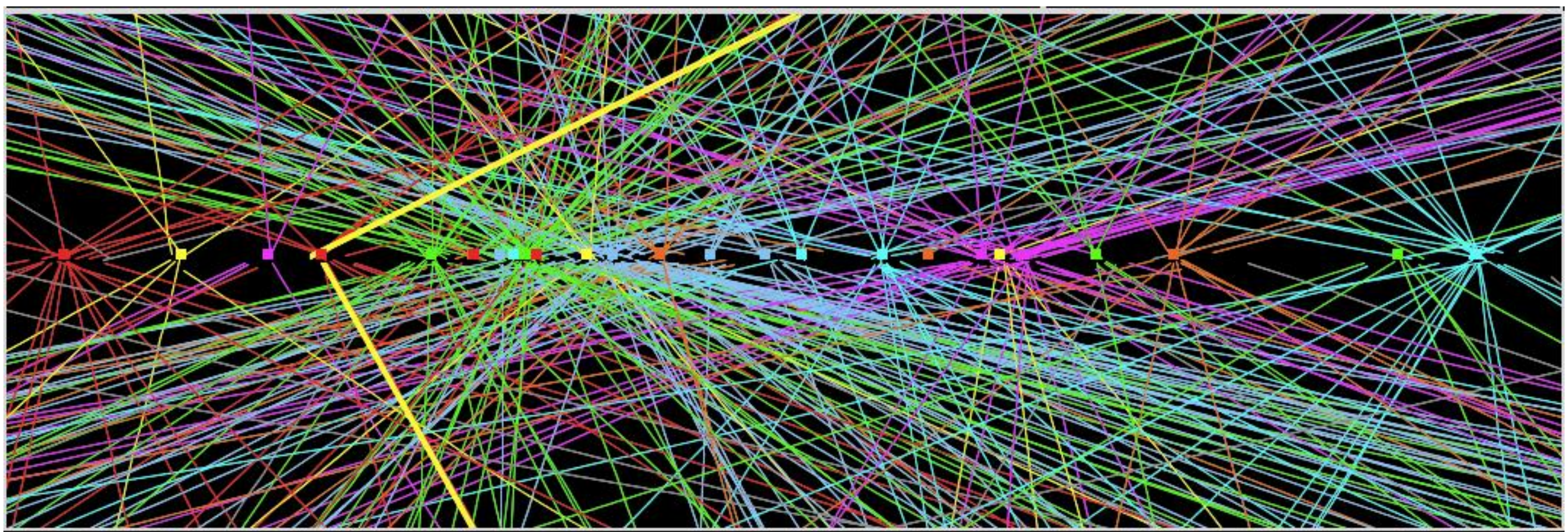
Data Quality			**ATLAS p-p run: April-Sept. 2012**							
Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
100	99.3	99.5	97.0	99.6	99.9	99.8	99.9	99.9	99.7	99.2
All good for physics: 93.7%										

Luminosity weighted relative detector uptime and good quality data delivery during 2012 stable beams in pp collisions at √s=8 TeV between April 4th and September 17th (in %) – corresponding to 14.0 fb-1 of recorded data. The inefficiencies in the LAr calorimeter will partially be recovered in the future.

Excellent LHC performance is a (nice) challenge for the experiment:

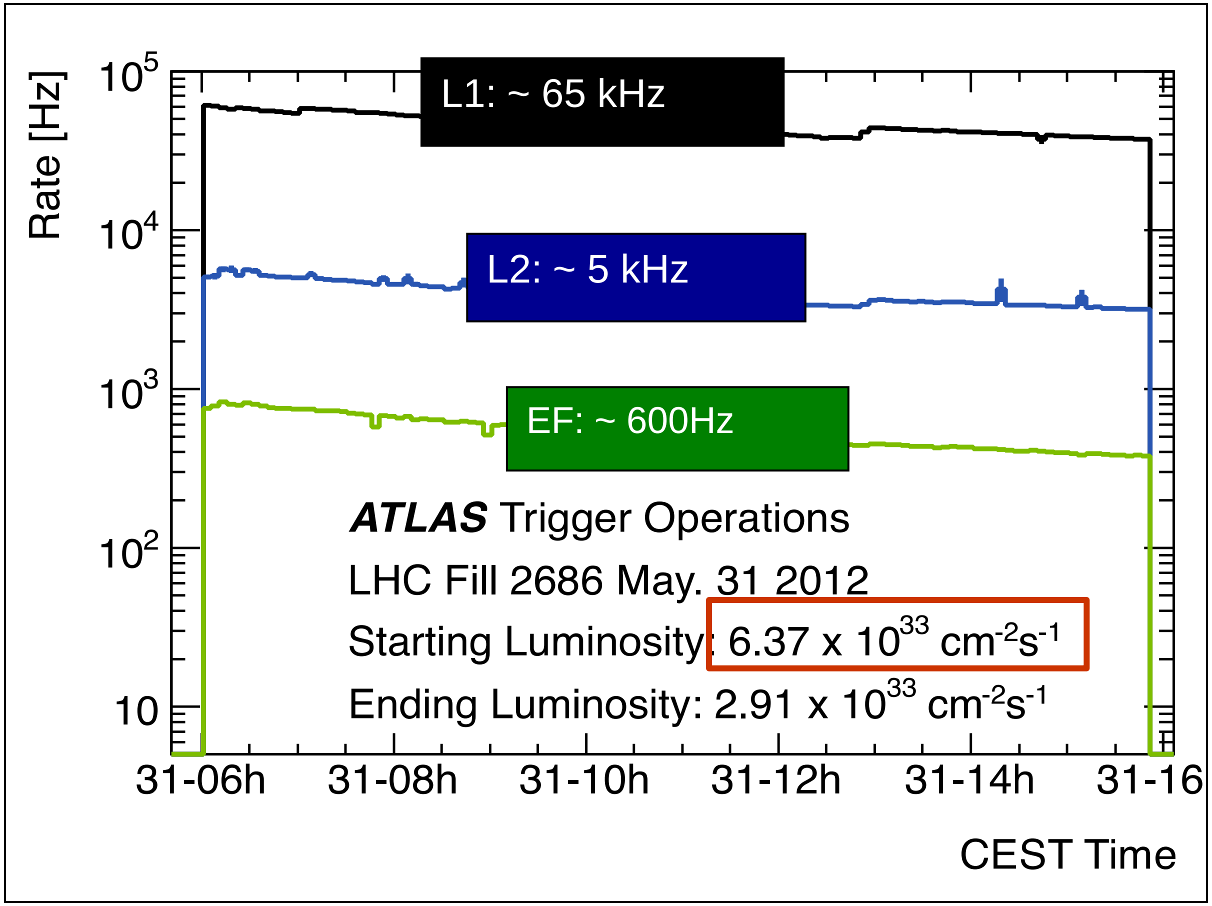
- **Trigger**
- **Pile-up**
- **Maintain accuracy of the the measurements in this environment**





Inner Detector for a Z → μμ event with 25 primary vertices

Example for the typical trigger rates



Three levels of event selections:

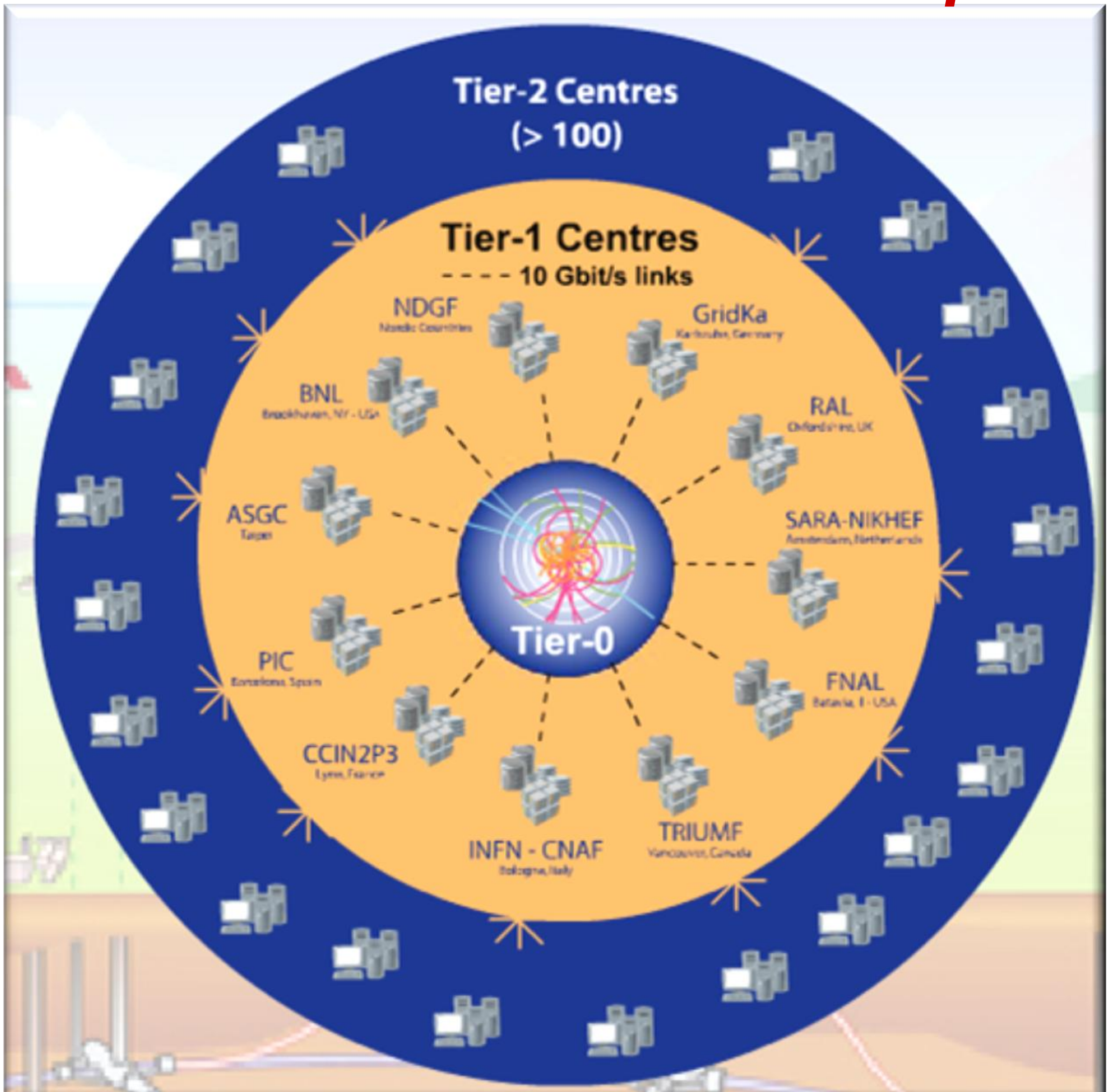
Level-1 underground with purpose-made electronics and processors

Level-2 and Event Filter in a large computer farm located at the surface of Point-1

(Noted in the plot are the output rates)

- ❑ **Typical recorded rates for main streams e/γ, Jets/τ/E_T^{miss} , Muons: ~ 100 Hz each**
- ❑ **Delayed stream (future Tier0 reconstruction): B-physics (~65 Hz) and Hadronic (~80 Hz)**
- ❑ **Note: currently 564 items in the trigger menu**

The Worldwide LHC Computing Grid (wLCG)



WLCG
Worldwide LHC Computing Grid

Tier-0 (CERN):
- Data recording
- Initial data reconstruction
- Data distribution

Tier-1 (11 centres):
- Permanent storage
- Re-processing
- Analysis
- Simulation

Tier-2 (federations of ~130 centres):
- Simulation
- End-user analysis

The large ATLAS Prague Tier-2 works very efficiently

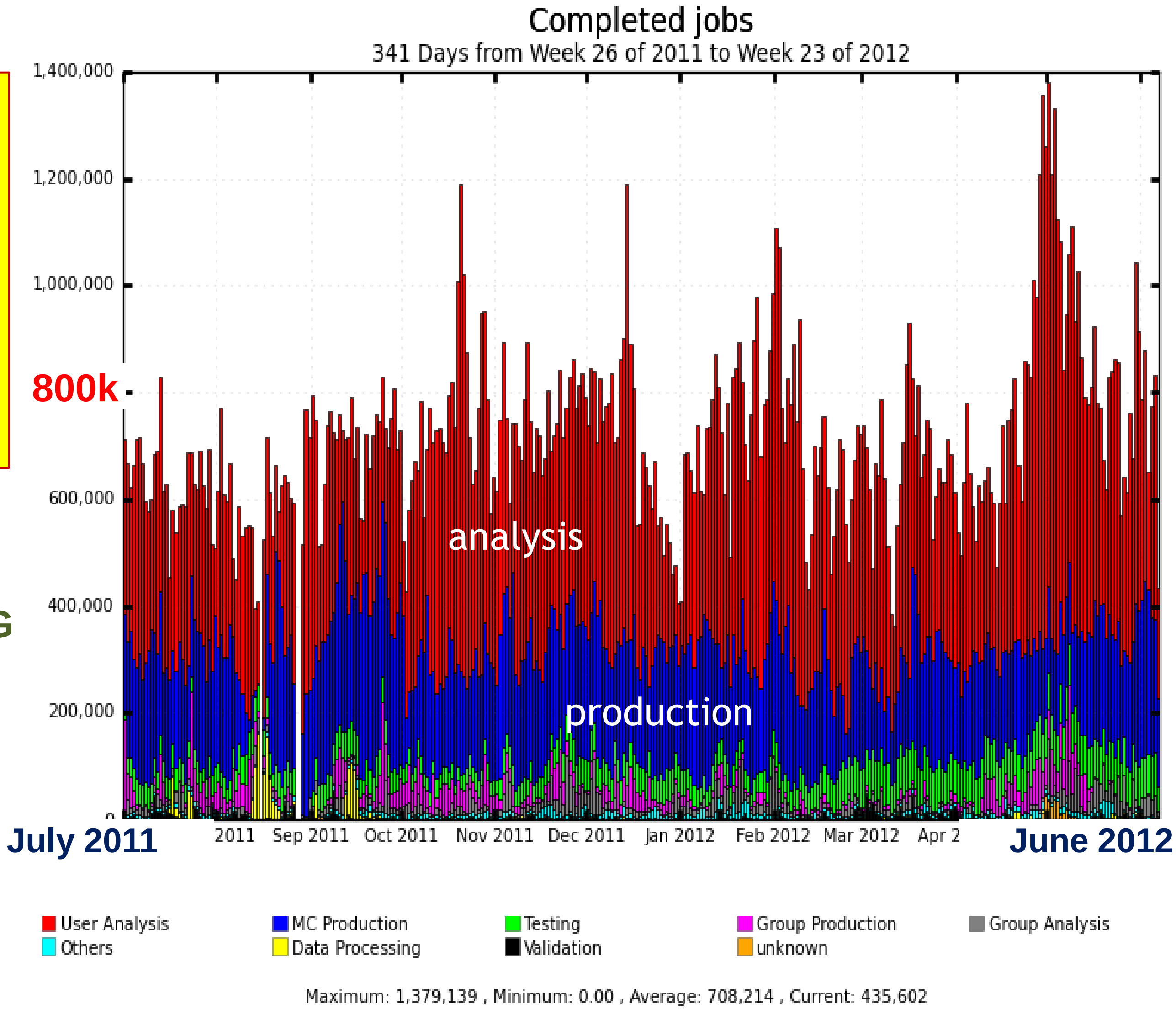
Computing Grid Delivers Physics

Data preparation:

- **First-pass reconstruction at Tier-0 within ~2 days**
- **Calibration good for physics analysis on Grid within ~1 week**

The high quality of the WLCG computing system allows LHC experiments to show results from data taken just few weeks before

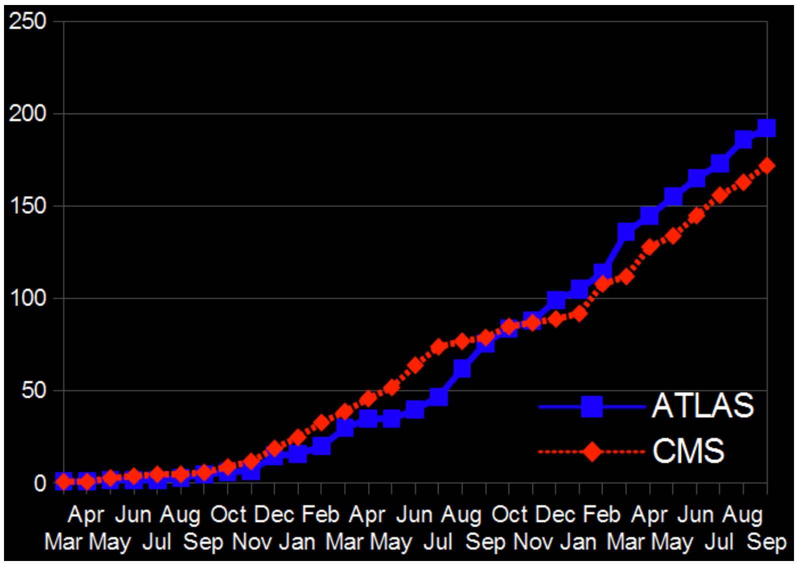
ATLAS jobs per day across all Tier-1 & Tier-2s

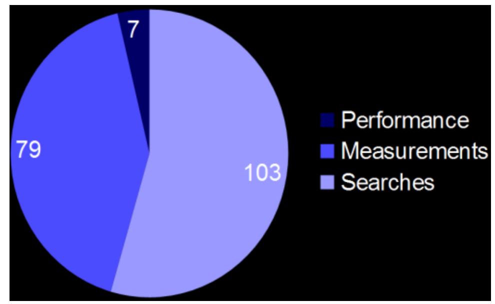


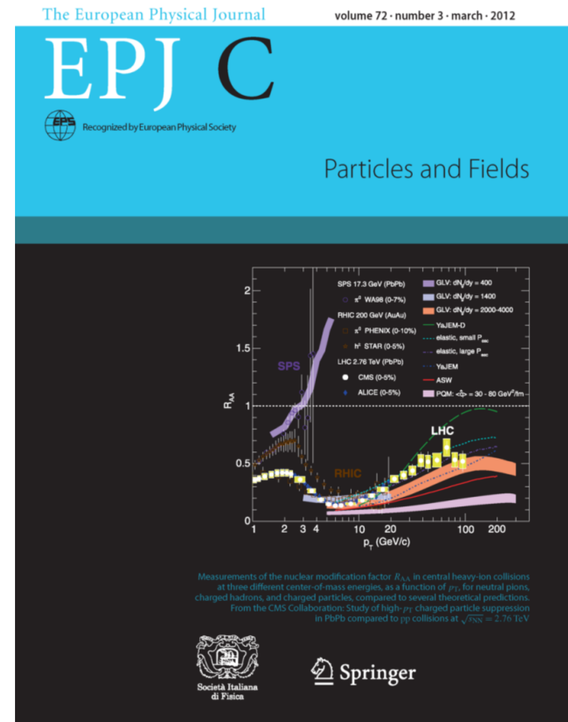
Physics Highlights

ATLAS (as well as CMS) have already published about 200 papers each in scientific journals (and many more as public conference notes…)

It is obviously not possible to cover all these results…







Note that all public results from CMS and ATLAS are available at:
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults
https://twiki.cern.ch/twiki/bin/view/AtlasPublic

Physics Highlights:

General event properties

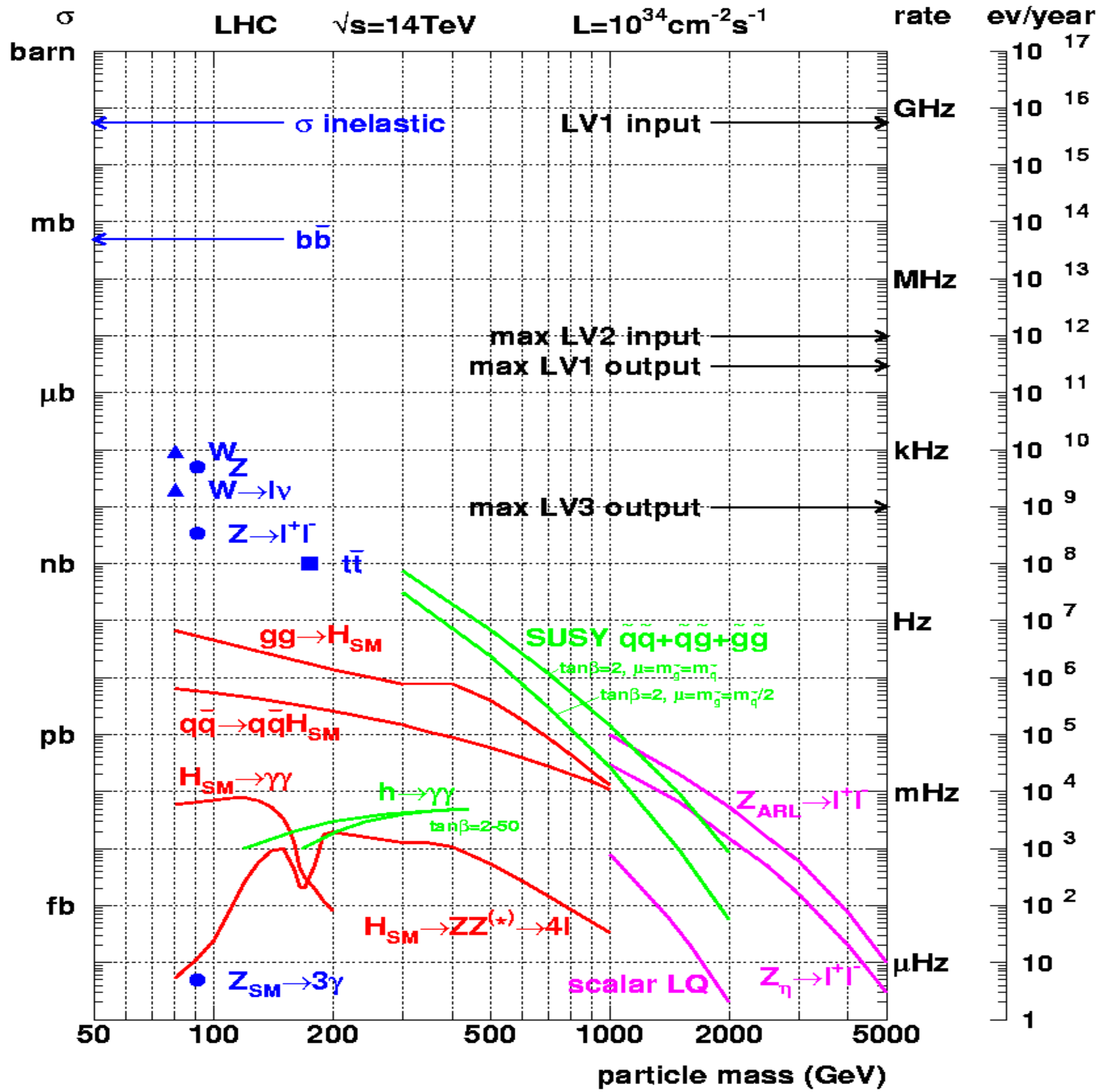
Heavy flavour physics

Standard Model physics including QCD jets

Higgs searches

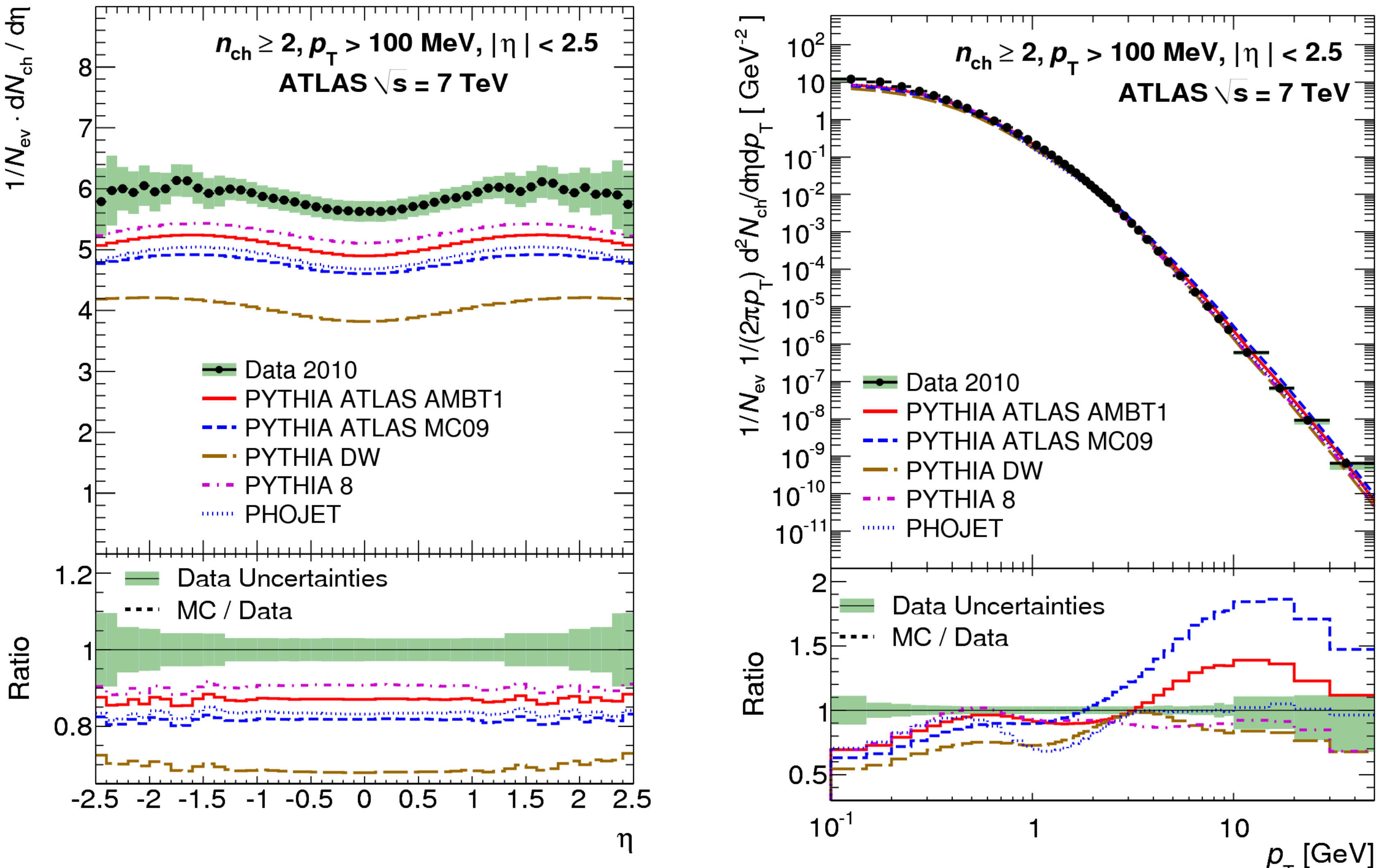
Searches for SUSY

Examples of searches for ‘exotic’ new physics

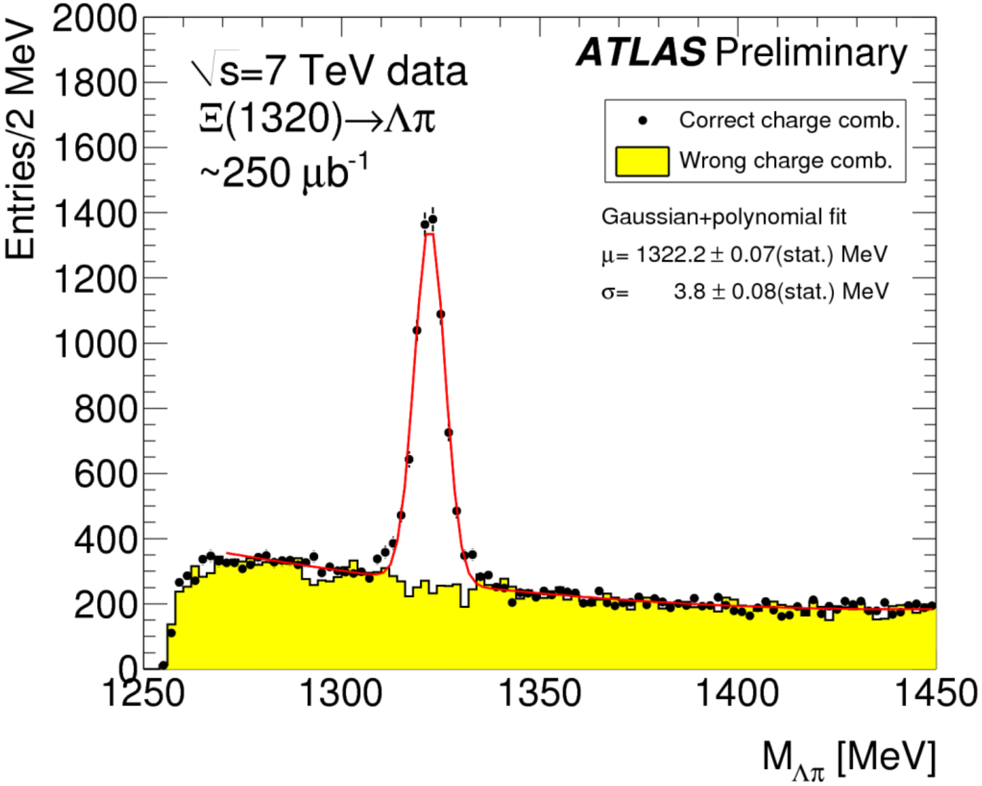


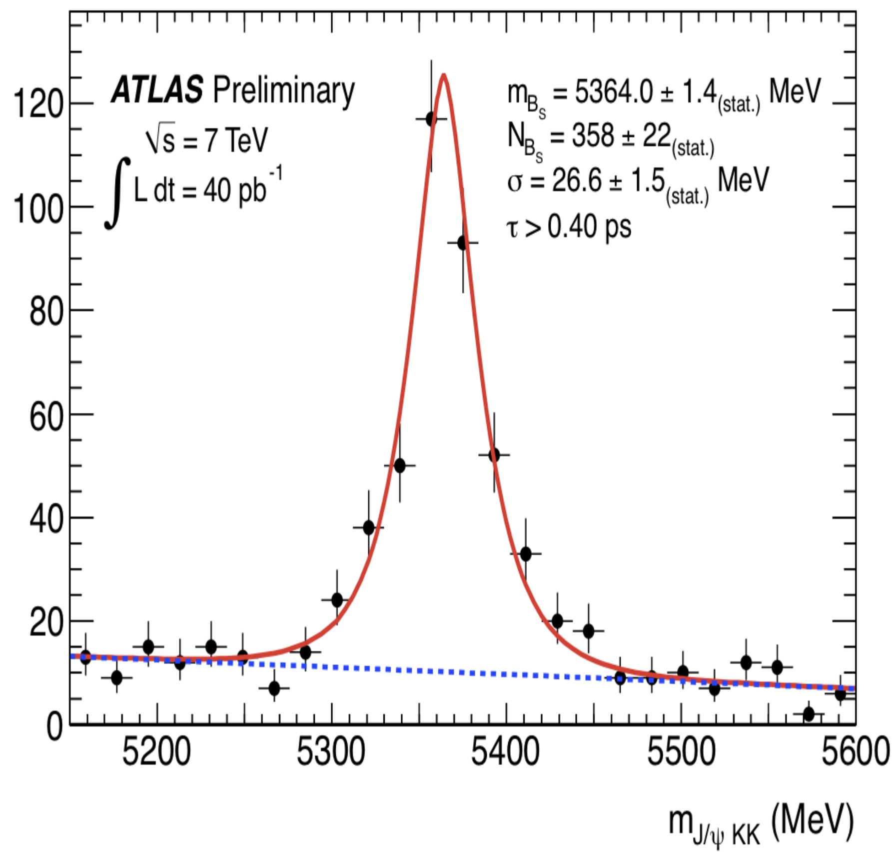
Charged-particle multiplicities as a function of pseudorapidity η and transverse momentum p_T for minimum bias events selected as specified, and compared to various Monte Carlo models

New J. Phys. 13 (2010) 053033



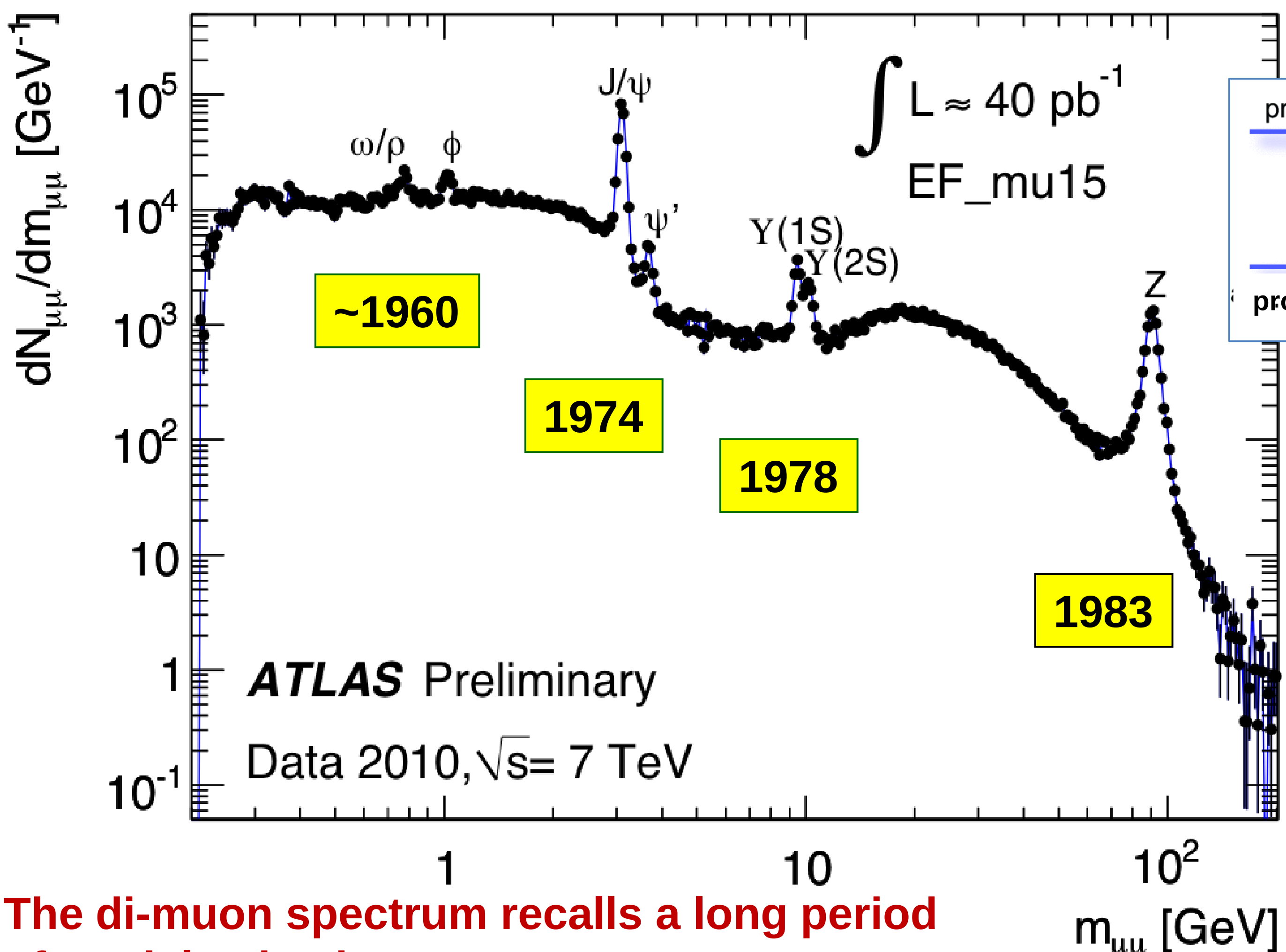
Examples of reconstructed final states

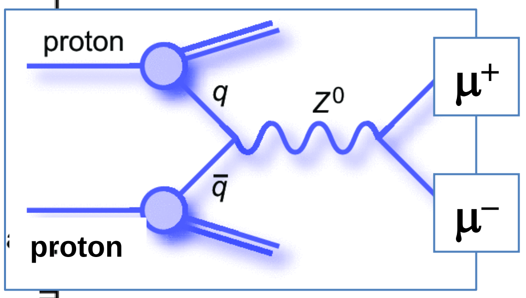




2010

Data corresponding to ~40 pb^{-1} collected → re-discovery of the Standard Model



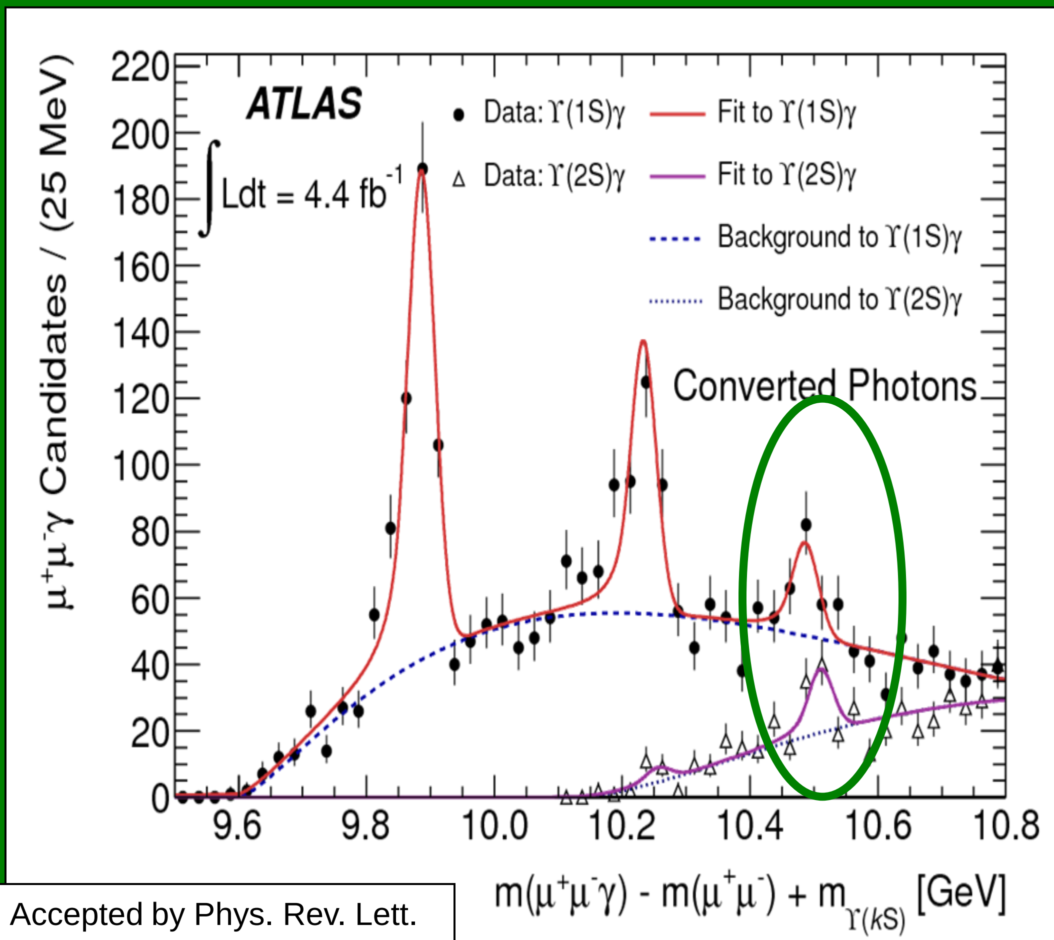


The di-muon spectrum recalls a long period of particle physics

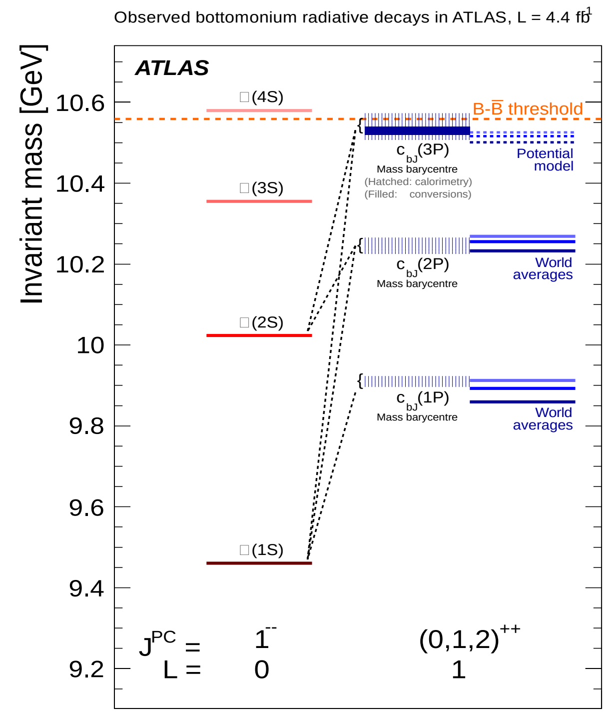
The first new particles ‘discovered’ at LHC: December 2011

$X_b(3P) \rightarrow Y(1s,2s)\ \gamma$

$m\ [\chi_b(3P)] = 10.530 \pm 0.005\ (stat) \pm 0.009\ (syst)$ GeV



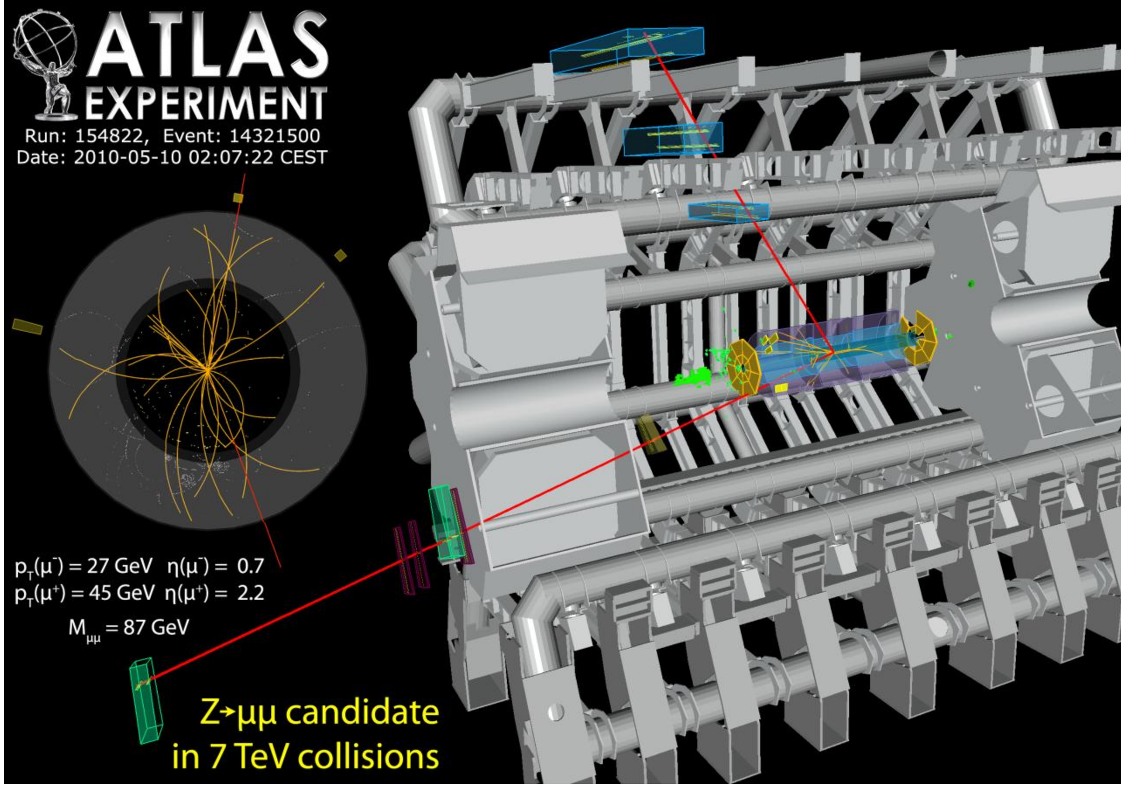
Accepted by Phys. Rev. Lett.
arXiv:1112.5154v4[hep-ex]



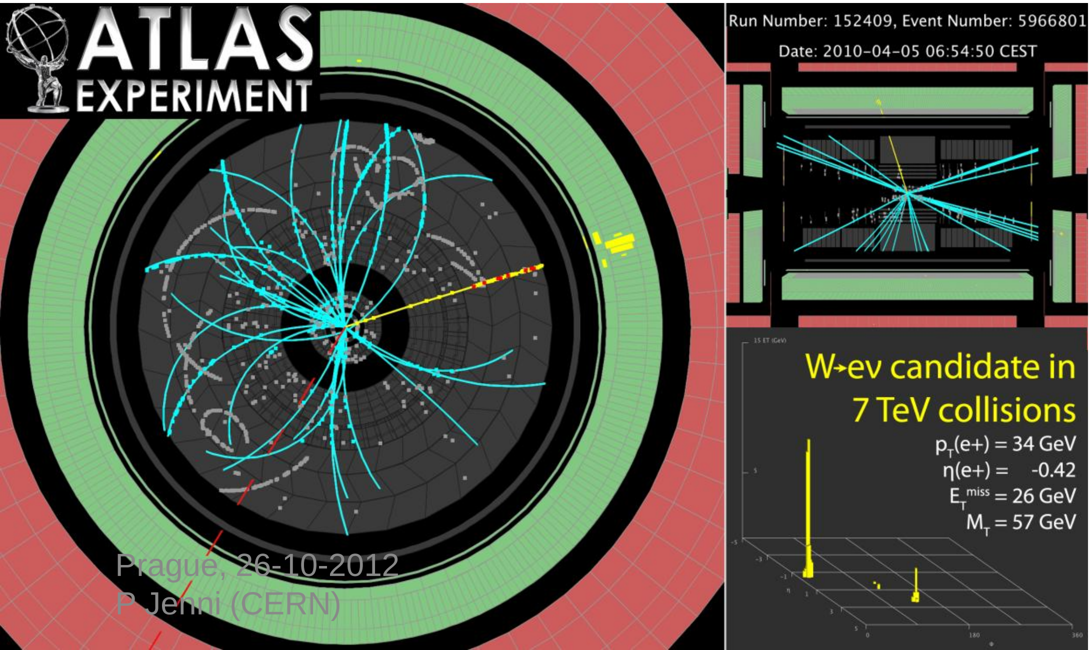
- ❑ **$\chi_b(nP) \rightarrow Y(1s,2s)\ \gamma \rightarrow \mu\mu\ \gamma$**
- ❑ **$X_b(1P)$ m= 9.9 GeV and $X_b(2P)$ m= 10.2 GeV states clearly visible**
- ❑ **New structure at 10.5 GeV $\rightarrow X_b(3P)$**
- ❑ **Confirmed with Y(2s) data and with un-converted photons**
- ❑ **Significance > 6 σ**
- ❑ **As theoretically predicted**

Standard Model Physics

Candidate Z → $\mu^+\mu^-$



W → eν candidate



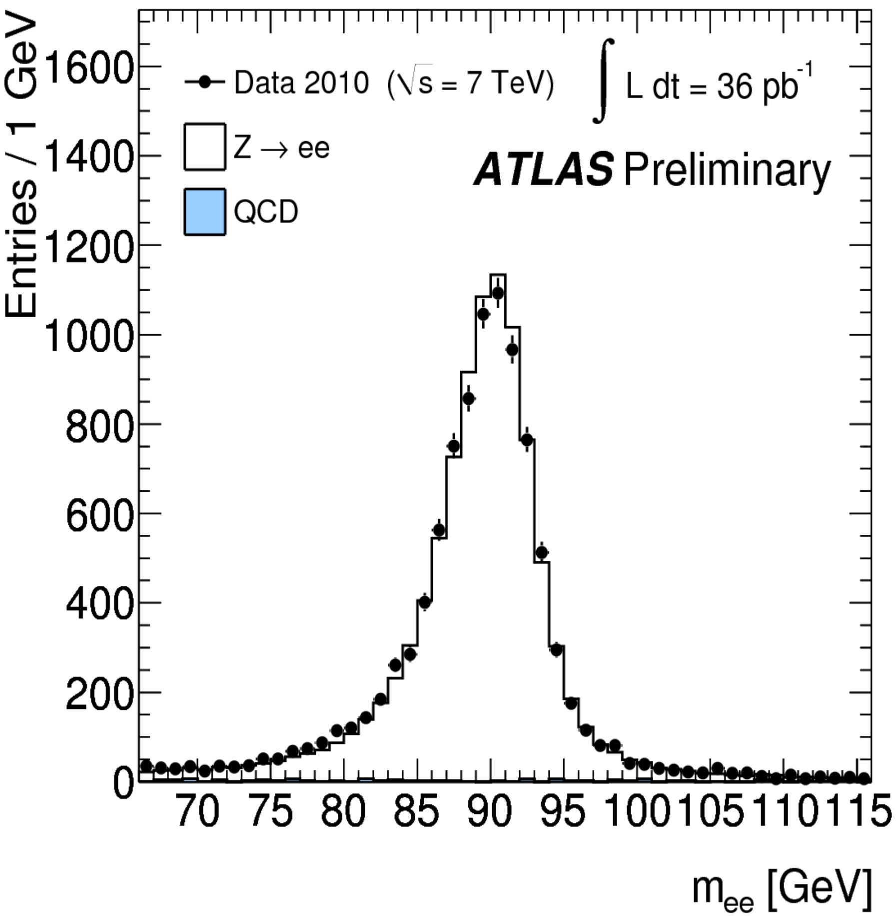
In its 2011 dataset (~ 5 fb^{-1}) ATLAS has:

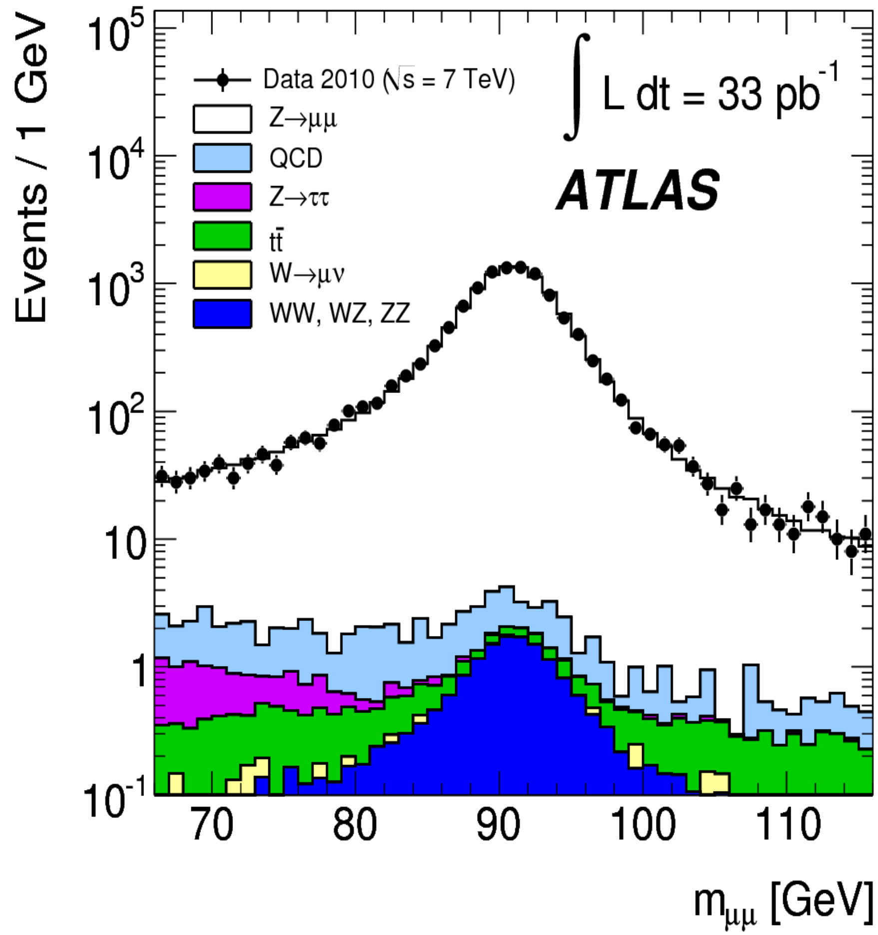
~ 30 M W→ μν, eν events
~ 3 M Z → μμ, ee events

after all selection cuts

Z and W production

Phys Rev D85 (2012) 072004

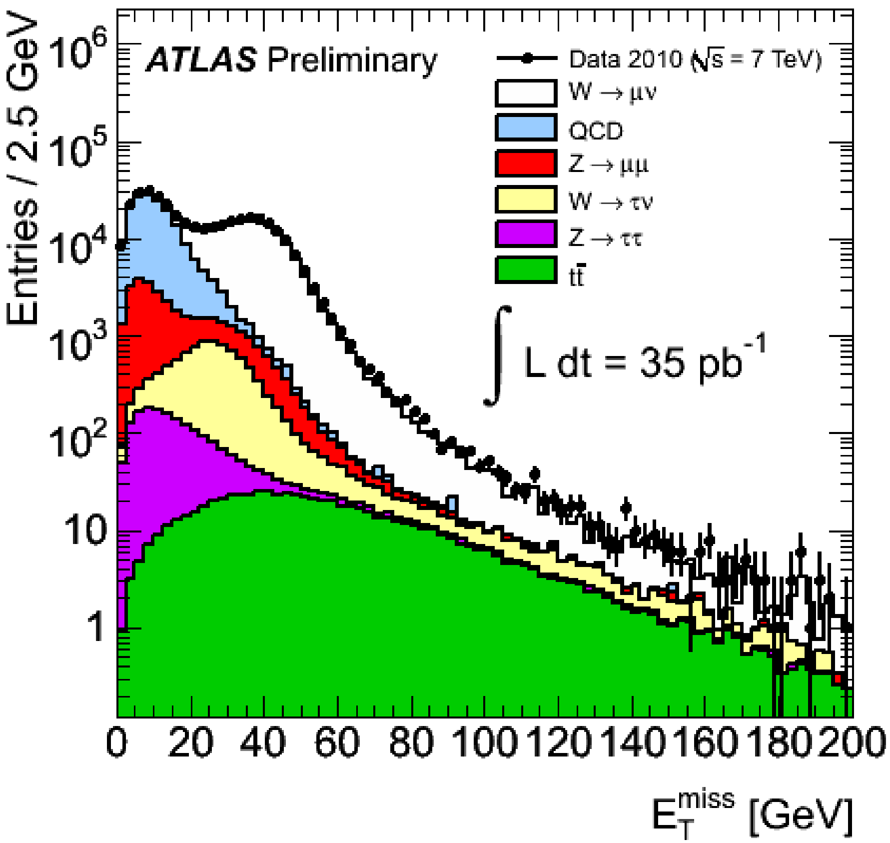




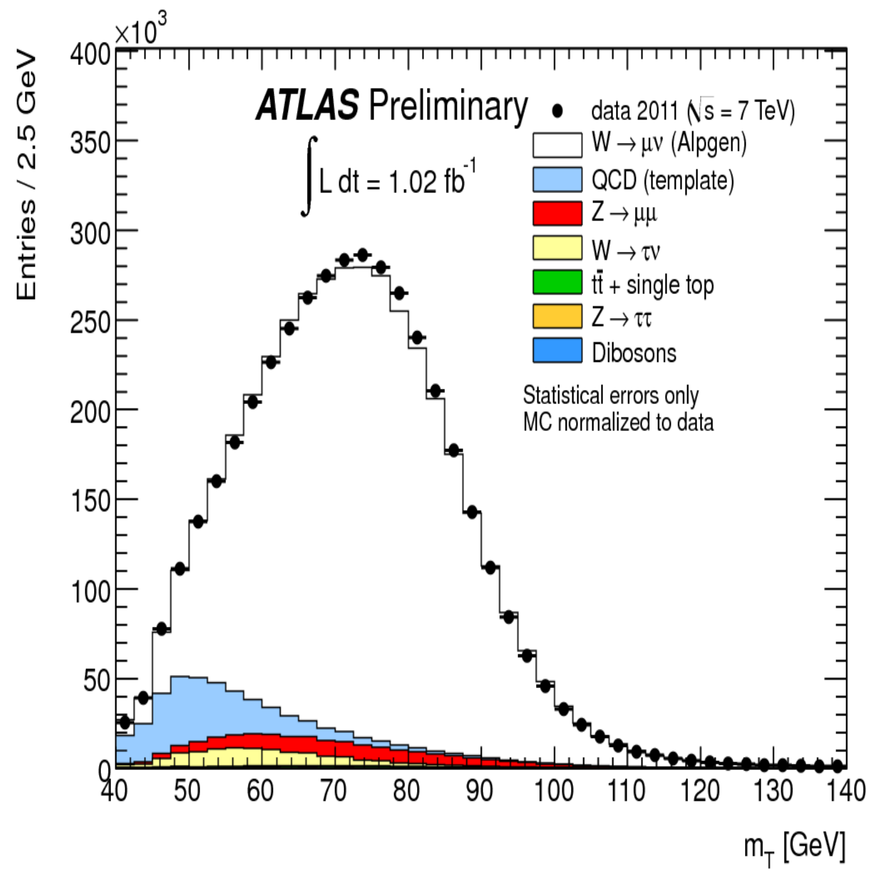
Z peak (di-lepton pair mass distributions, can be extracted essentially background-free)

$$m = \sqrt{(E_1 + E_2)^2 - (\vec{p}_1 + \vec{p}_2)^2}$$

W transverse mass



μ with p_T>20 GeV, E_T^{miss}>25 GeV



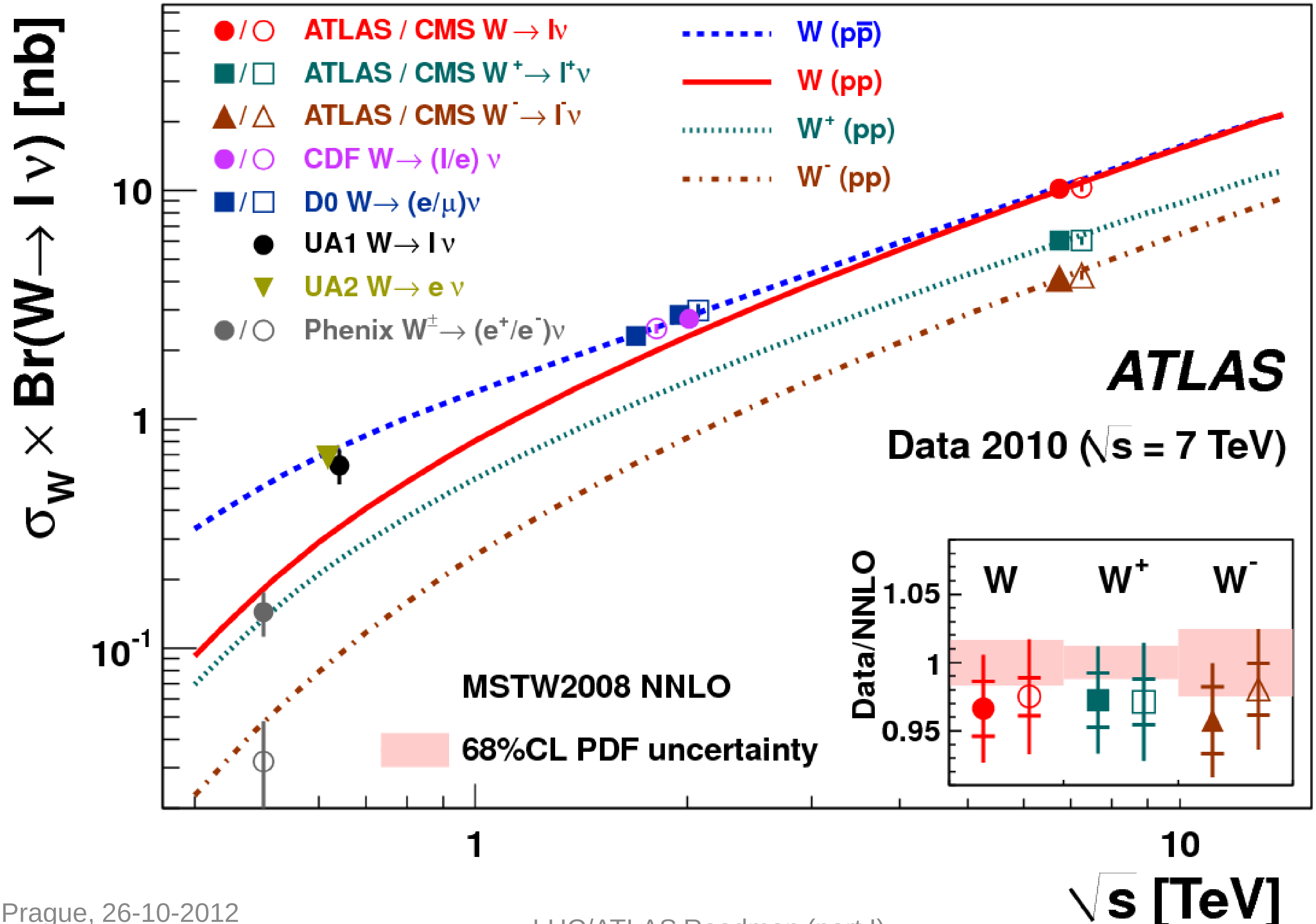
Missing transverse energy from the W → μ + ν decays

ATLAS-CONF-2011-041

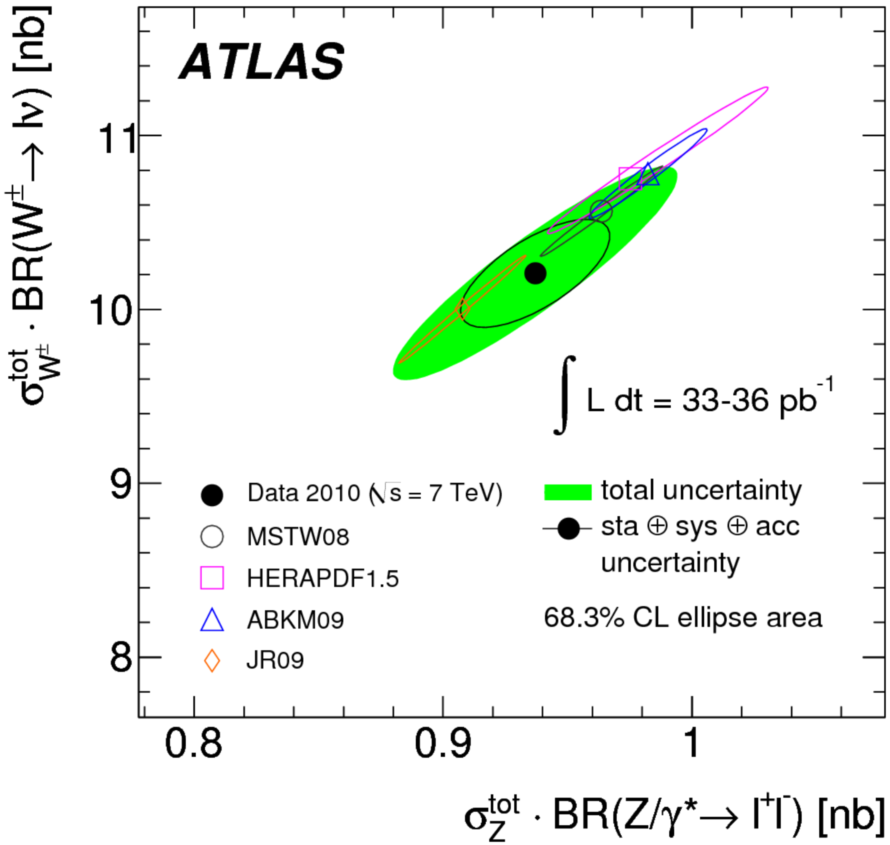
$$m_T = \sqrt{2 p_T^\ell p_T^\nu (1 - \cos(\phi^\ell - \phi^\nu))}$$

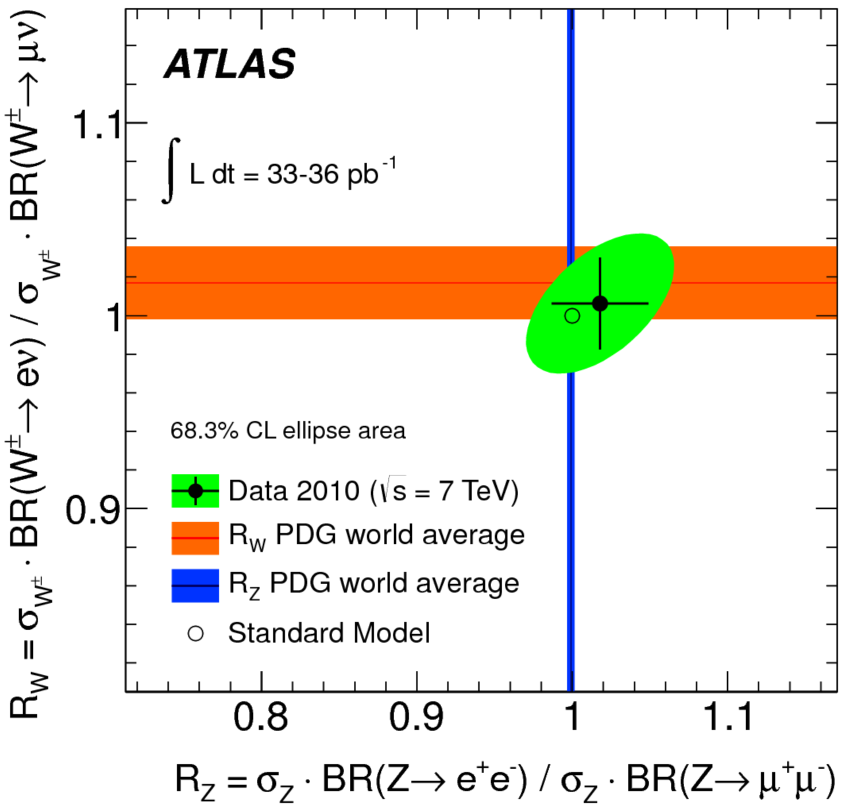
W cross section measurement with e and μ

Phys Rev D85 (2012) 072004



Two examples of confronting the 2010 ATLAS data with SM theory

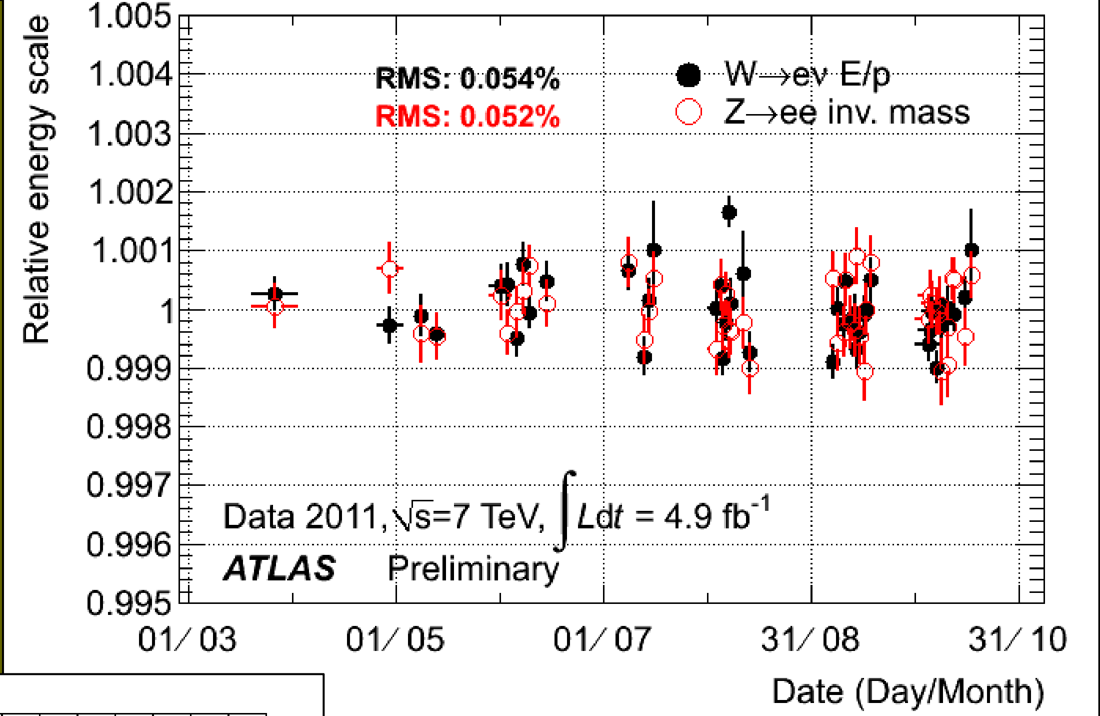




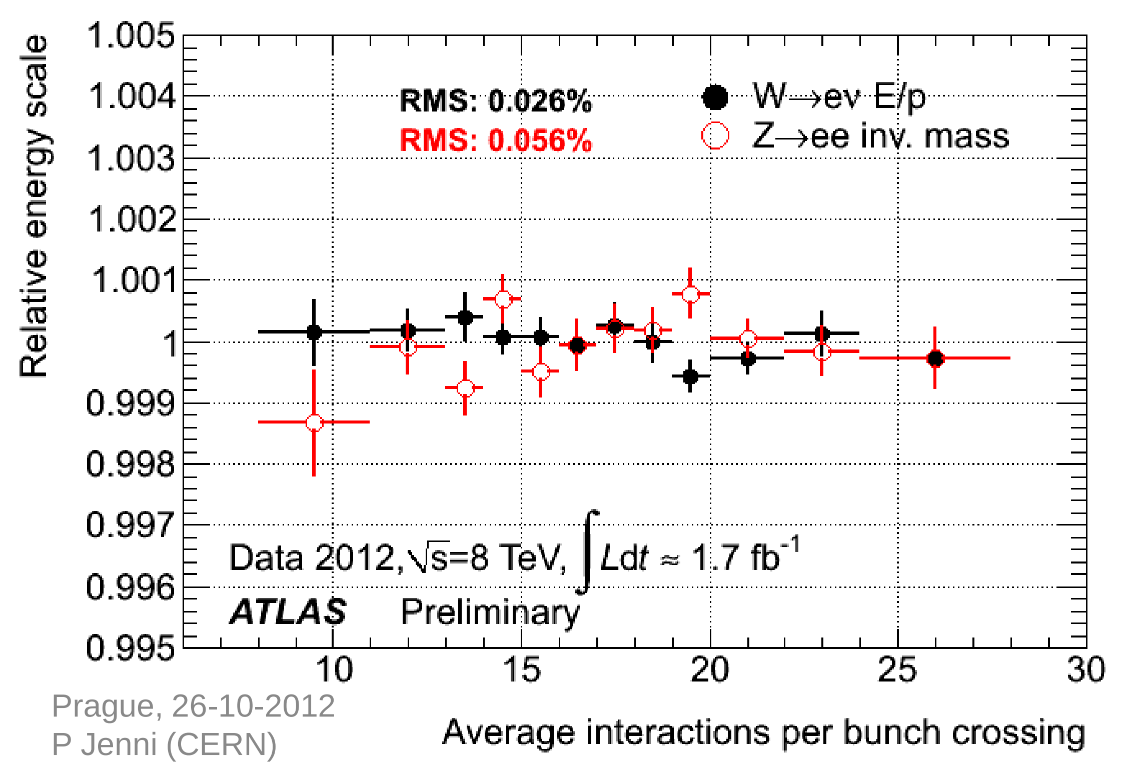
Phys Rev D85 (2012) 072004

Example: W and Z as a 'tool' to assure the performance of the detector

vs time over the full 2011 run



vs pile-up in 2012

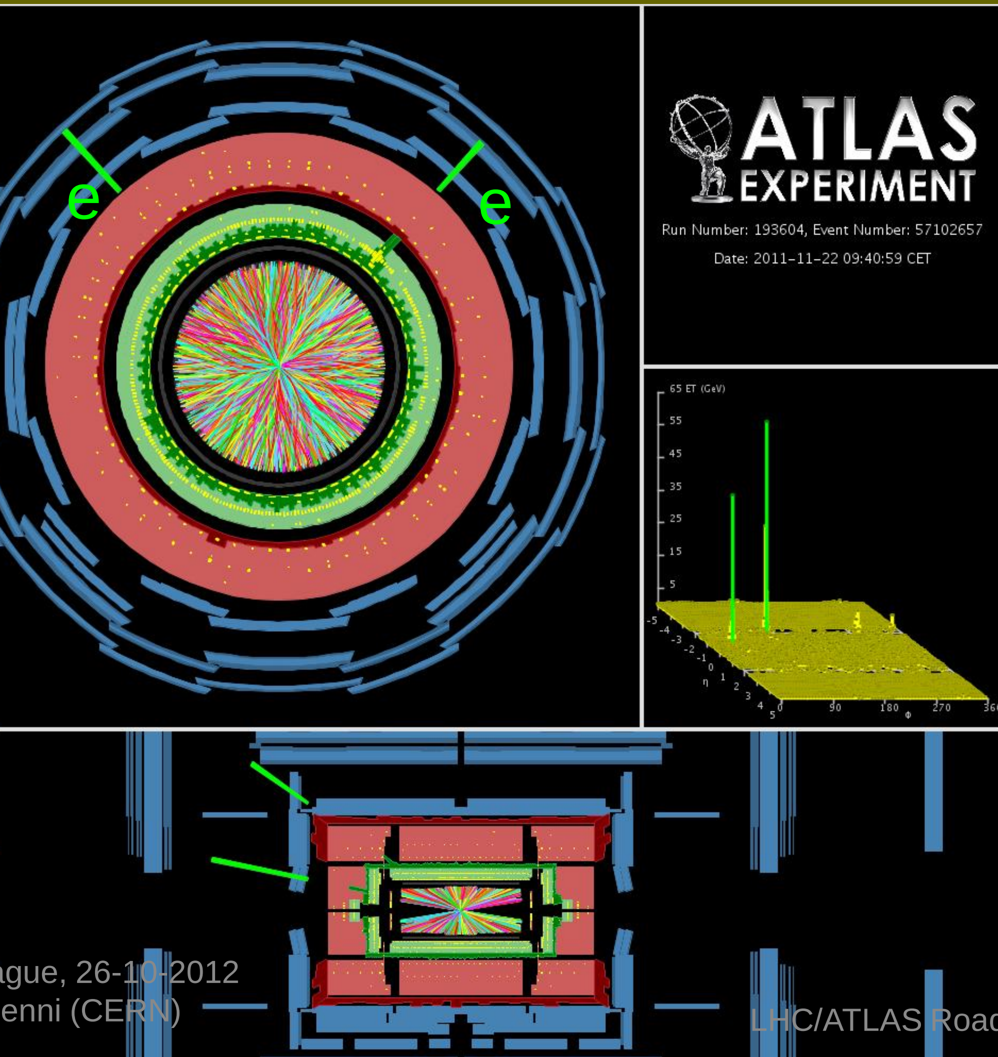


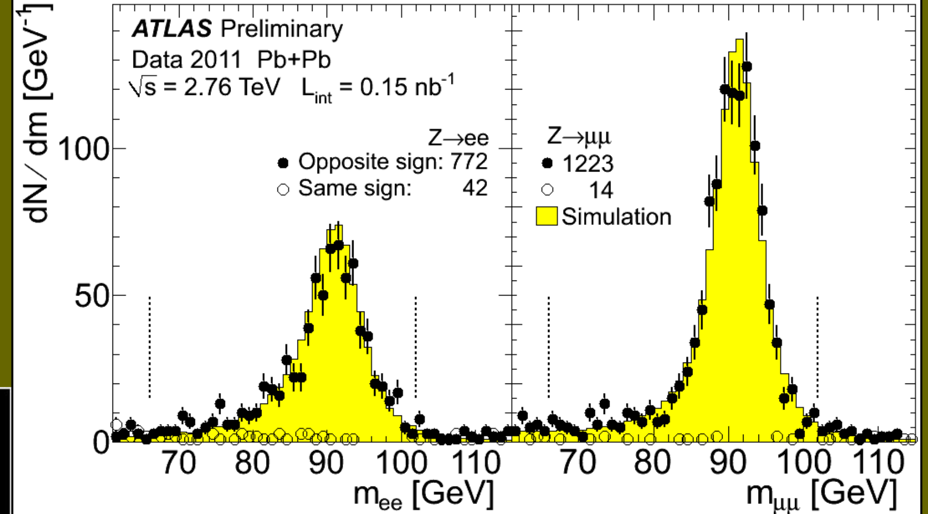
Stability of EM calorimeter E-scale: better than 0.1%

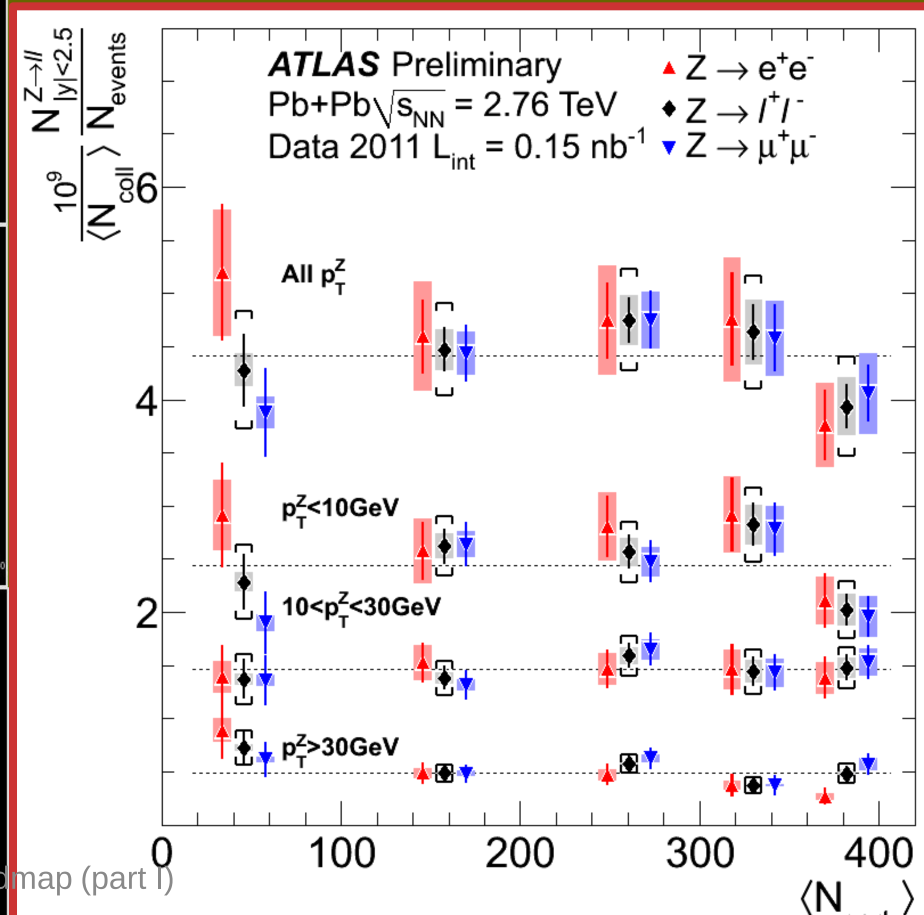
Z → ee, μμ in Heavy Ions

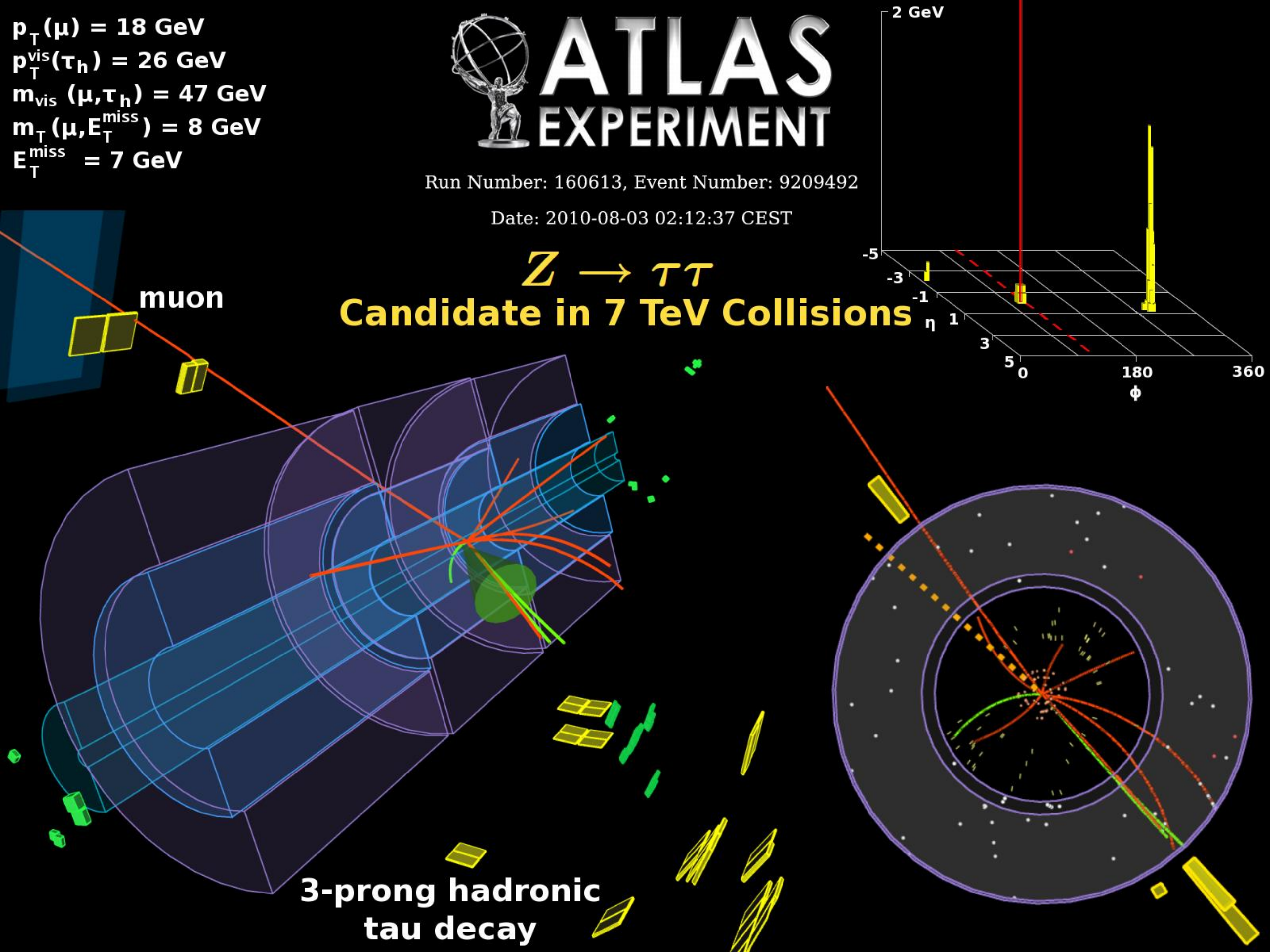
- Studied with full 2011 dataset (~ 150 μb^{-1})
- As expected: no suppression observed of the weakly interacting bosons

ATLAS-CONF-2012-119





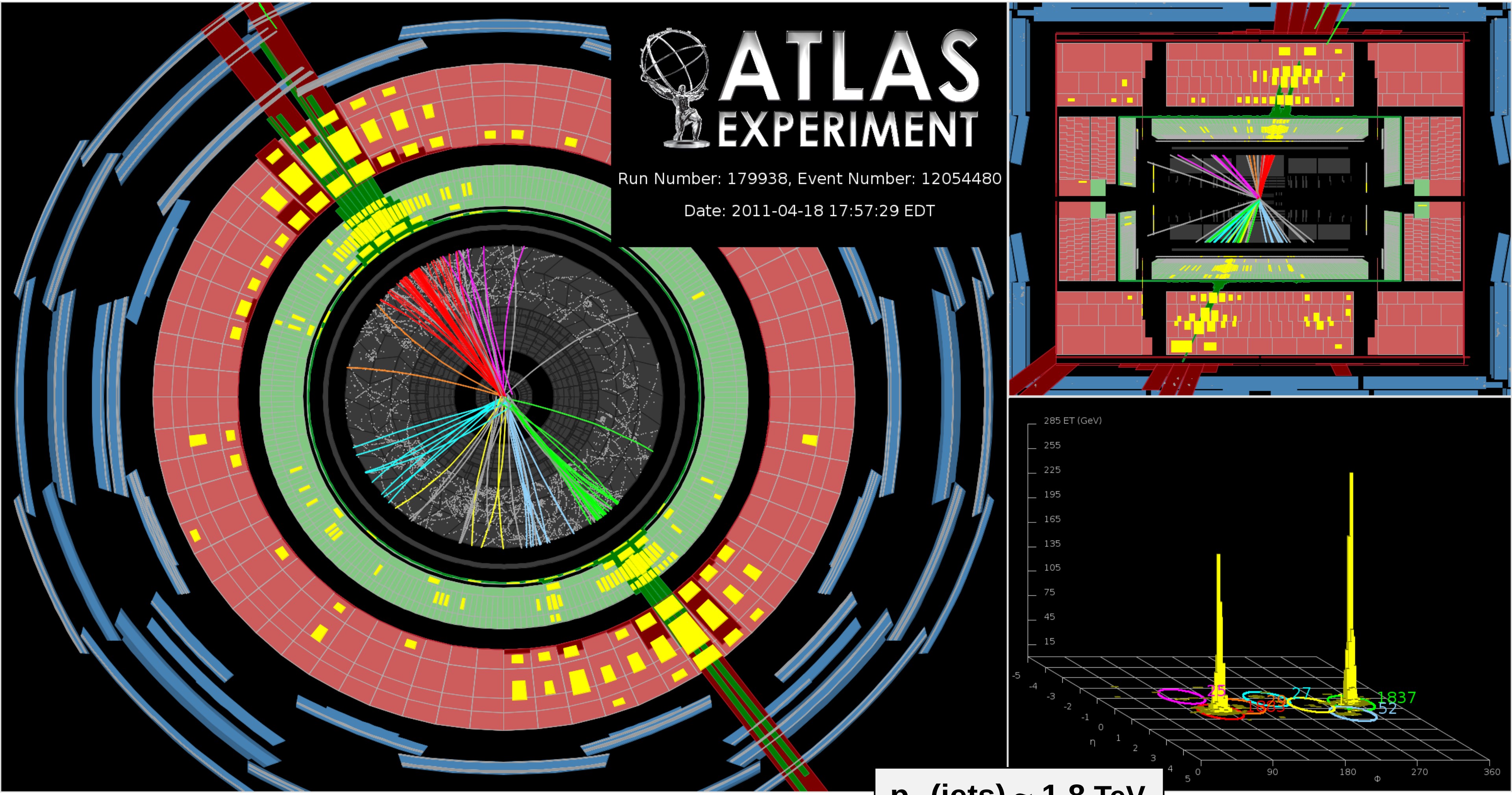




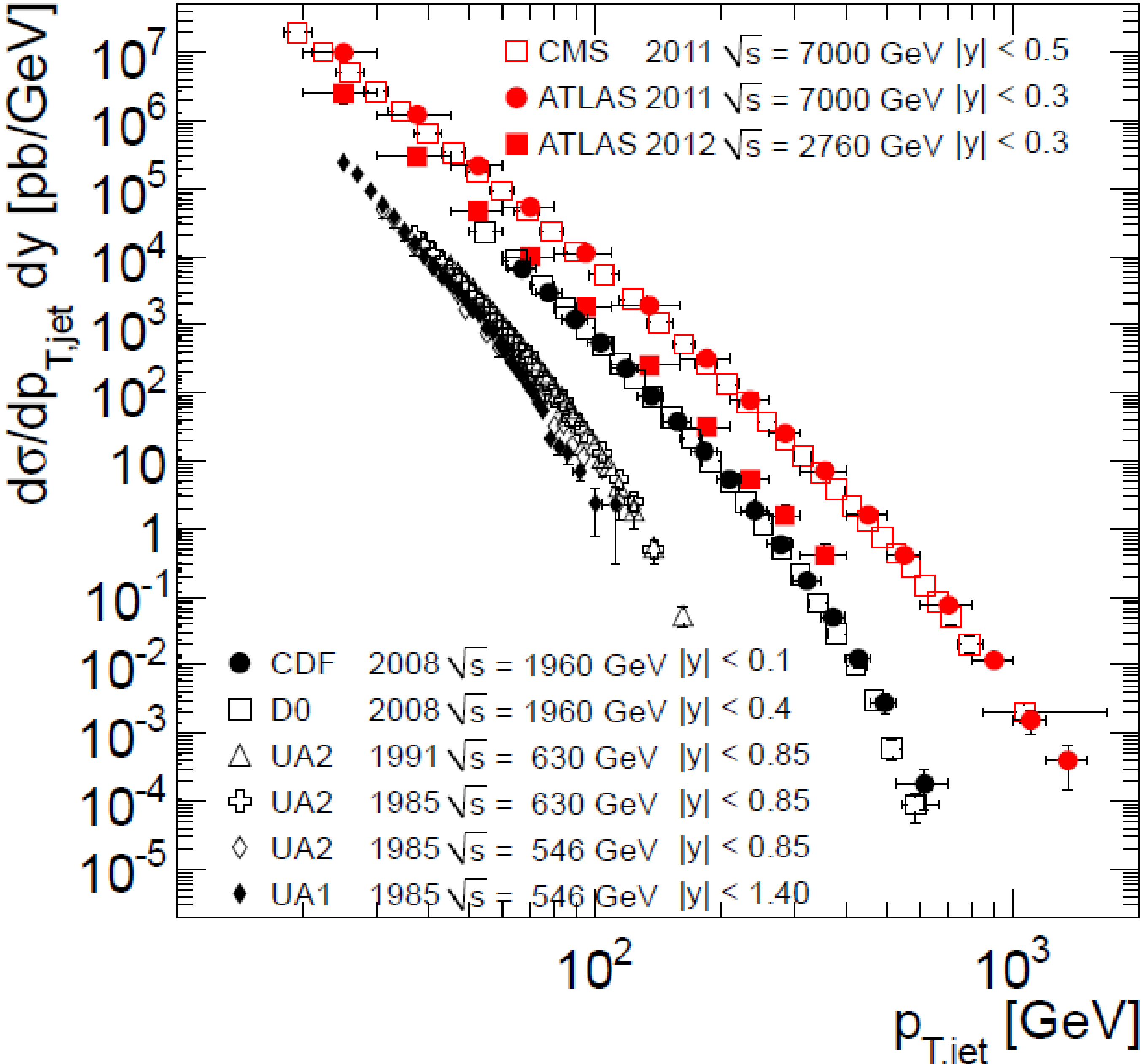
$p_T(\mu)$ = 18 GeV
$p_T^{vis}(\tau_h)$ = 26 GeV
$m_{vis}(\mu,\tau_h)$ = 47 GeV
$m_T(\mu,E_T^{miss})$ = 8 GeV
E_T^{miss} = 7 GeV
ATLAS EXPERIMENT
Run Number: 160613, Event Number: 9209492
Date: 2010-08-03 02:12:37 CEST
$Z \rightarrow \tau\tau$
Candidate in 7 TeV Collisions
muon
3-prong hadronic tau decay
2 GeV
-5
-3
-1
1
3
5
η
0
180
360
φ

Jet physics

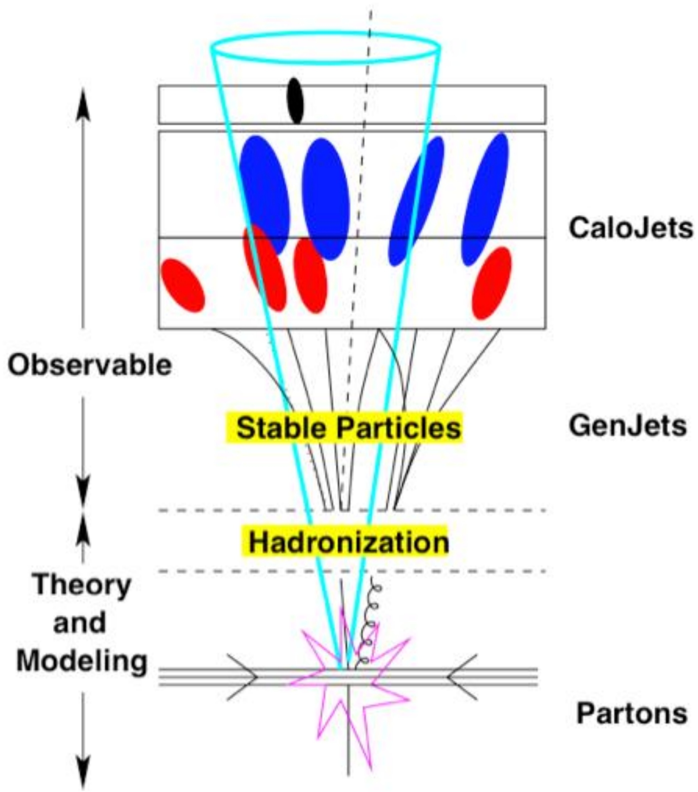
One of the most spectacular dijet events: M_{jj} ~ 4 TeV



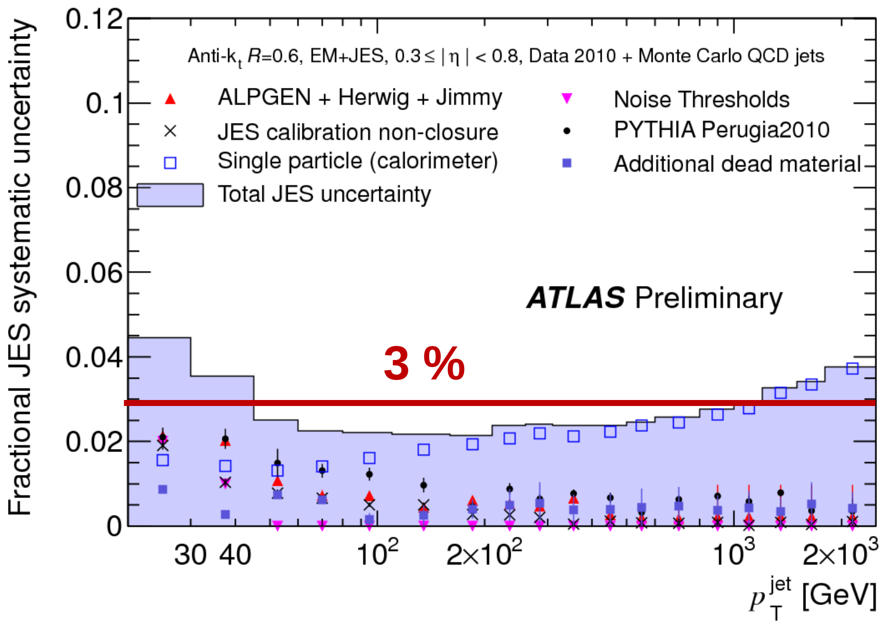
p_T (jets) ~ 1.8 TeV

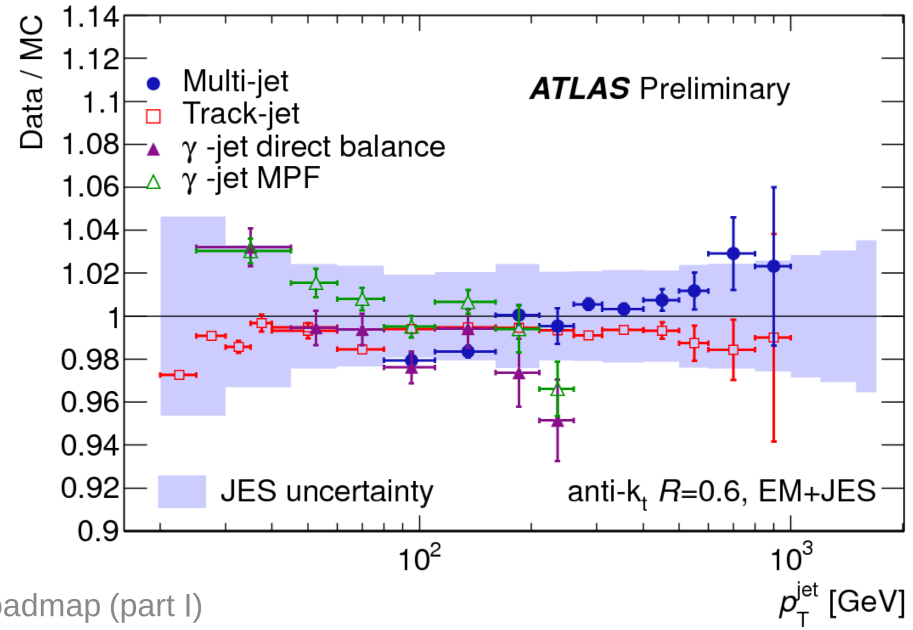

CMS 2011 √s = 7000 GeV |y| < 0.5
ATLAS 2011 √s = 7000 GeV |y| < 0.3
ATLAS 2012 √s = 2760 GeV |y| < 0.3
CDF 2008 √s = 1960 GeV |y| < 0.1
D0 2008 √s = 1960 GeV |y| < 0.4
UA2 1991 √s = 630 GeV |y| < 0.85
UA2 1985 √s = 630 GeV |y| < 0.85
UA2 1985 √s = 546 GeV |y| < 0.85
UA1 1985 √s = 546 GeV |y| < 1.40
dσ/dp_T,jet dy [pb/GeV]
p_T,jet [GeV]

A considerable effort went into understanding the Jet Energy Scale (JES), the dominant source of uncertainties for most jet measurements



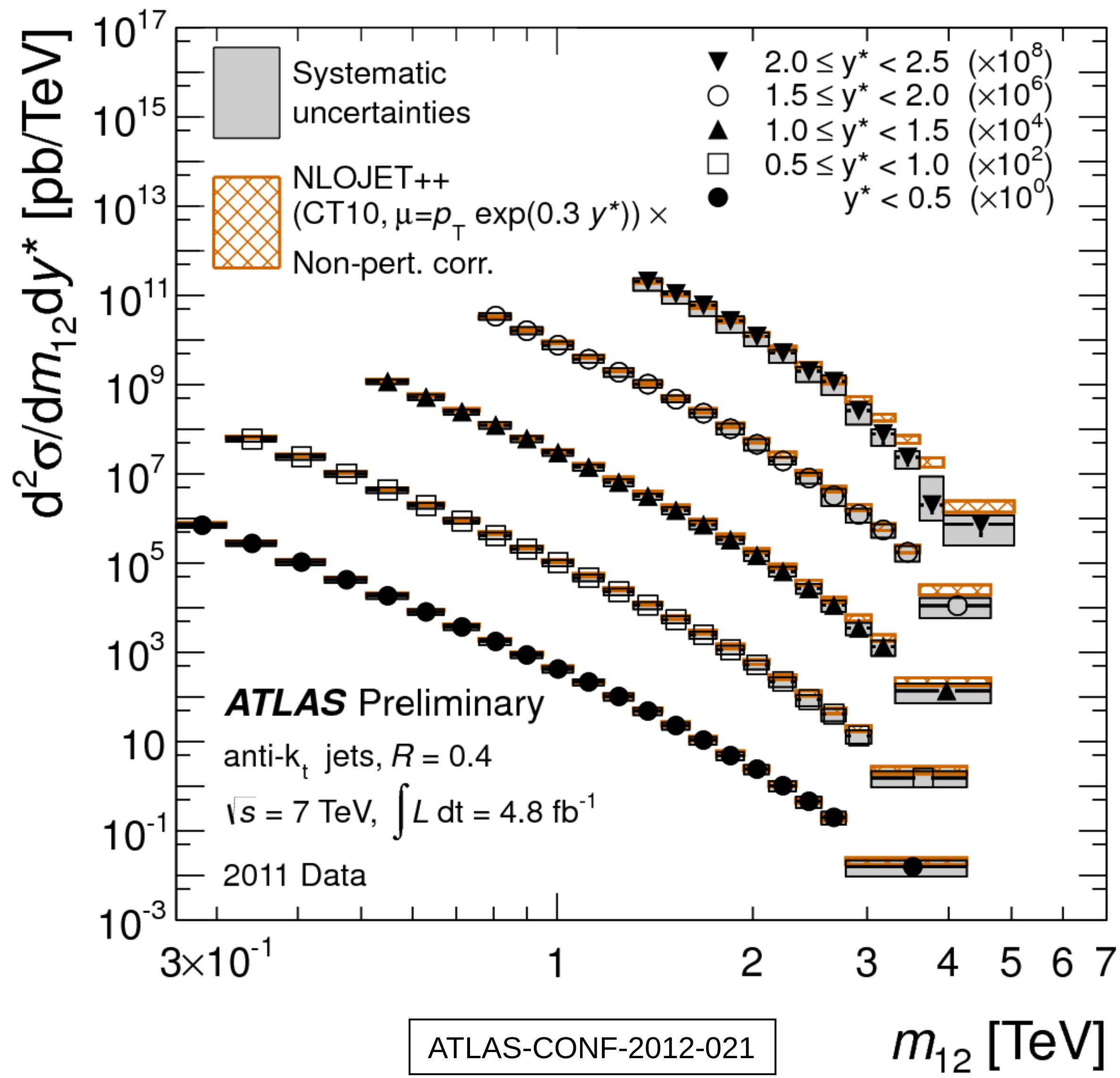
ATLAS-CONF-2011-032 and arXiv:1112.6426v1[hep-ex]





Very detailed jet measurements are now available from LHC that can be compared with QCD calculations …

Example:
The inclusive di-jet cross sections as a function of the di-jet mass for various rapidity separations



ATLAS-CONF-2012-021

The data are spanning jets over a large phase space:

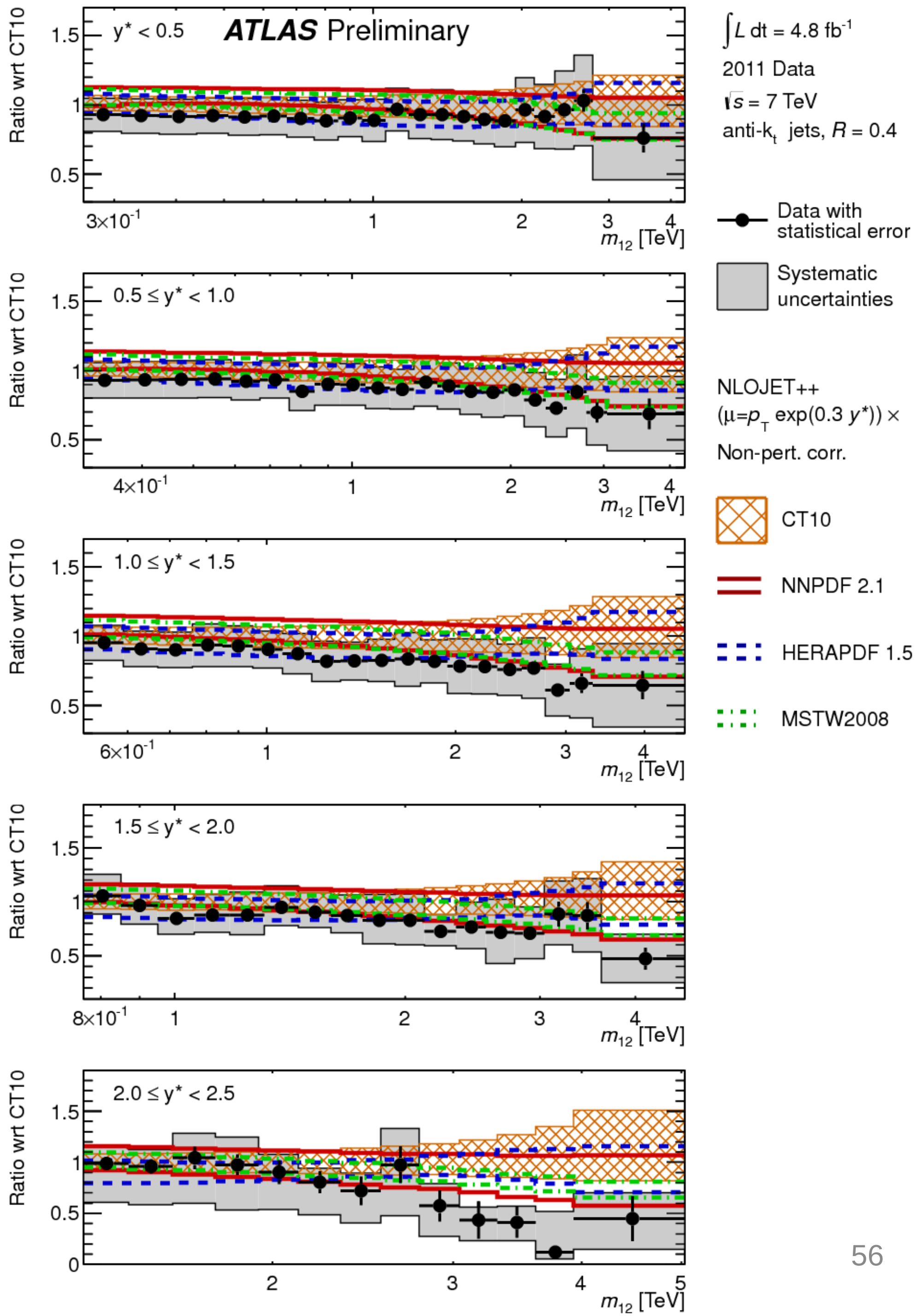
- **20 GeV < p_T < 2 TeV**
- **|η| < 4.4**

($y^* = 0.5\,|\eta_1 - \eta_2|$)

Systematic uncertainty dominated by JES

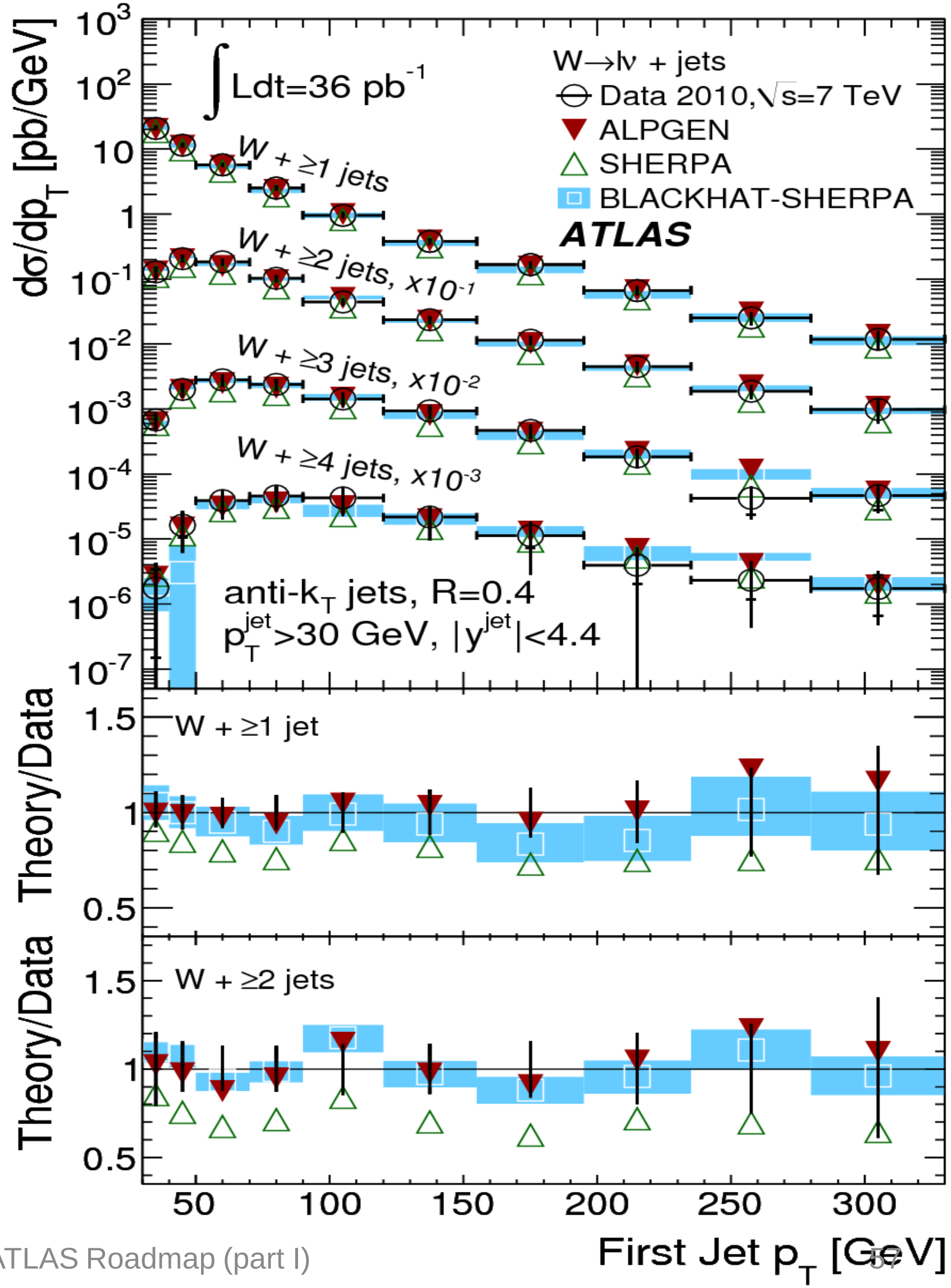
Good agreement between data and NLO pQCD with various PDFs globally…

ATLAS-CONF-2012-021



W + jet(s) production

Both an interesting QCD measurement as well as a dominant background to many searches

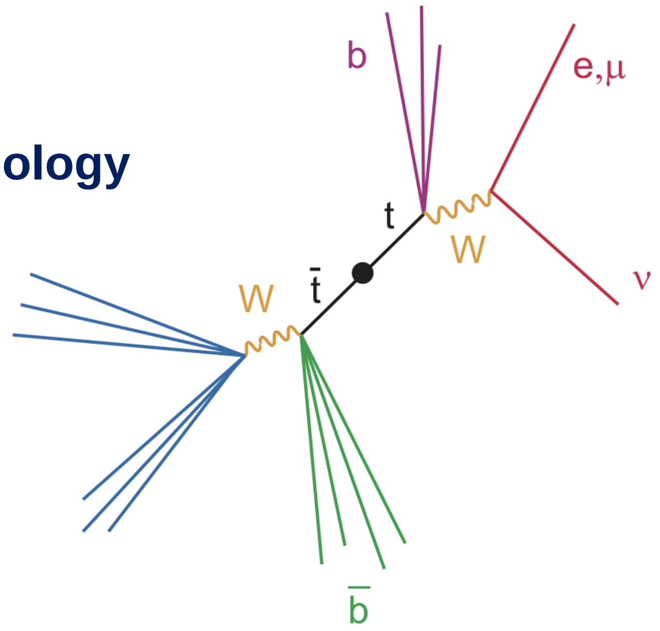


Phys. Rev. D85 (2012) 092002

Top measurements

- Complete set of ingredients to investigate production of ttbar, which is the next step in verifying the SM at the LHC:
  - e, μ, E_T^{miss}, jets, b-tag

- Assume all tops decay to Wb: event topology then depends on the W decays:

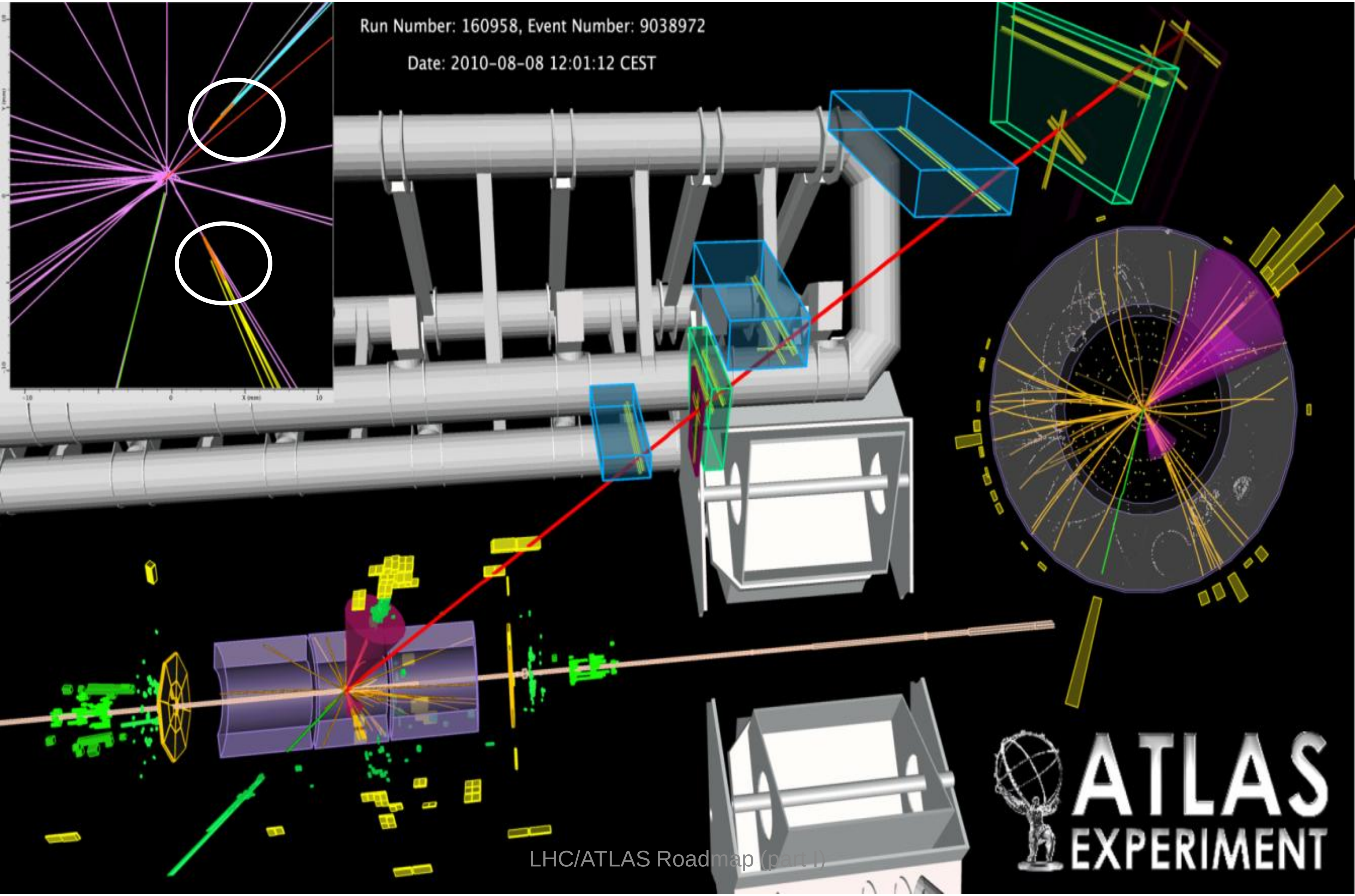


  - one lepton (e or μ), E_T^{miss}, jjbb (37.9%)
  - di-lepton (ee, μμ or eμ), E_T^{miss}, bb (6.46%)

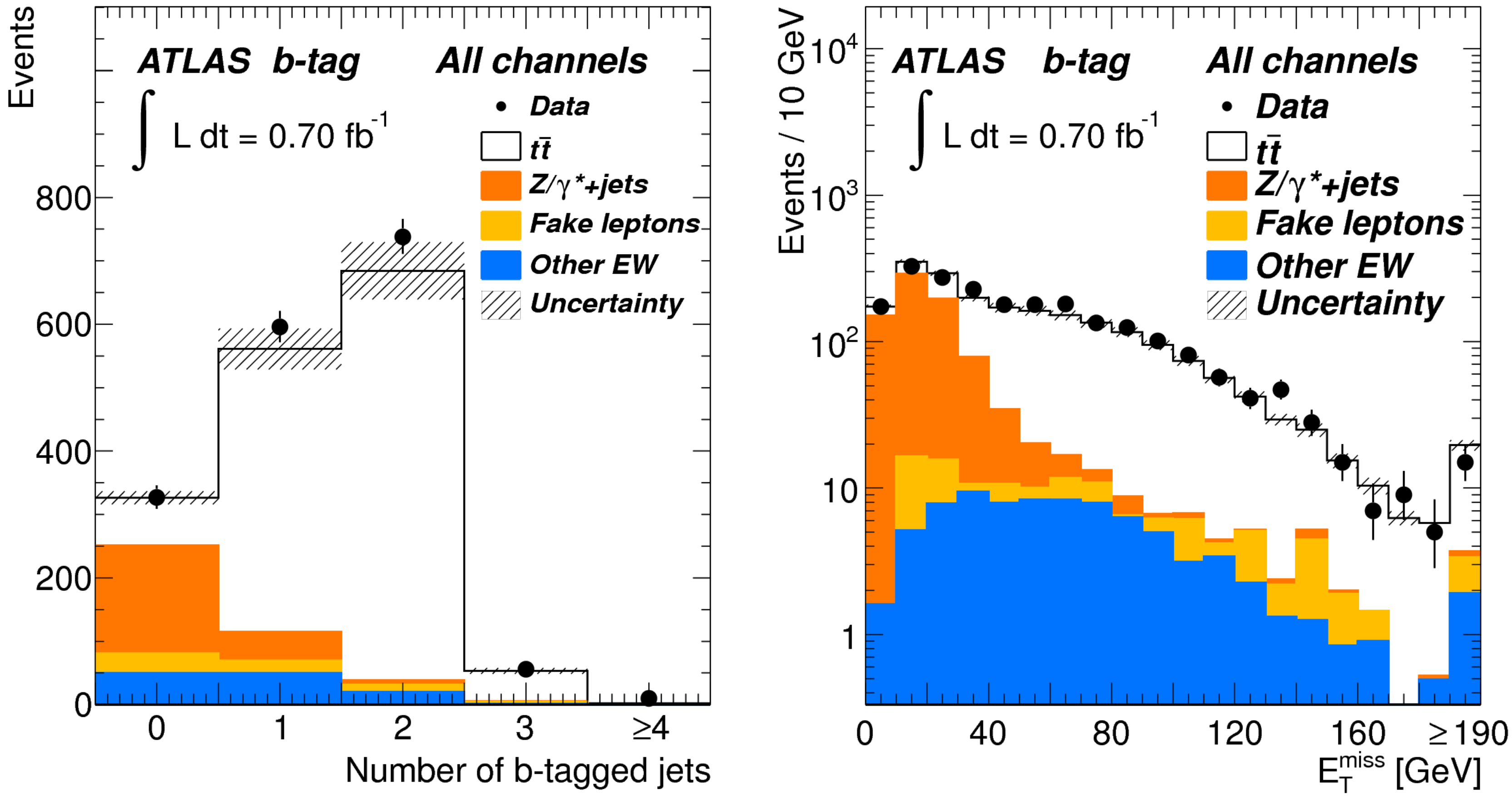
- Data-driven methods to control QCD and W+jets backgrounds

$t\bar{t}$ candidate event

e + μ + 2 jets (b-tagged) +ETmiss

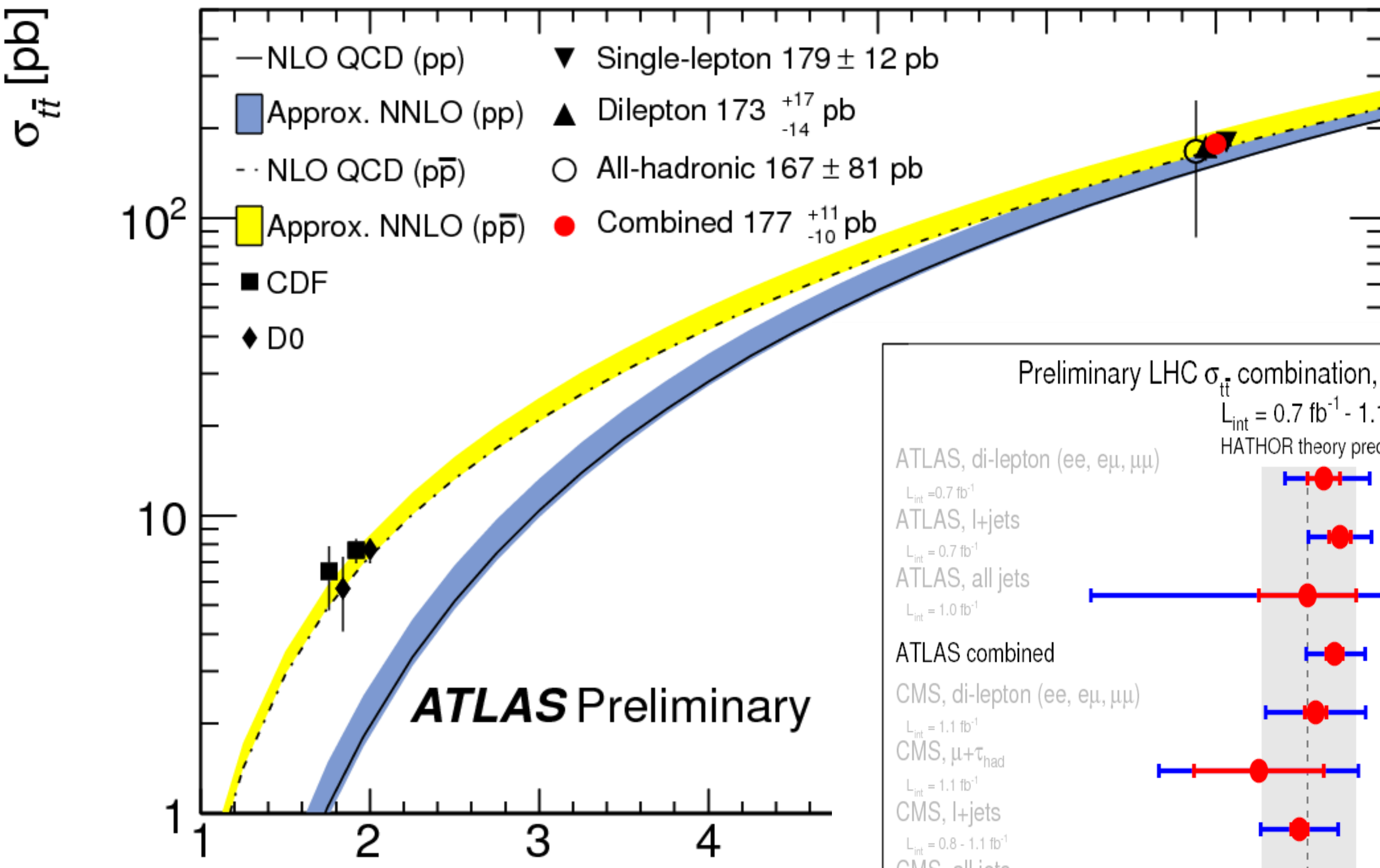


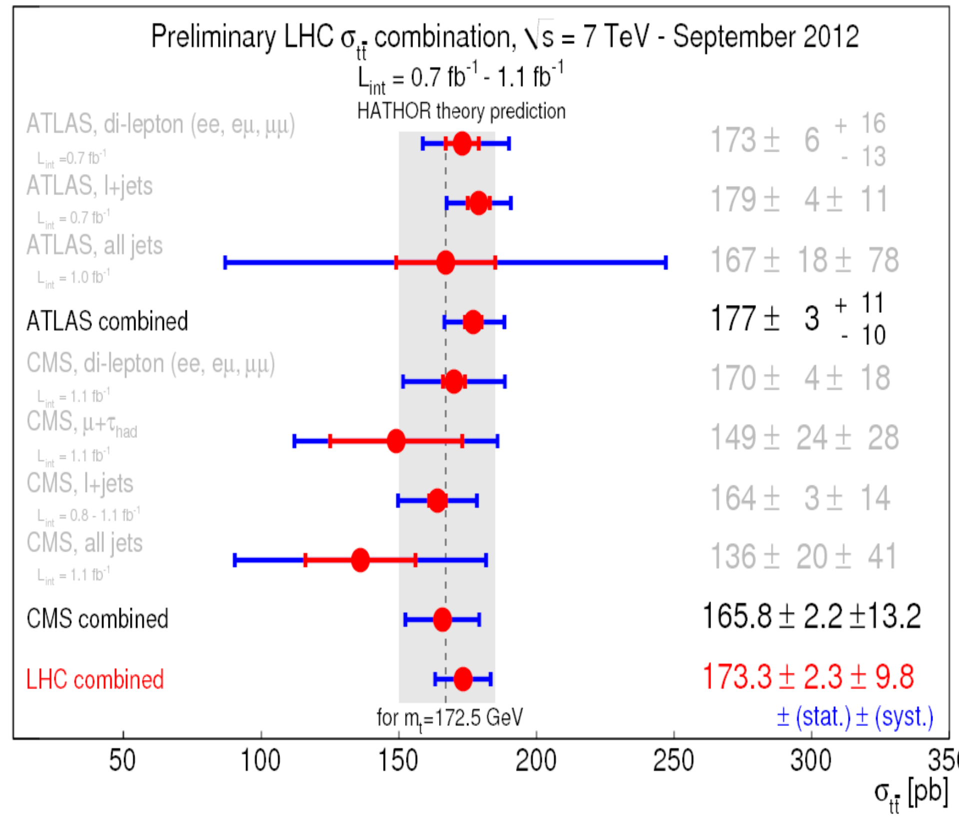
Example of top signals in the case of di-lepton channels



JHEP 1205 (2012) 059

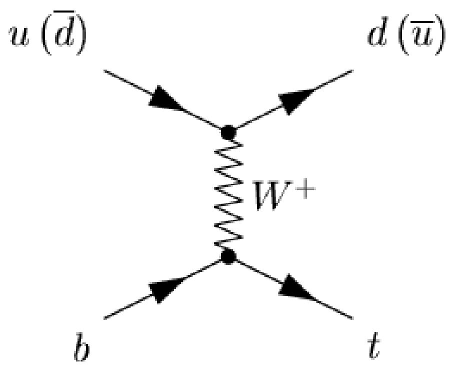
ATLAS-CONF-2012-024

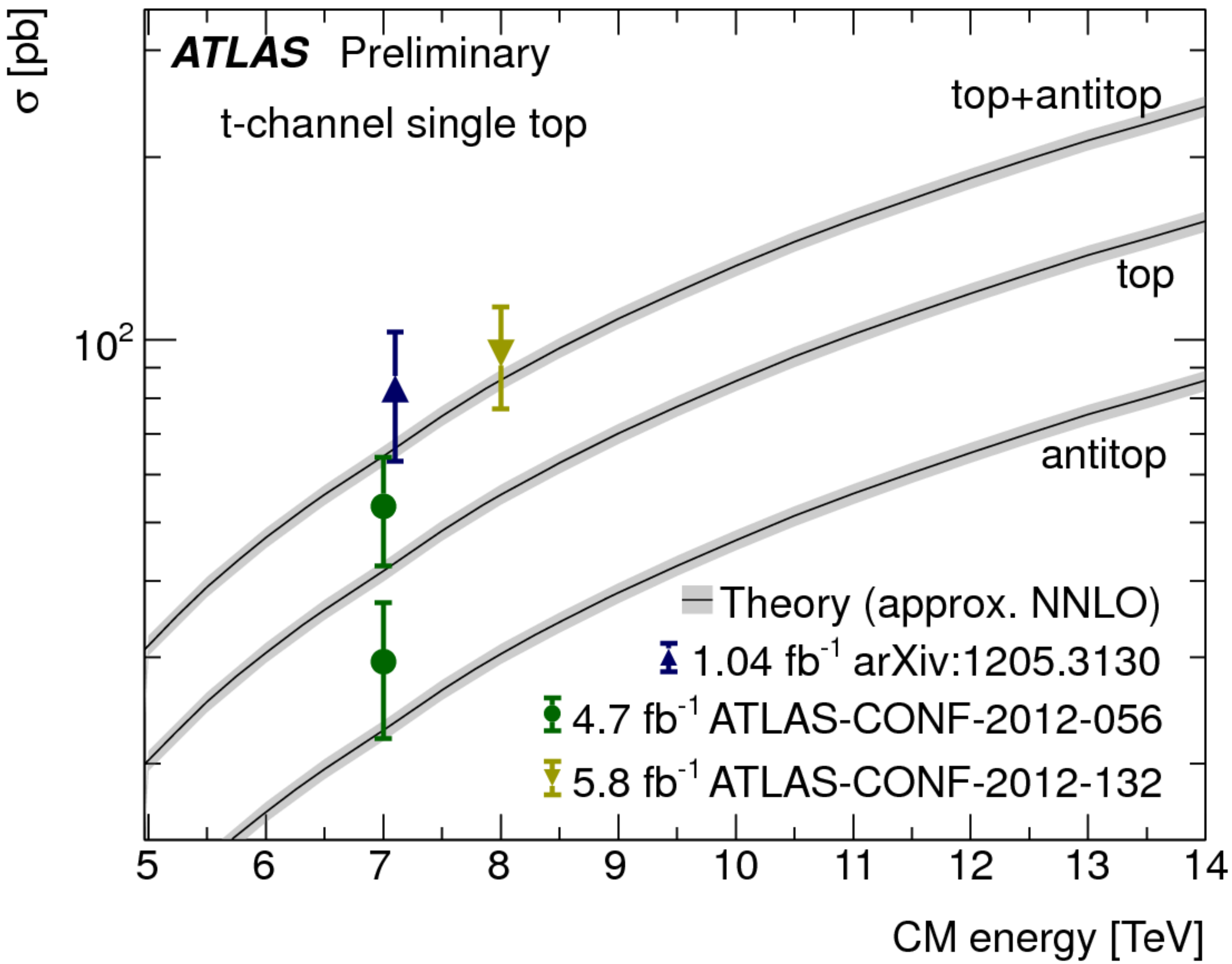


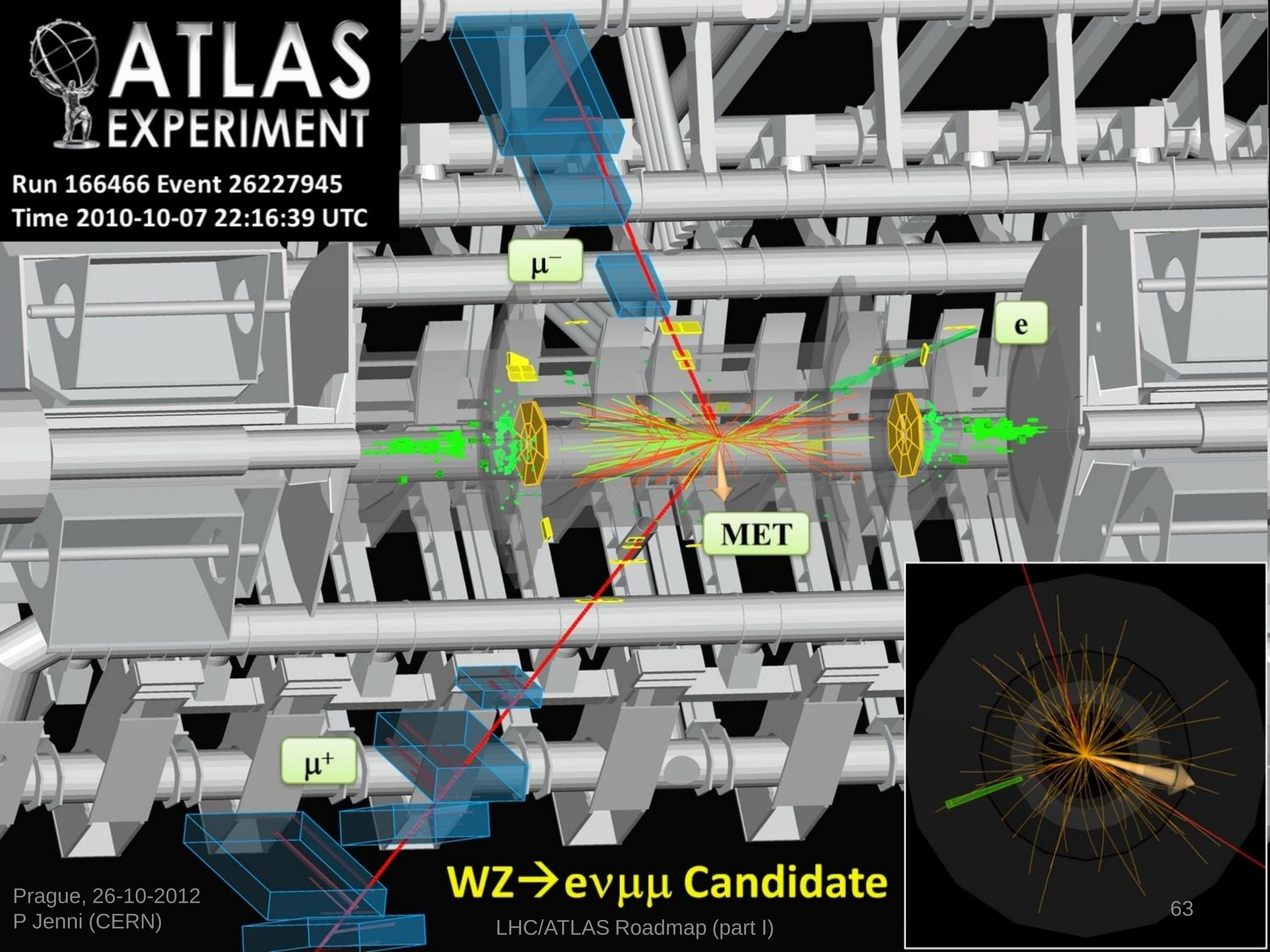


$t\bar{t}$ pair production cross-sections

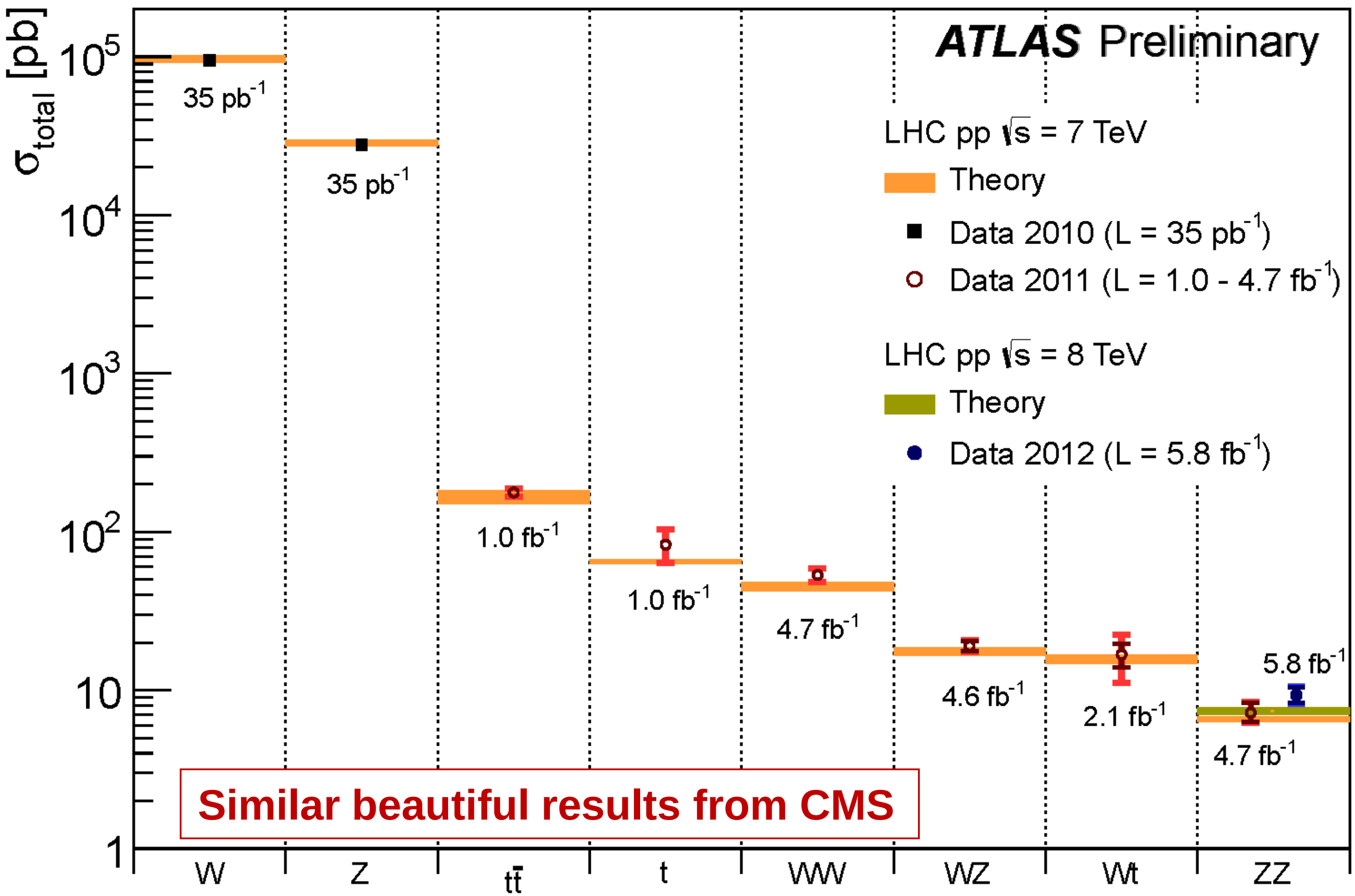
Single Top production






ATLAS EXPERIMENT
Run 166466 Event 26227945
Time 2010-10-07 22:16:39 UTC
μ^-
e
MET
μ^+
WZ→eνμμ Candidate

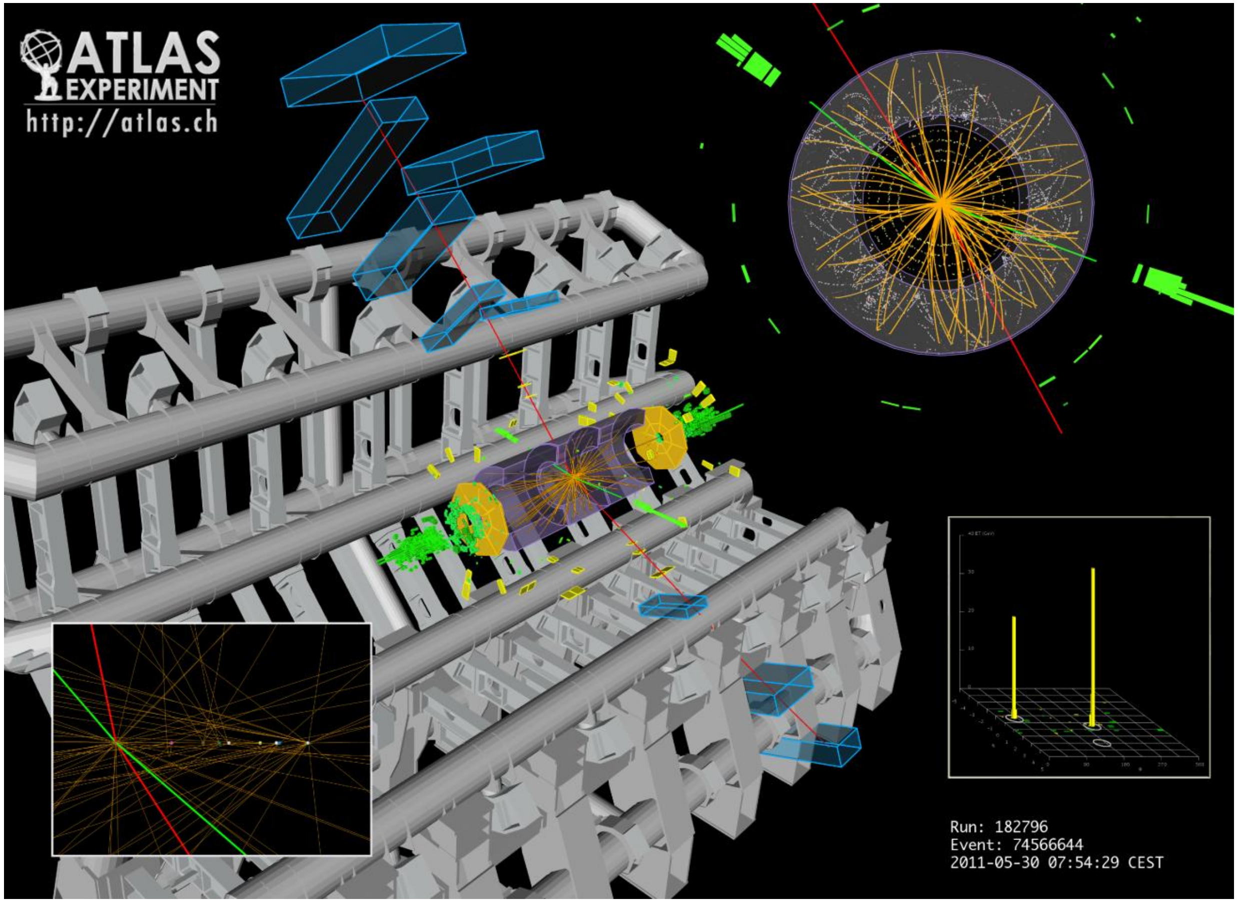
A summary of Standard Model measurements



The excellent performance in measuring Standard Model physics gives confidence for the readiness of the two experiments to search for New Physics

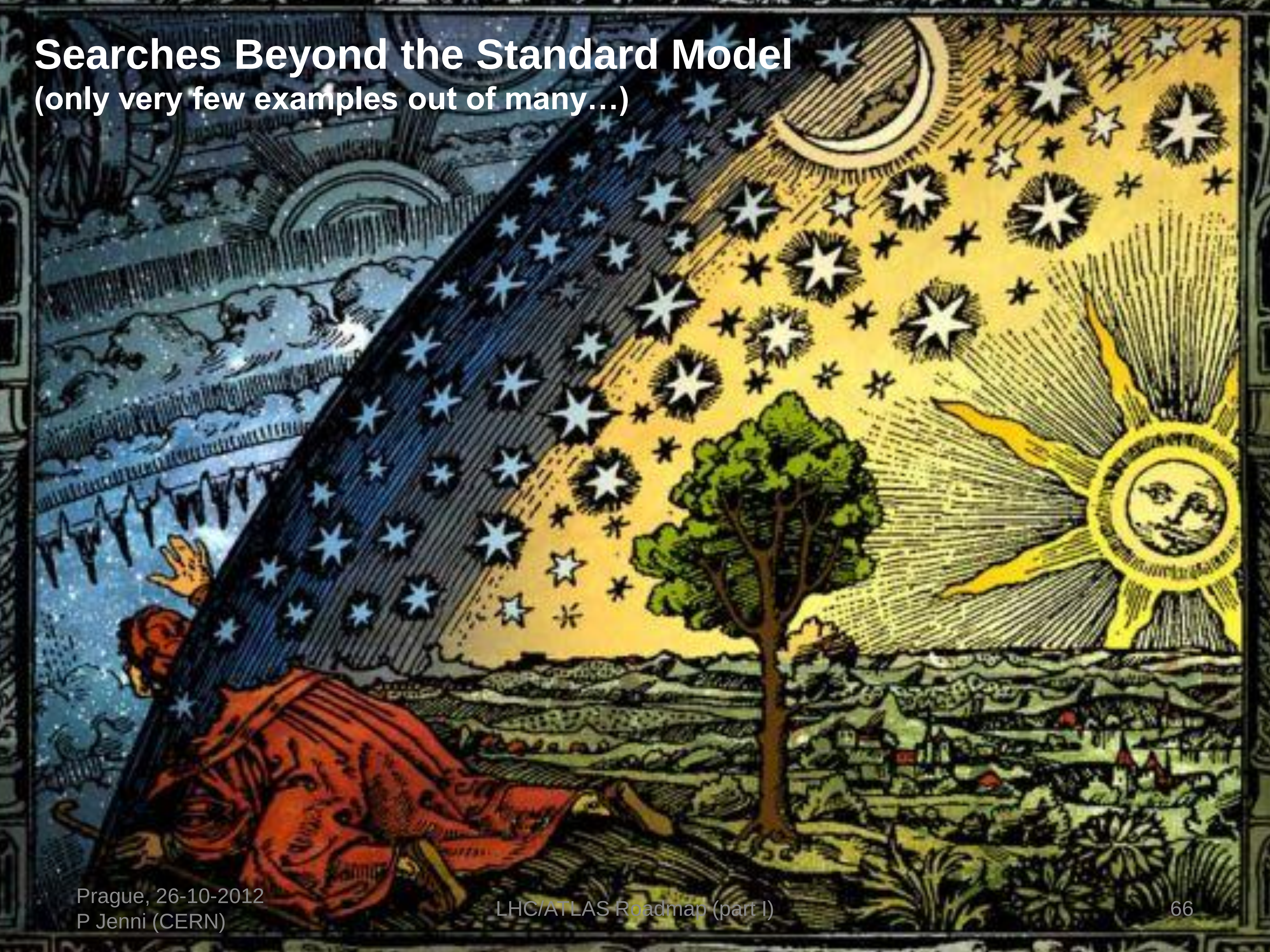
We are in the year of the Dragon…

Candidate for a 124.5 GeV mass $H \to \mu\mu$ ee event in ATLAS



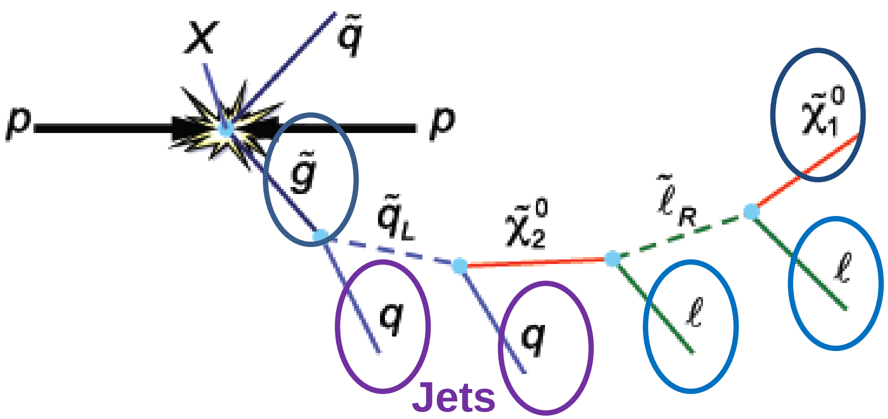
… but it will also become the one of the Higgs Boson as Fabiola Gianotti will tell in the next talk !

Searches Beyond the Standard Model
(only very few examples out of many…)

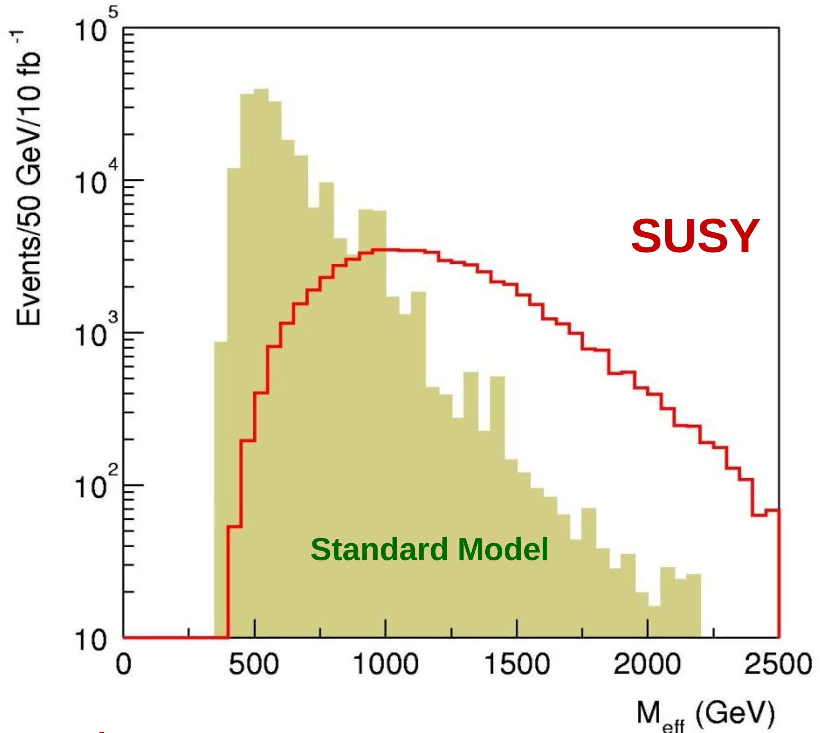


In practice SUSY searches at LHC are rather complicated

- Complex (and model-dependent) squark/gluino cascades



- Focus on signatures covering large classes of models while strongly rejecting SM background
  - large missing E_T
  - High transverse momentum jets
  - Leptons
    - Perform separate analyses with and without lepton veto (0-lepton / 1-lepton / 2-leptons)
  - B-jets: to enhance sensitivity to third-generation squarks
  - Photons: typically for models with the gravitino as LSP



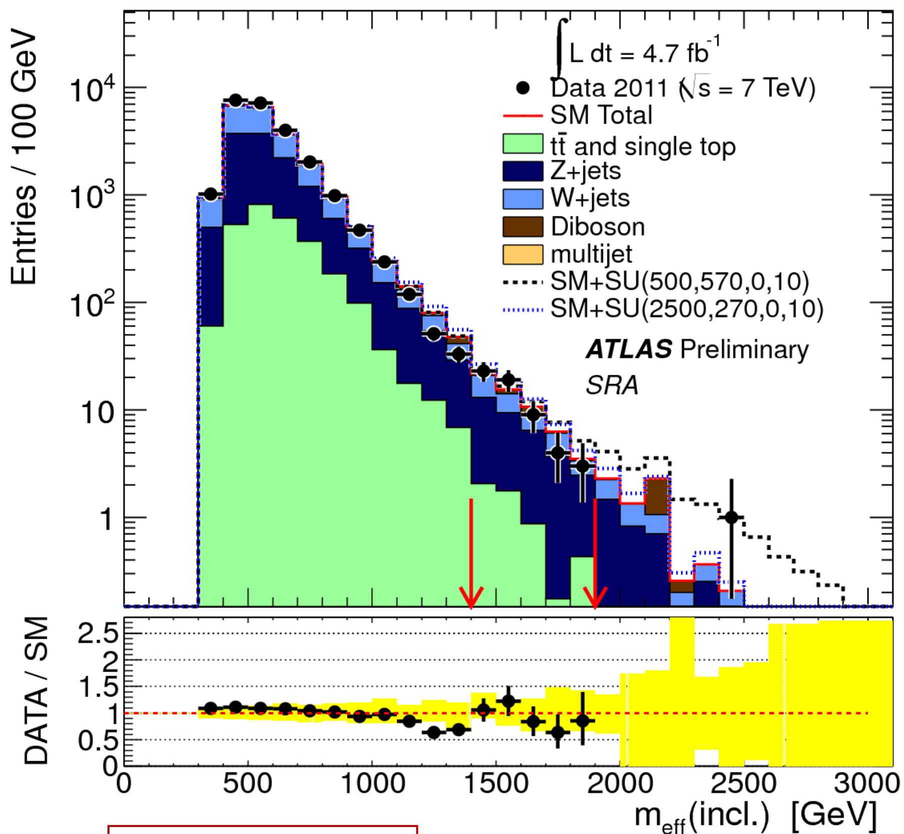
Meff = Etmiss + Σ pT(jets)

Analyses re-optimized and updated with full 2011 Luminosity

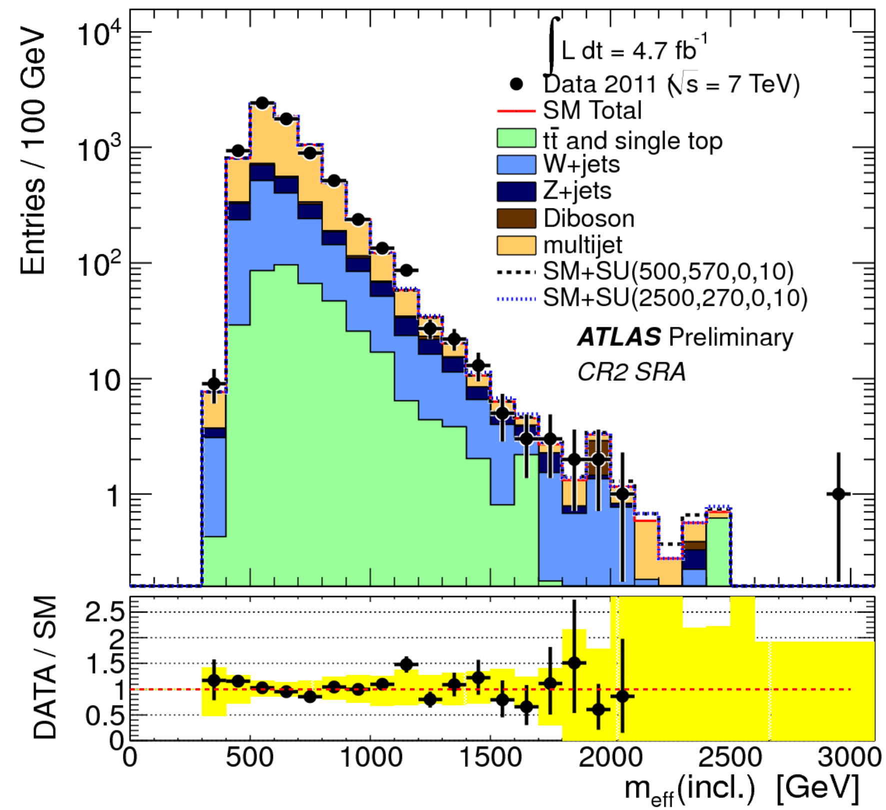
- **0-lepton + 2−6 jets + high MET (based on Et-miss+jet triggers)**
- **0-lepton + 6−9 (multi-)jets + MET (based on multi-jet triggers)**
- **1-lepton + 3,4 jets + high MET (based on lepton triggers)**

ATLAS-CONF-2012-033, 037, and 041

Example: O-leptons + 2-6 Jets analysis



A signal region

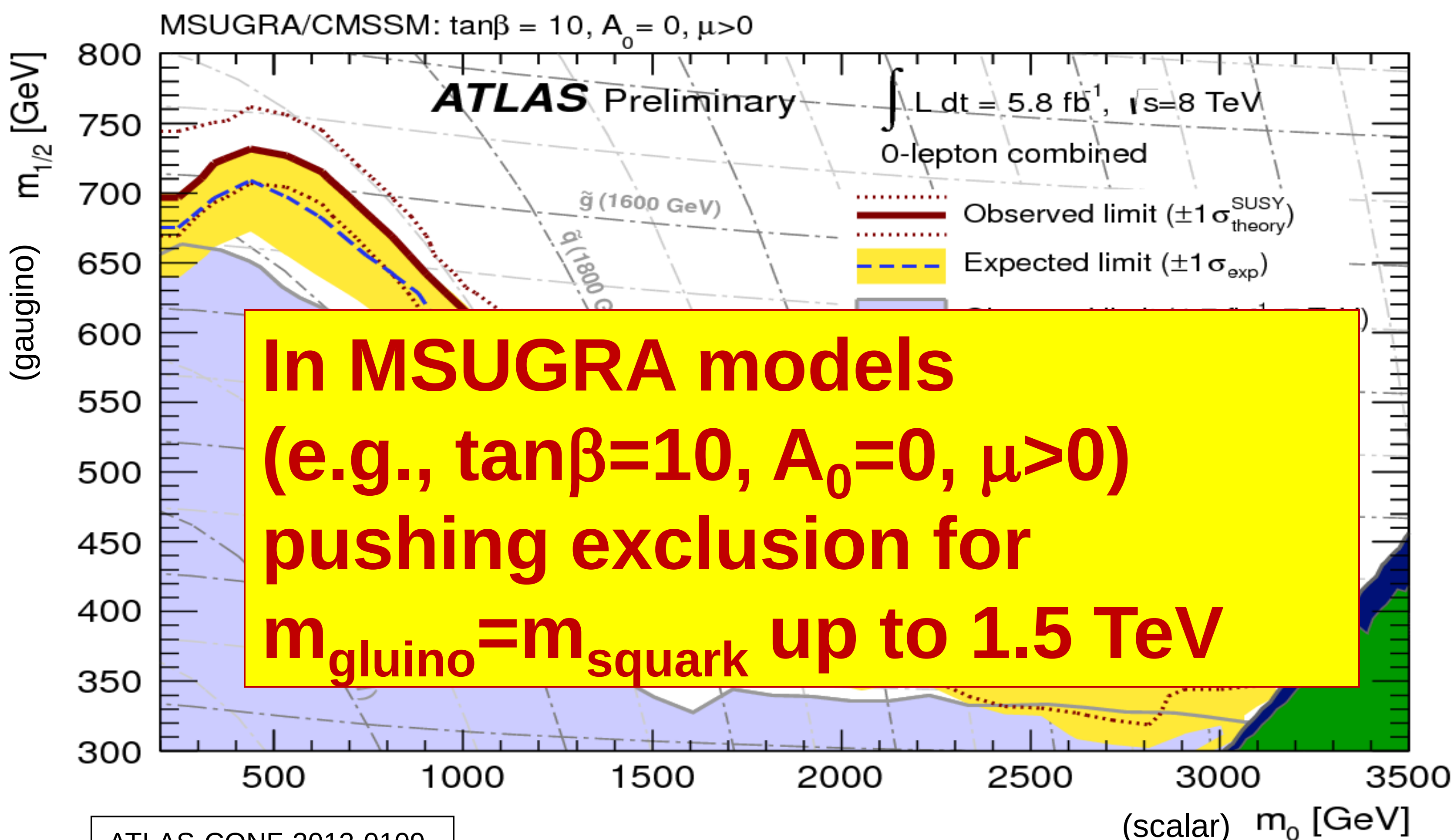


A control region where no signal is expected

Interpretation of the results (I)

A sophisticated likelihood method is used that includes correlations of uncertainties where appropriate

→Estimate upper limits at 95% C.L. on N signal events and effective cross sections independently of new physics models **(background-only hypothesis)**

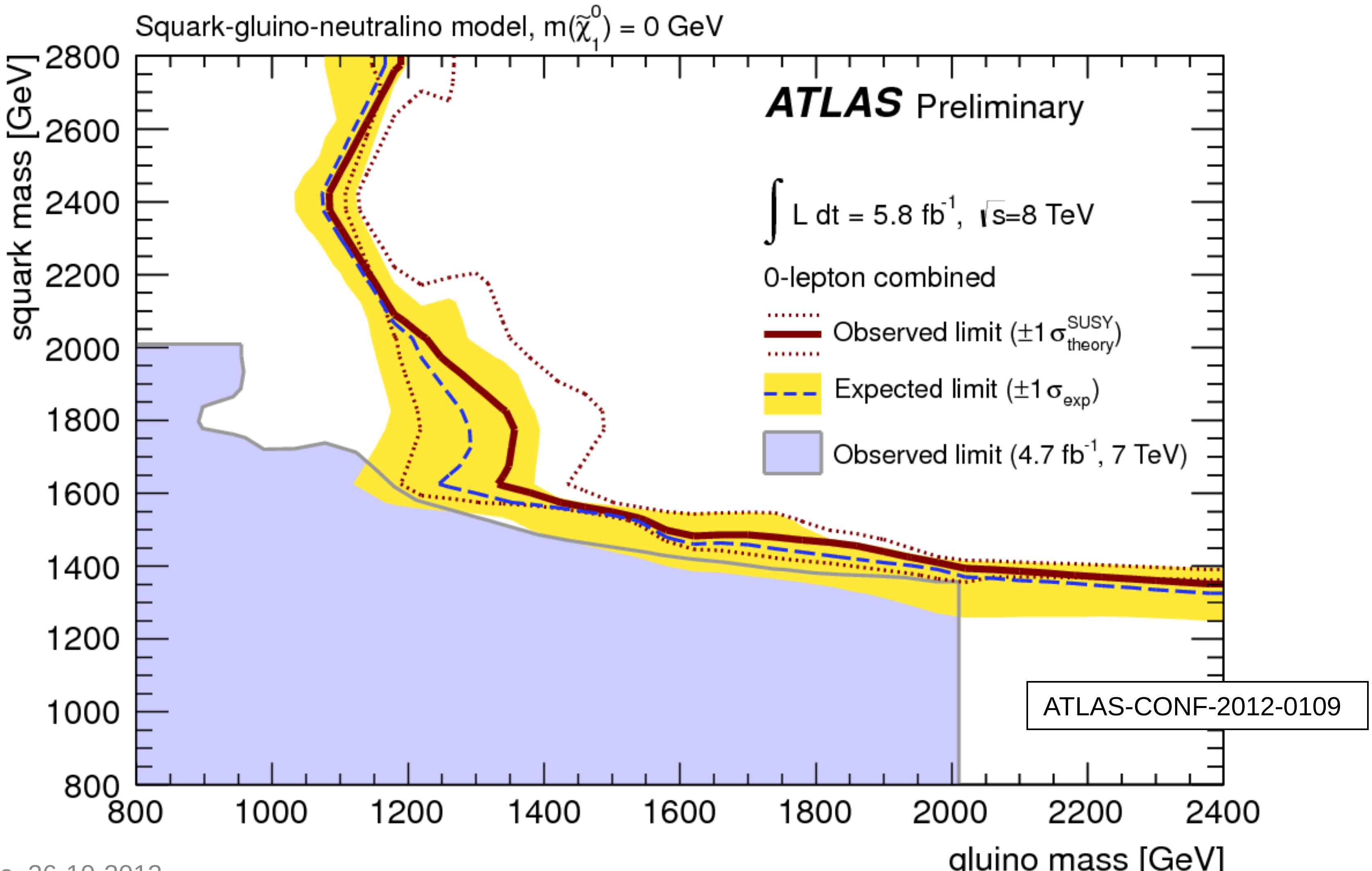


In MSUGRA models (e.g., $\tan\beta=10$, $A_0=0$, $\mu>0$) pushing exclusion for $m_{gluino}=m_{squark}$ up to 1.5 TeV

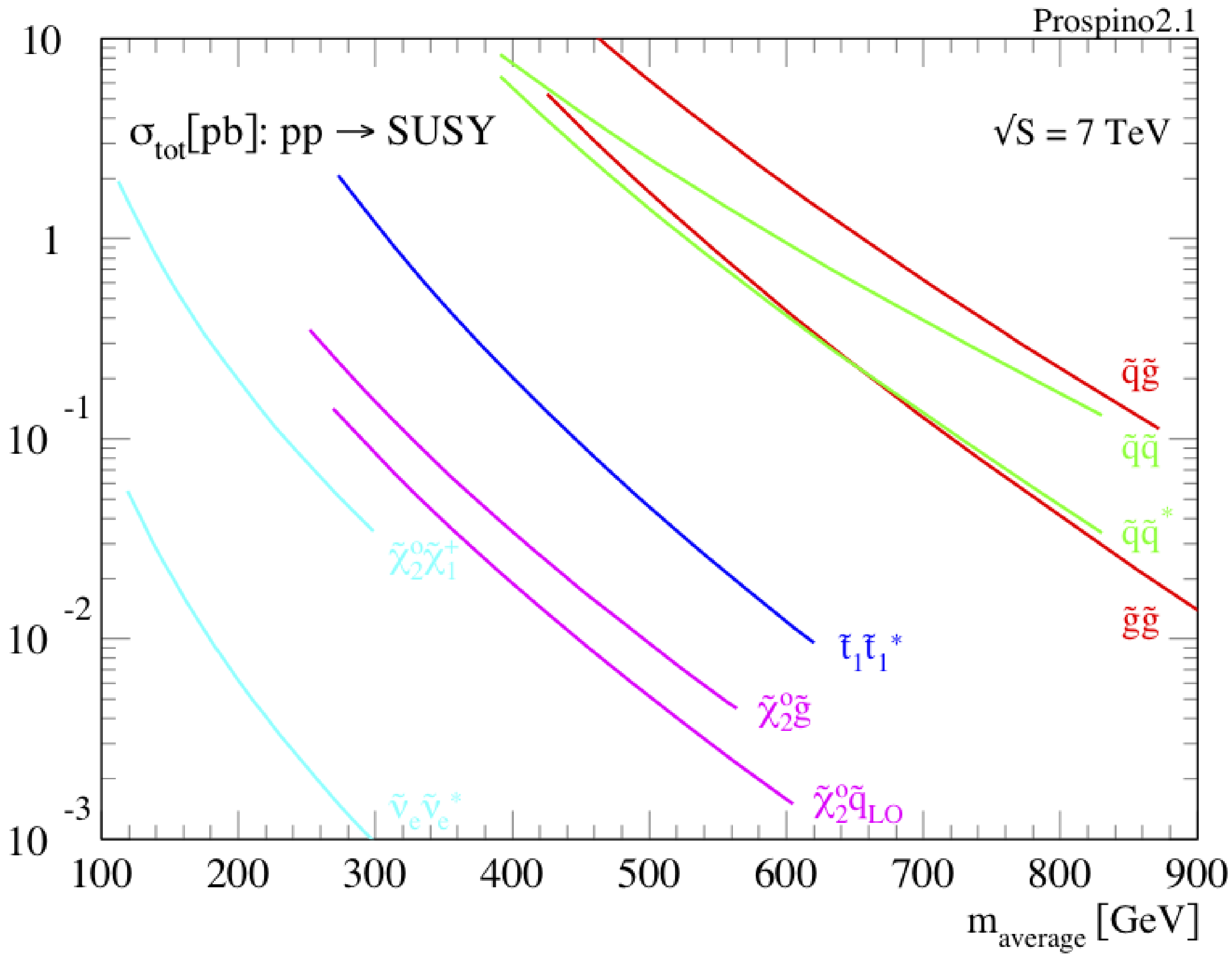
ATLAS-CONF-2012-0109

Interpretation of the results (II)

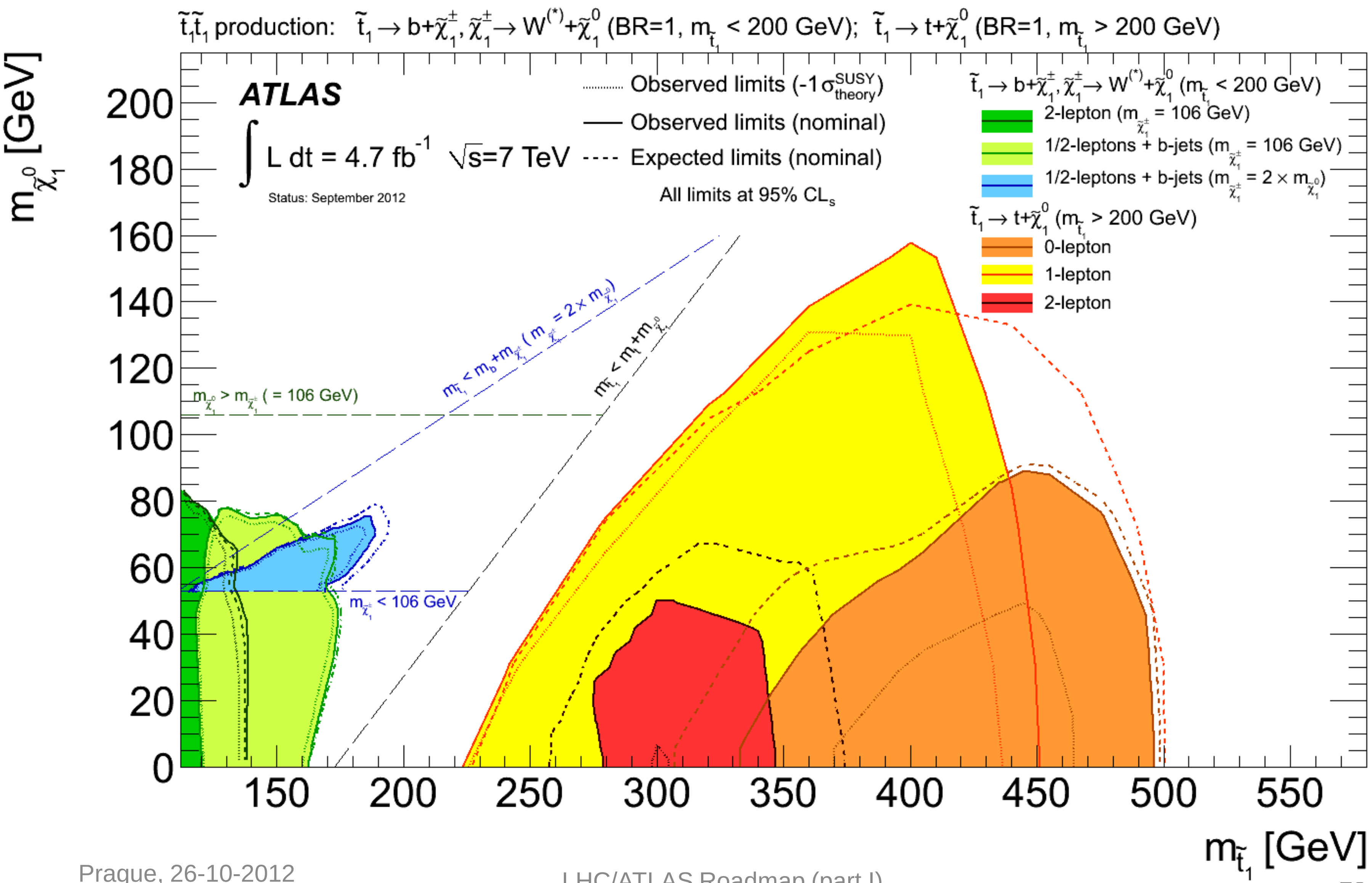
Consider phenomenological MSSM models containing only squarks of 1st and 2nd generation, gluino and light neutralinos



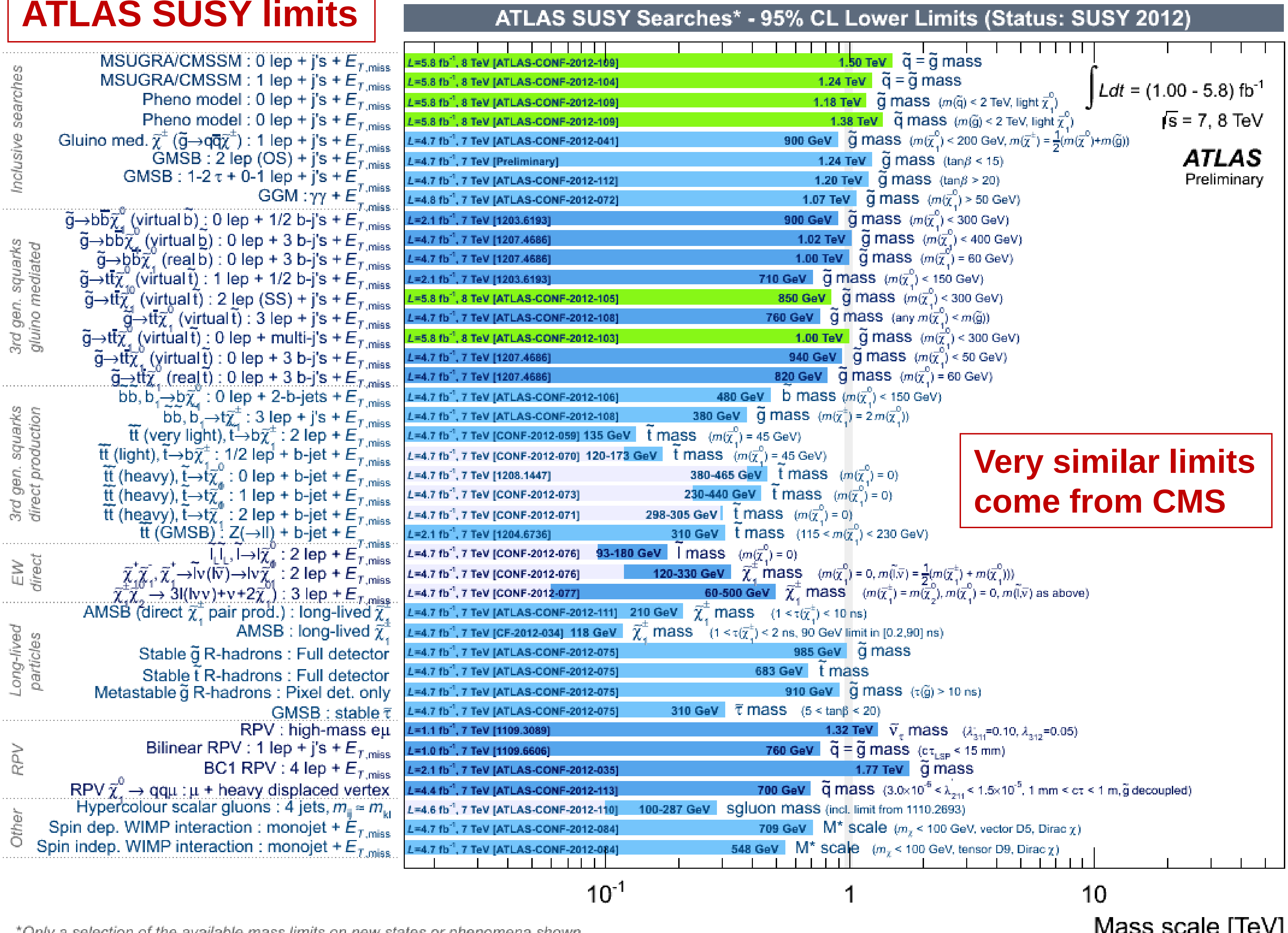
Expected production cross-sections at LHC



Summary of five dedicated searches for top squark pair production for theoretically preferred models with relatively light 3rd generation squarks



ATLAS SUSY limits



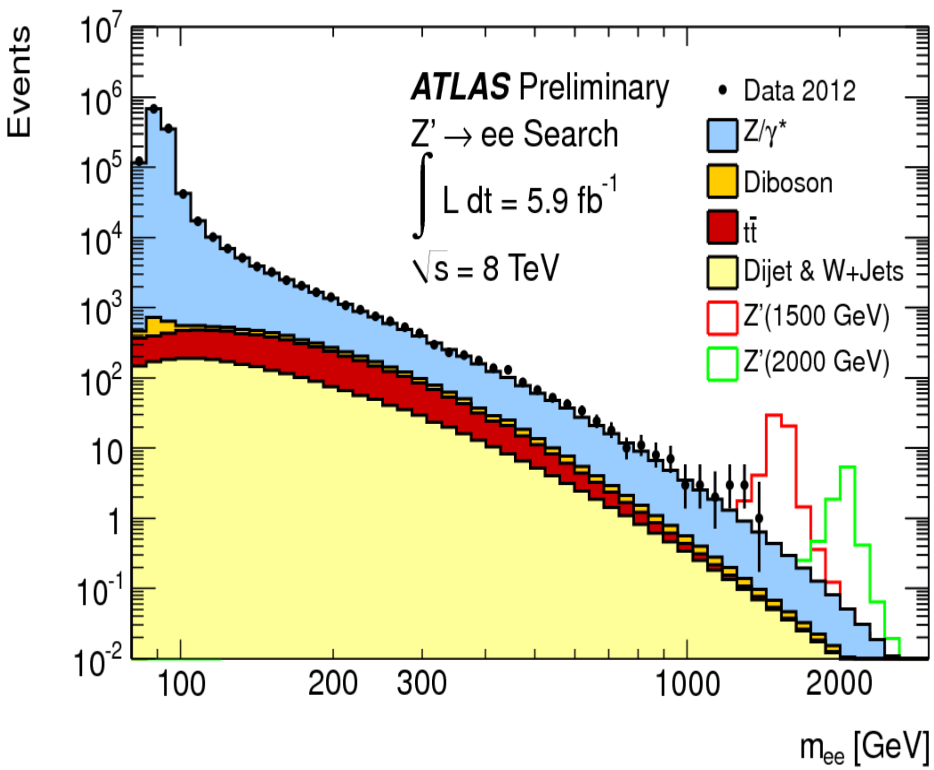
Very similar limits come from CMS

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

Searches for heavy W and Z like particles

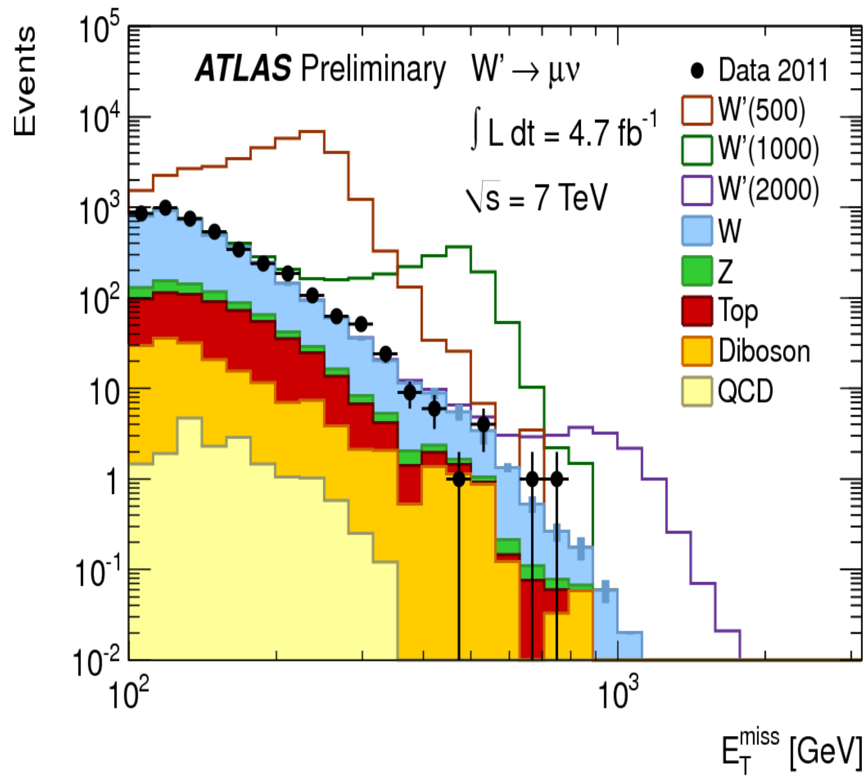
These searches are quite straight-forward, following basically the same analyses as for the familiar W and Z bosons

Z': Di-lepton pairs

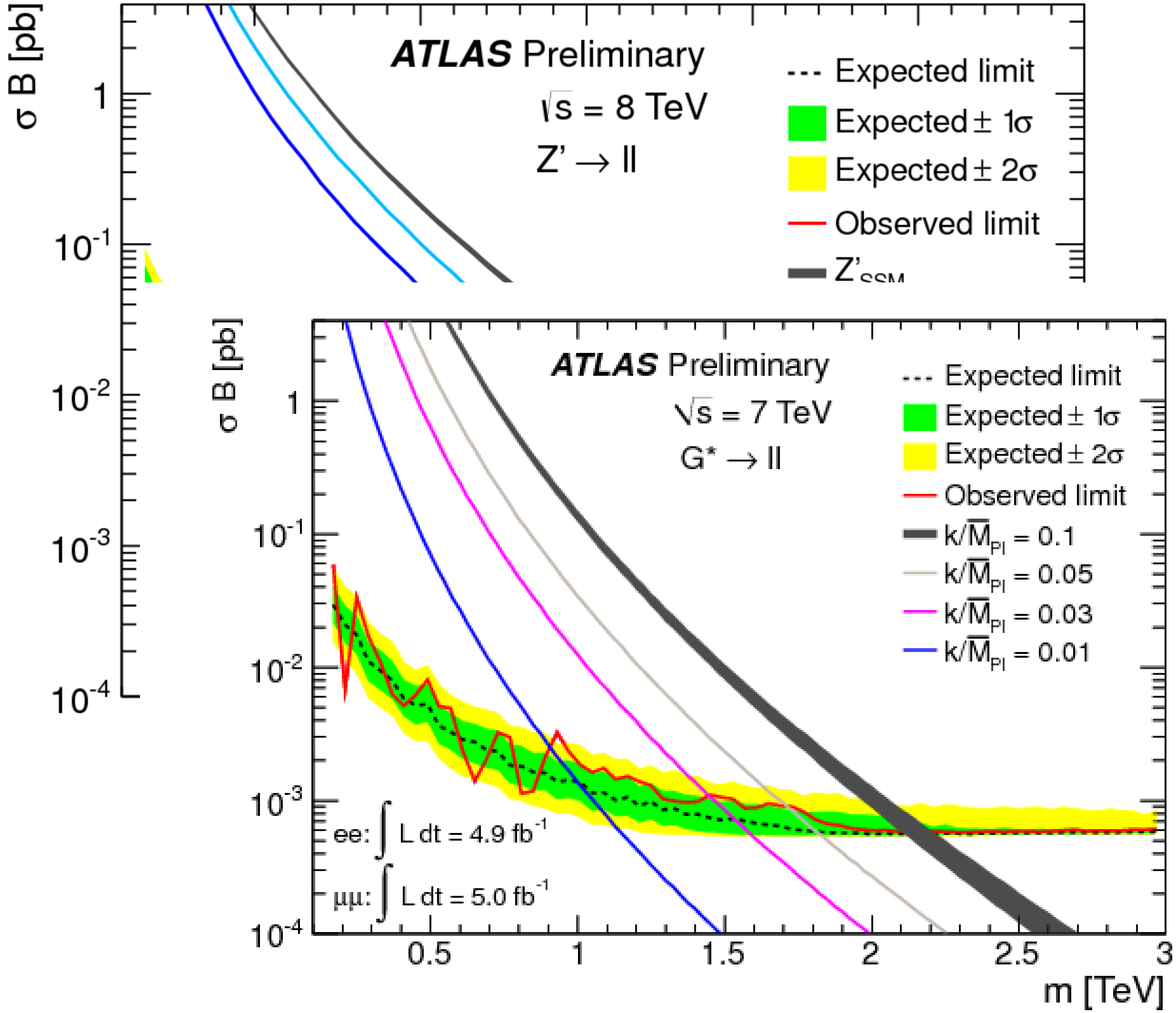


ATLAS-CONF-2012-129

W': Lepton + ETmiss



ATLAS-CONF-2012-086



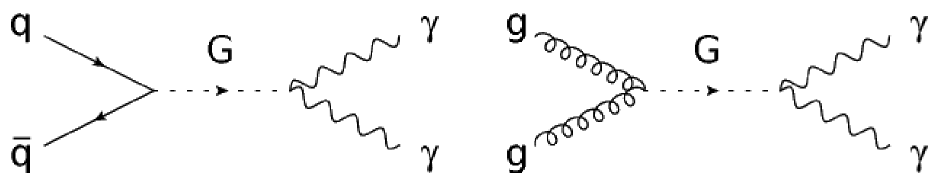
R Sundrum
L Randall
F Gianotti

ATLAS-CONF-2012-129

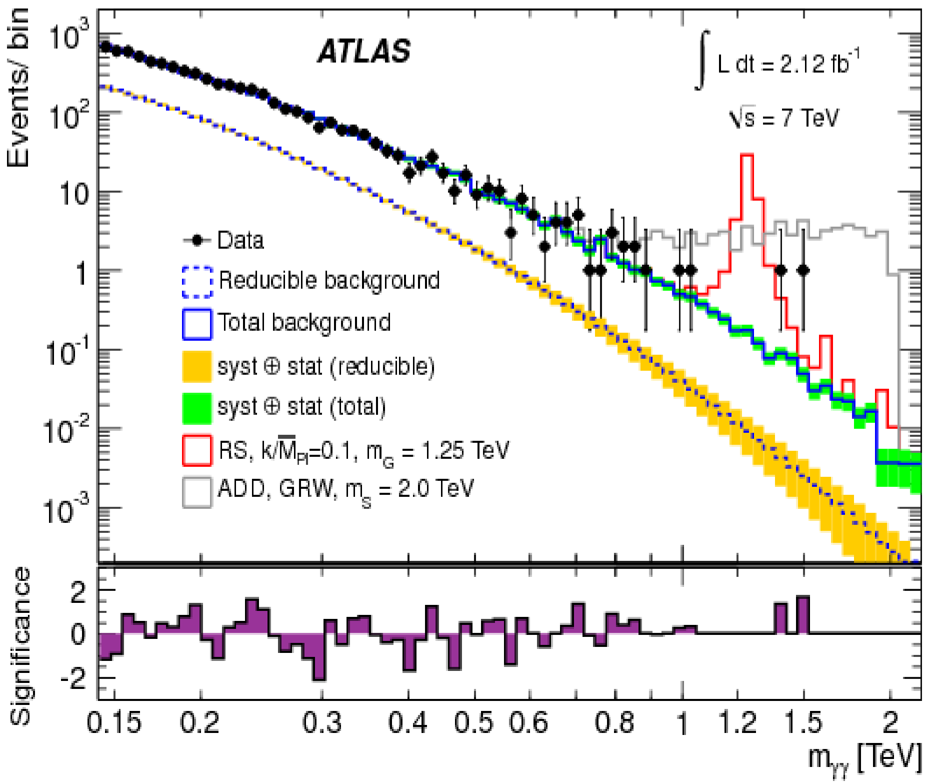
ATLAS-CONF-2012-007

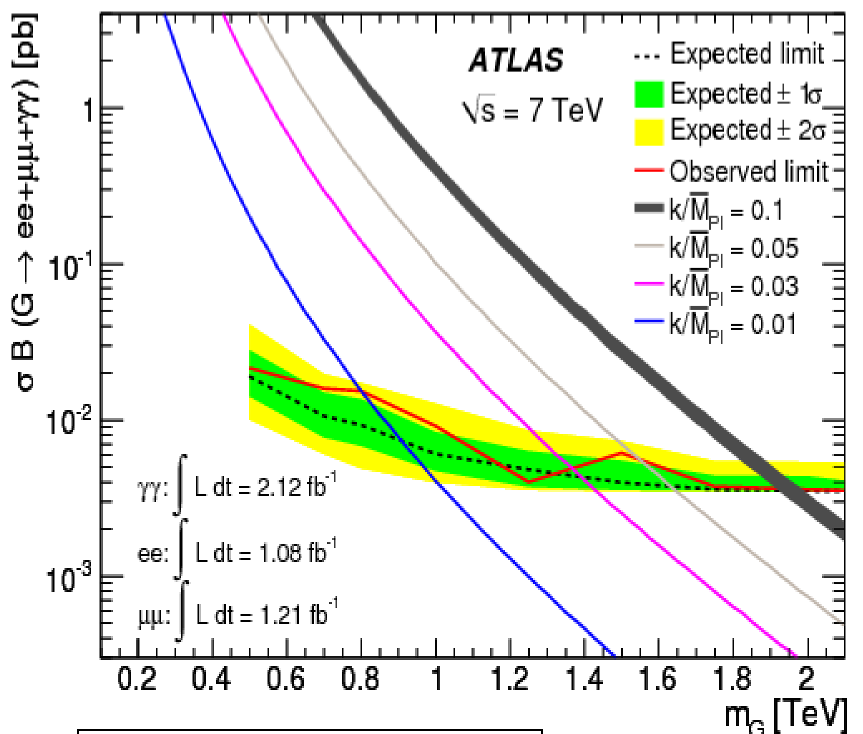
Randall-Sundrum Graviton

New particles decaying into two photons



Example for a search of extra dimension signals (Kaluza-Klein Graviton in the Randall-Sundrum and Arkani-Hamed, Dimopoulos and Dvali models)



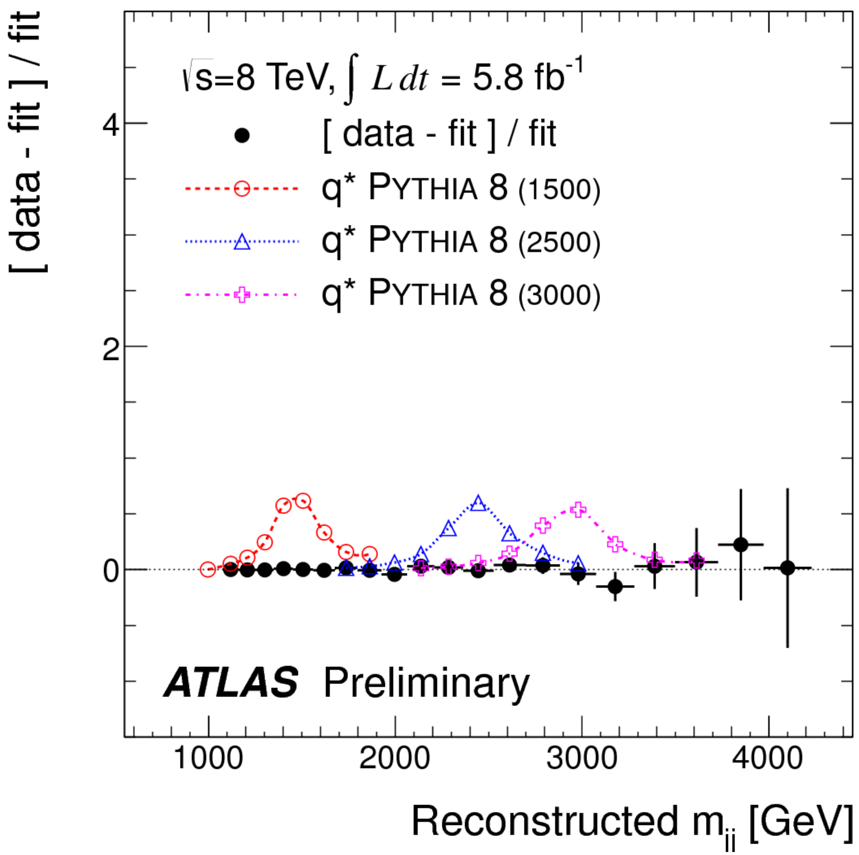


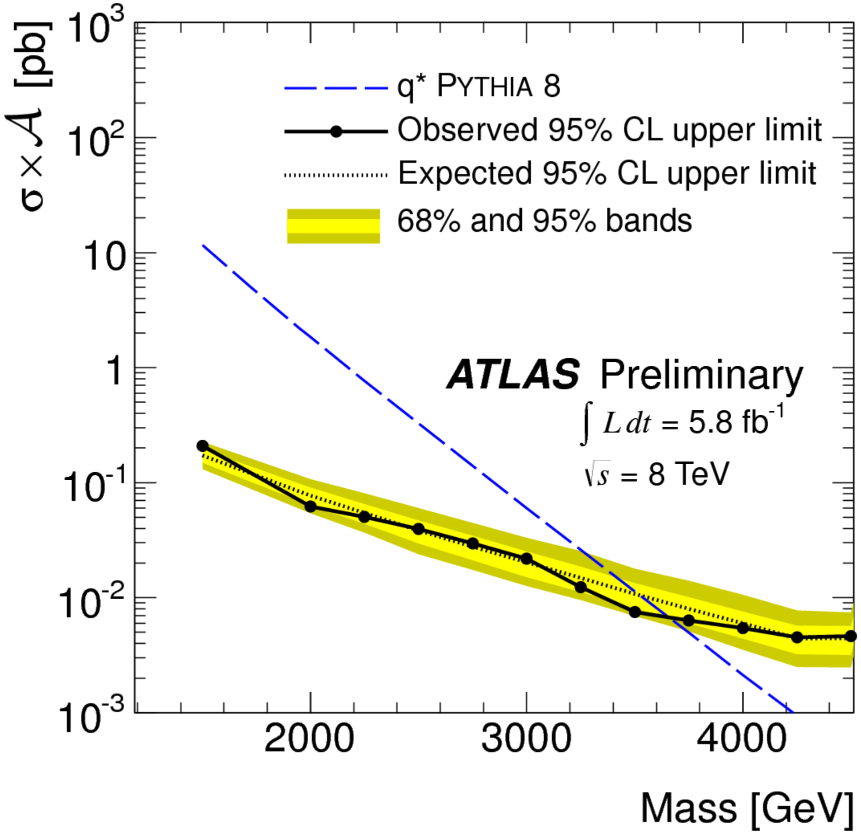
Phys. Lett. B710 (2012) 538

Example of searches for New Physics as deviations from QCD behaviour of hadronic jet distributions

Search for resonances in the di-jet mass spectrum

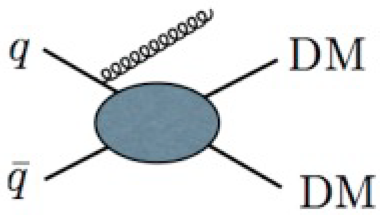
ATLAS-CONF-2012-088



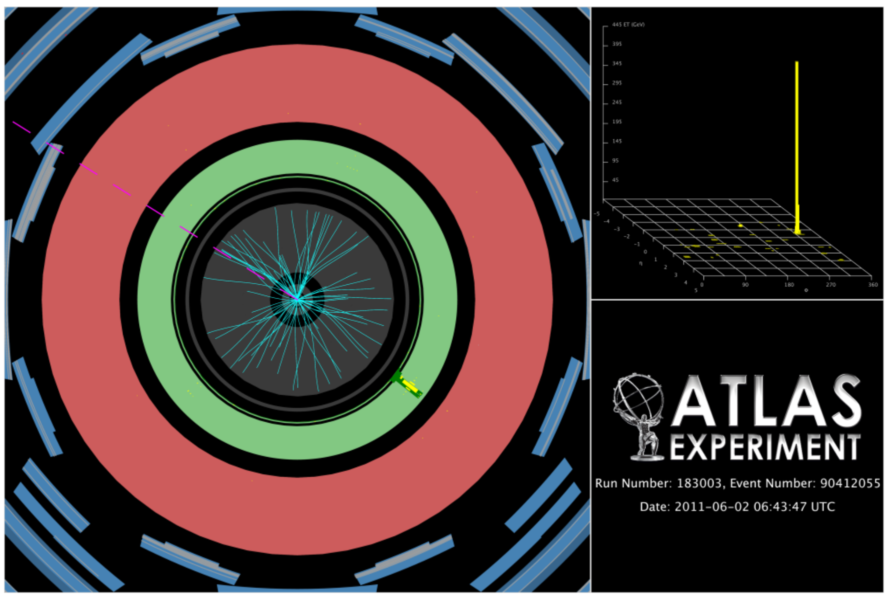


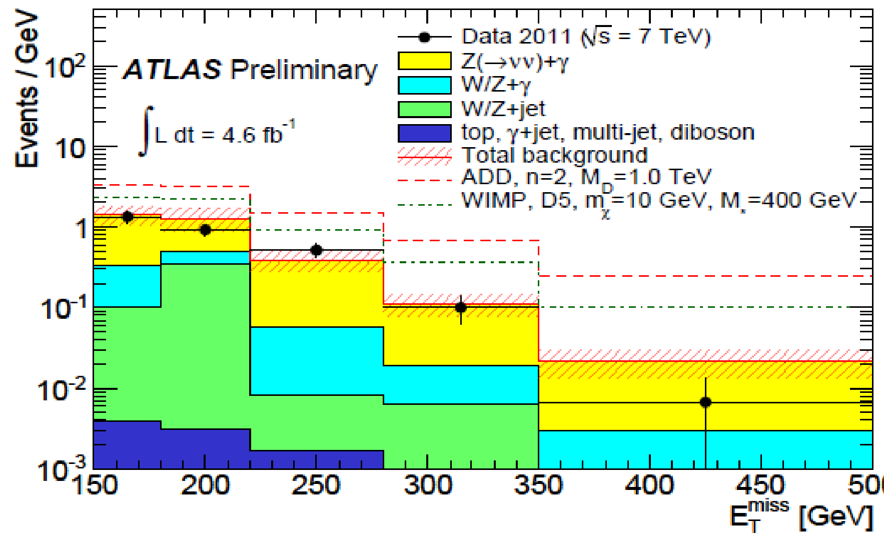
95% CL excluded mass: 3.66 TeV

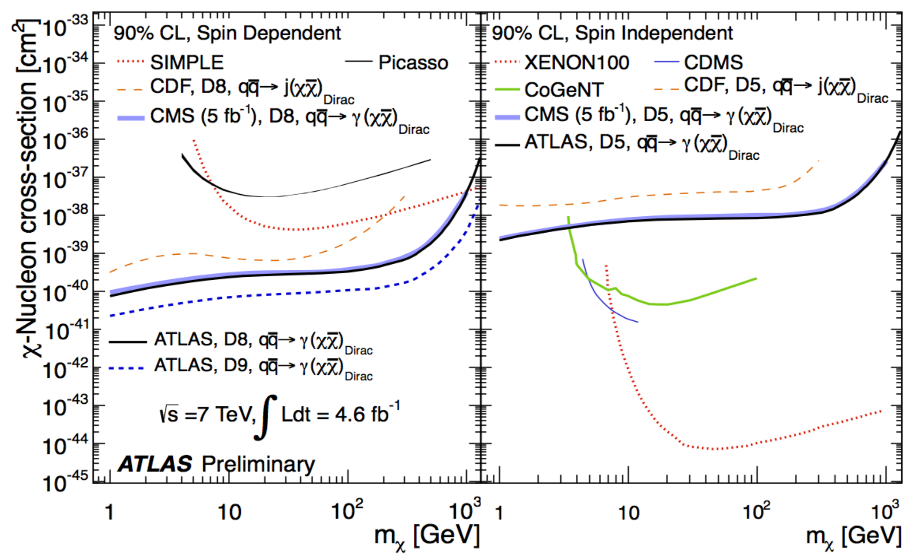
Search for direct Dark Matter (DM) particles in pair-production



A single photon (150 GeV) or jet plus ETmiss

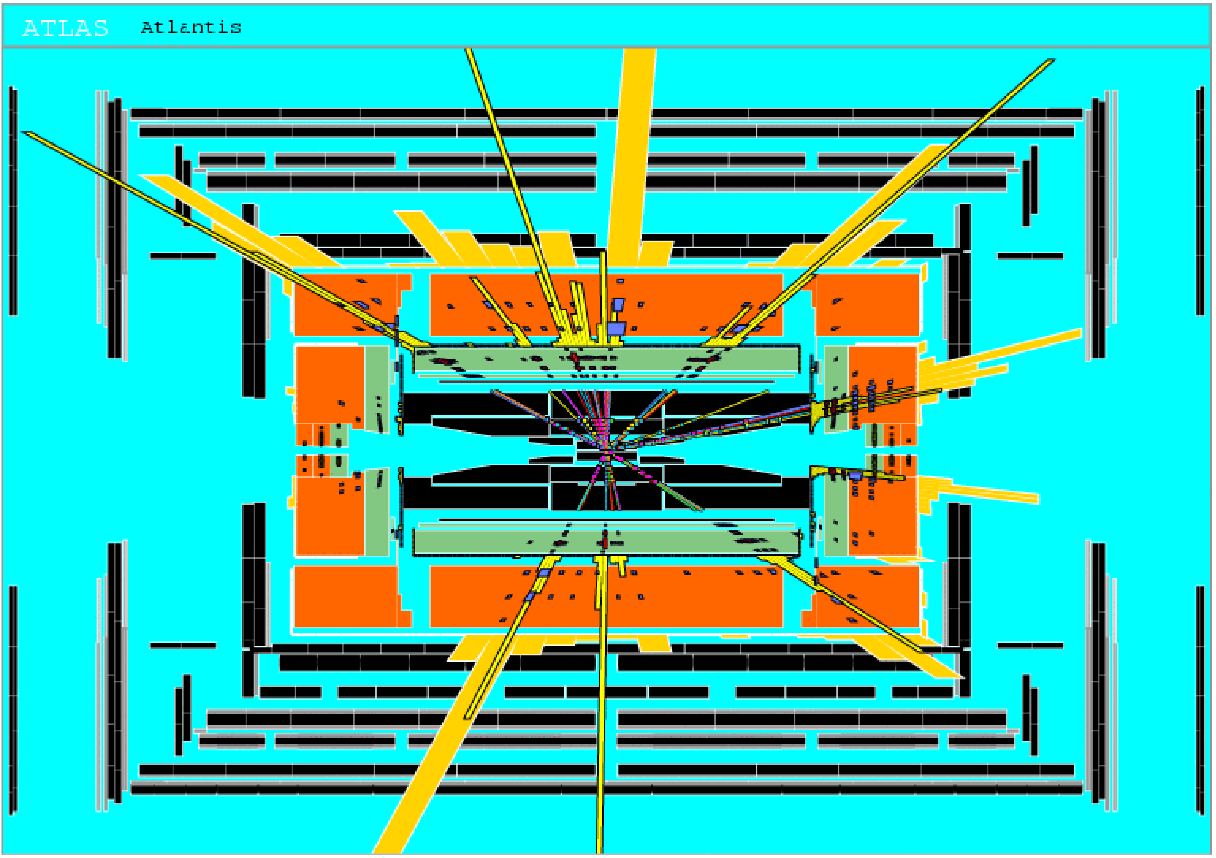






ATLAS-CONF-2012-085
arXiv:1210.4491v1[hep-ex]

If theories with Extra-dimensions are true, microscopic black holes could be abundantly produced and observed at the LHC



Simulation of a black hole event with M_{BH} ~ 8 TeV in ATLAS

They decay immediately through Stephen Hawking radiation

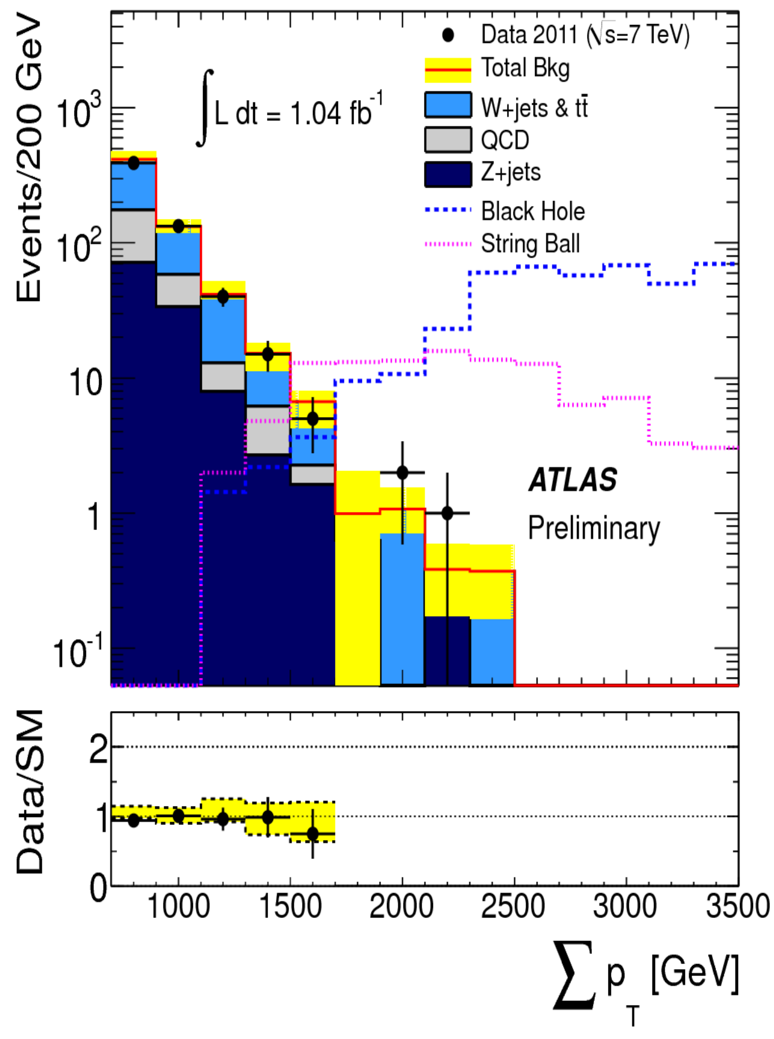
Search for Microscopic Black Hole production in models wth large extra dimensions
(Arkani-Hamed, Dimopoulos, Dvali)

ATLAS-CONF-2011-147
arXiv:1204.4646v1[hep-ex]

Decay into many objects (jets, leptons, photons)

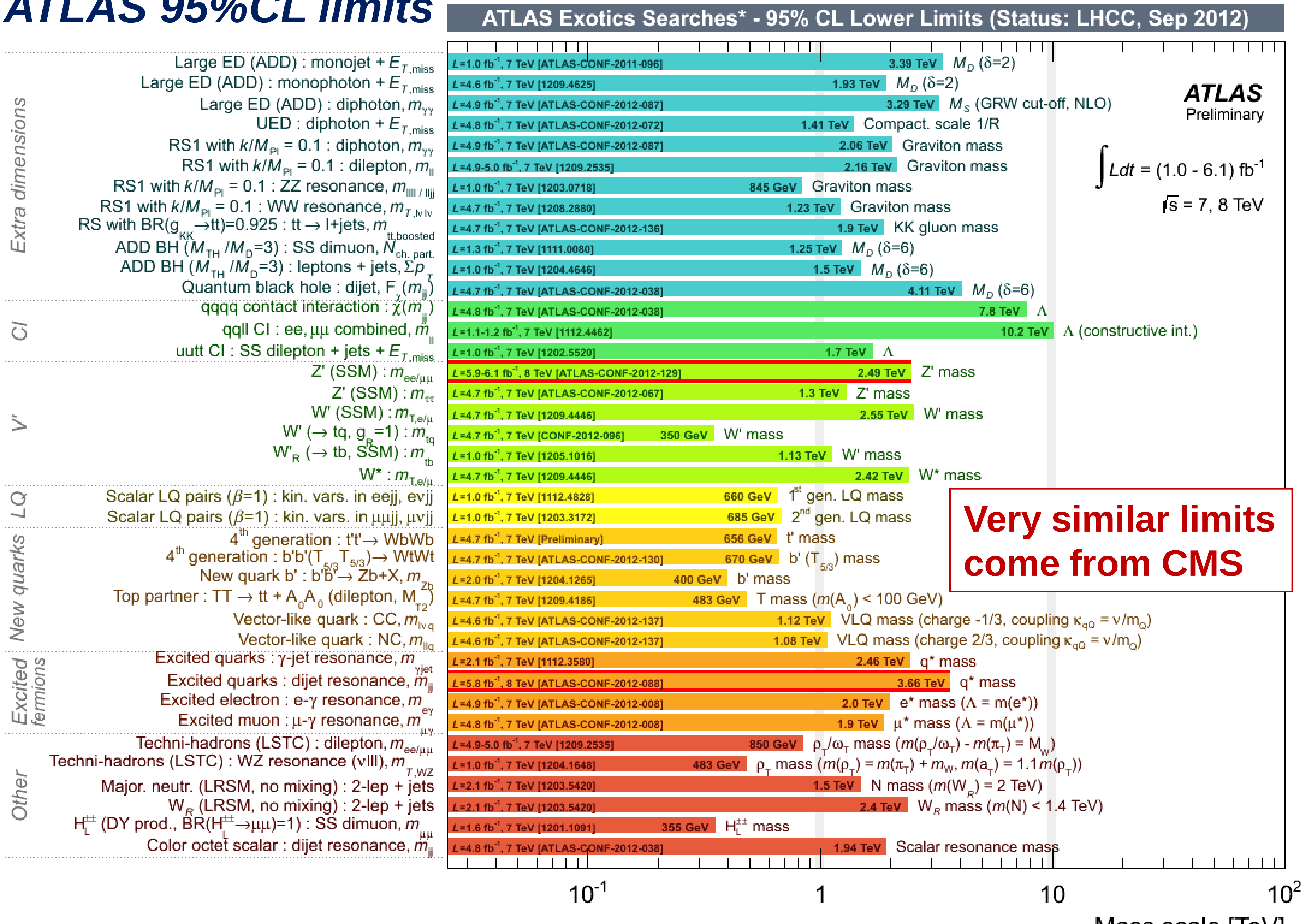
ΣP_T : scalar sum of the E_T of the N objects in the event

<u>Example:</u> at least one electron or muon and two or more jets



No deviation is seen for events with at least 3 objects with > 50 GeV pT

ATLAS 95%CL limits



Very similar limits come from CMS

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

20 years of working with the Czech colleagues and friends in ATLAS was a real pleasure, and we are looking forward to a bright common future with LHC and its upgrades of the machine and the experiment

Exciting times are ahead of us!

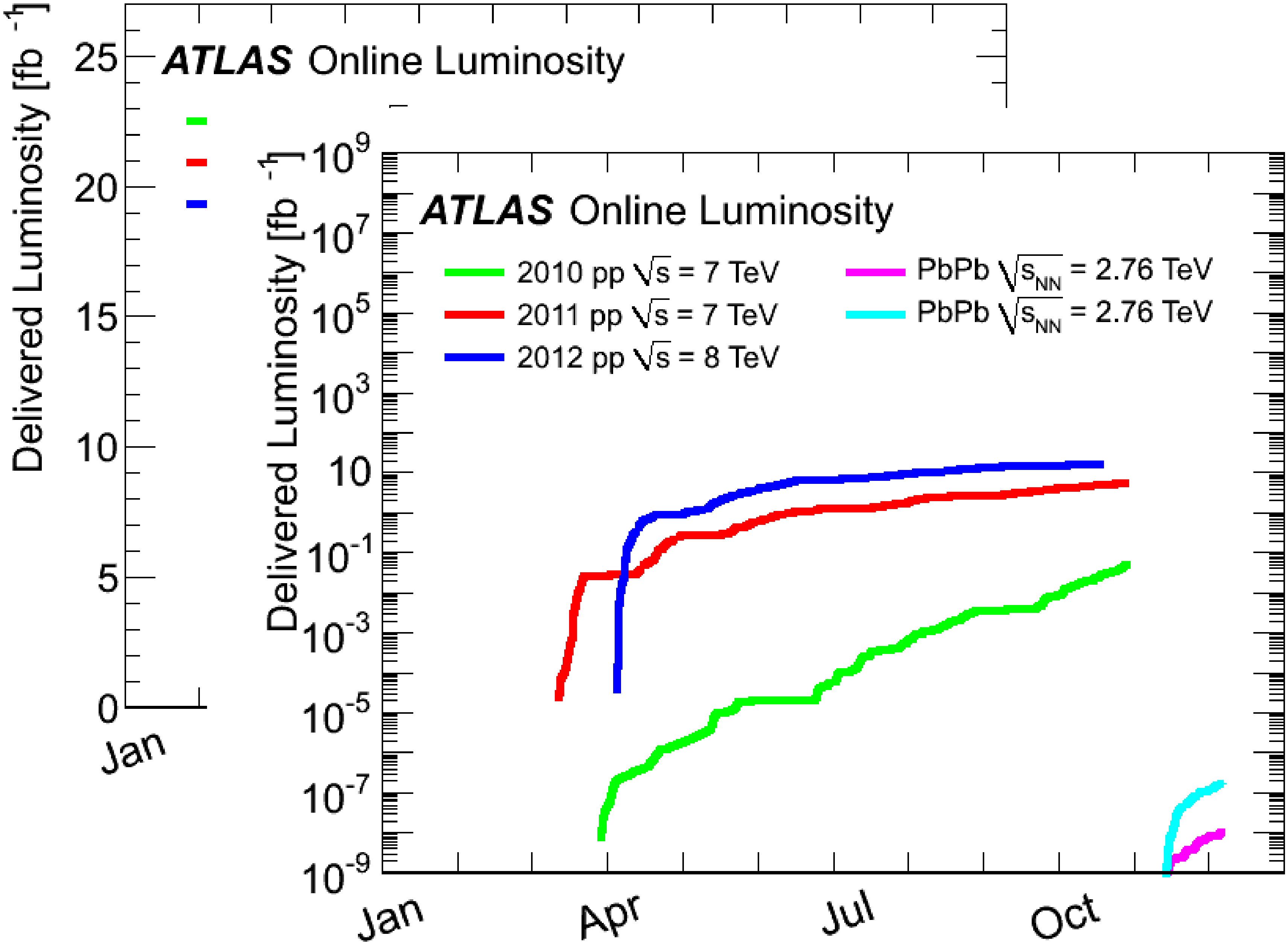
Thank you for your attention!

Spares

LHC Schedule Assumptions

- 2009 — LHC start-up $\sqrt{s}$ = 900GeV
- 2010–2012 — $\sqrt{s}$ = 7TeV rising to 8TeV, $\mathcal{L}$= $6\times10^{33}cm^{-2}s^{-1}$, bunch spacing 50ns — ~20fb^{-1}
- 2013–2014 LS1 — Go to design energy and nominal luminosity
- 2015–2017 — $\sqrt{s}$ = 13-14TeV, $\mathcal{L}$= $1\times10^{34}cm^{-2}s^{-1}$, bunch spacing 25ns — ≥50fb^{-1}
- 2018 LS2 — Injector and LHC Phase-I upgrade to full design luminosity
- 2019–2021 — $\sqrt{s}$ = 14TeV, $\mathcal{L}$= $2\text{-}3\times10^{34}cm^{-2}s^{-1}$, bunch spacing 25ns — ≥300fb^{-1}
- 2022 LS3 — HL-LHC Phase-II upgrade, crab cavities, new IR, ...
- 2023 ... 2030? — $\sqrt{s}$ = 14TeV, $\mathcal{L}$= $5\times10^{34}cm^{-2}s^{-1}$ (luminosity levelling) 25ns — ~3000 fb^{-1}

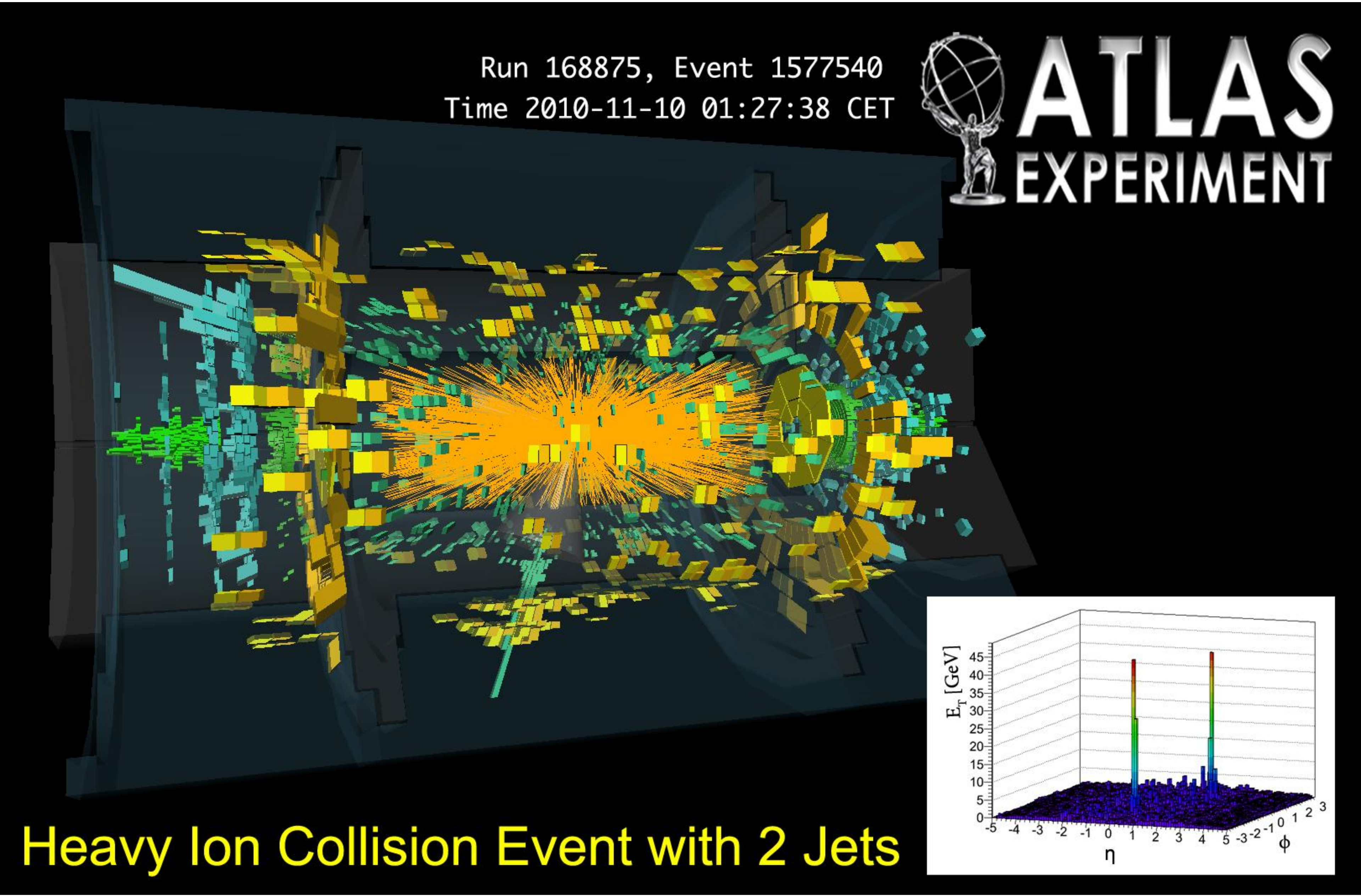
Hector Berlioz, “Les Troyens”, opera in five acts
Valencia, Palau de les Arts Reina Sofia, 31 October -12 November 2009



ATLAS Online Luminosity
Delivered Luminosity [fb -1]
25
20
15
10
5
0
Jan
ATLAS Online Luminosity
2010 pp √s = 7 TeV
2011 pp √s = 7 TeV
2012 pp √s = 8 TeV
PbPb √sNN = 2.76 TeV
PbPb √sNN = 2.76 TeV
Delivered Luminosity [fb -1]
10^9
10^7
10^5
10^3
10
10^-1
10^-3
10^-5
10^-7
10^-9
Jan
Apr
Jul
Oct
Month in Year

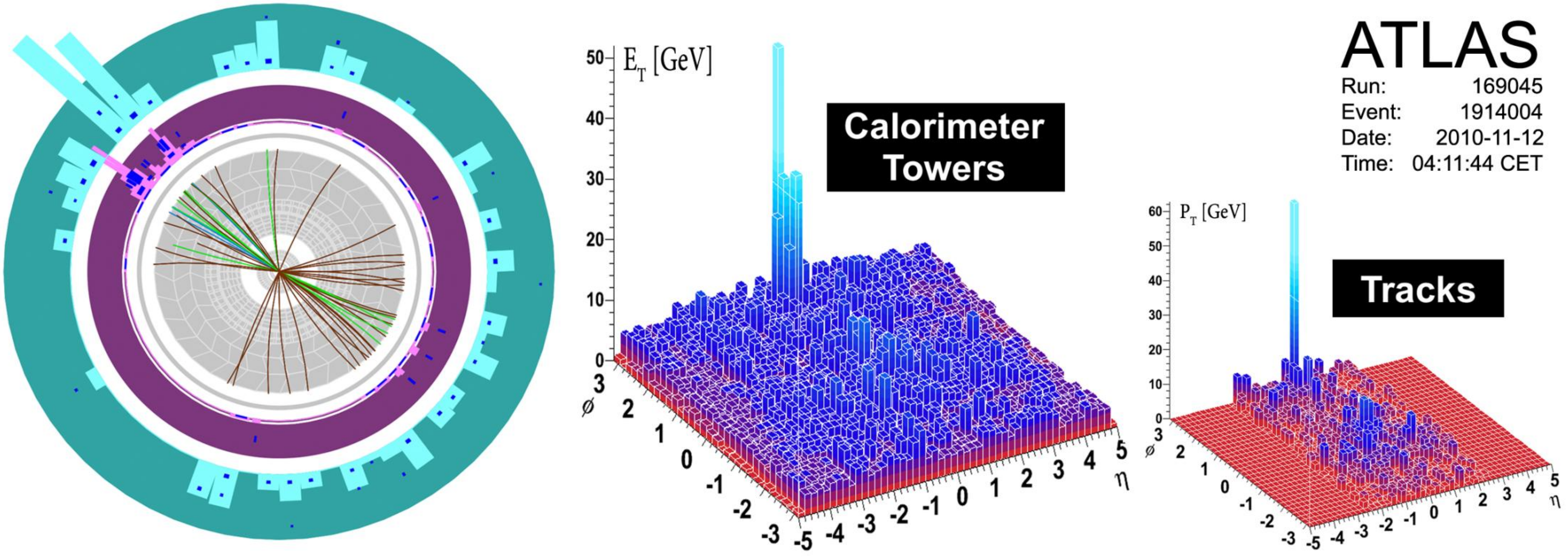
Pb-Pb event with jets

Uncorrected p_T of each jet ~160 GeV



Observation of a Centrality-Dependent Dijet Asymmetry in Lead-Lead Collisions at $\sqrt{s_{NN}} = 2.76$ TeV with the ATLAS Detector at the LHC

G. Aad *et al.* (The ATLAS Collaboration)*



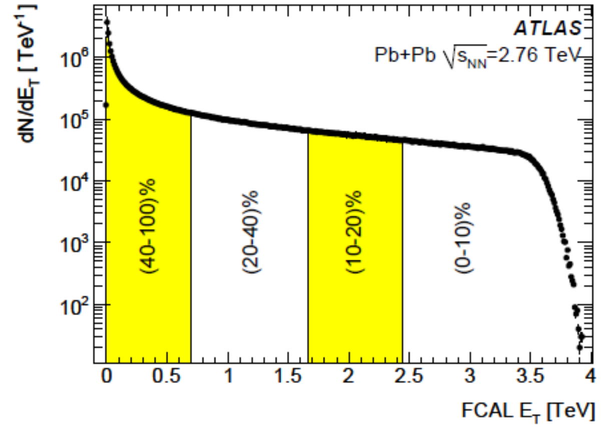
Phys. Rev. Lett. 105 (2010) 252303

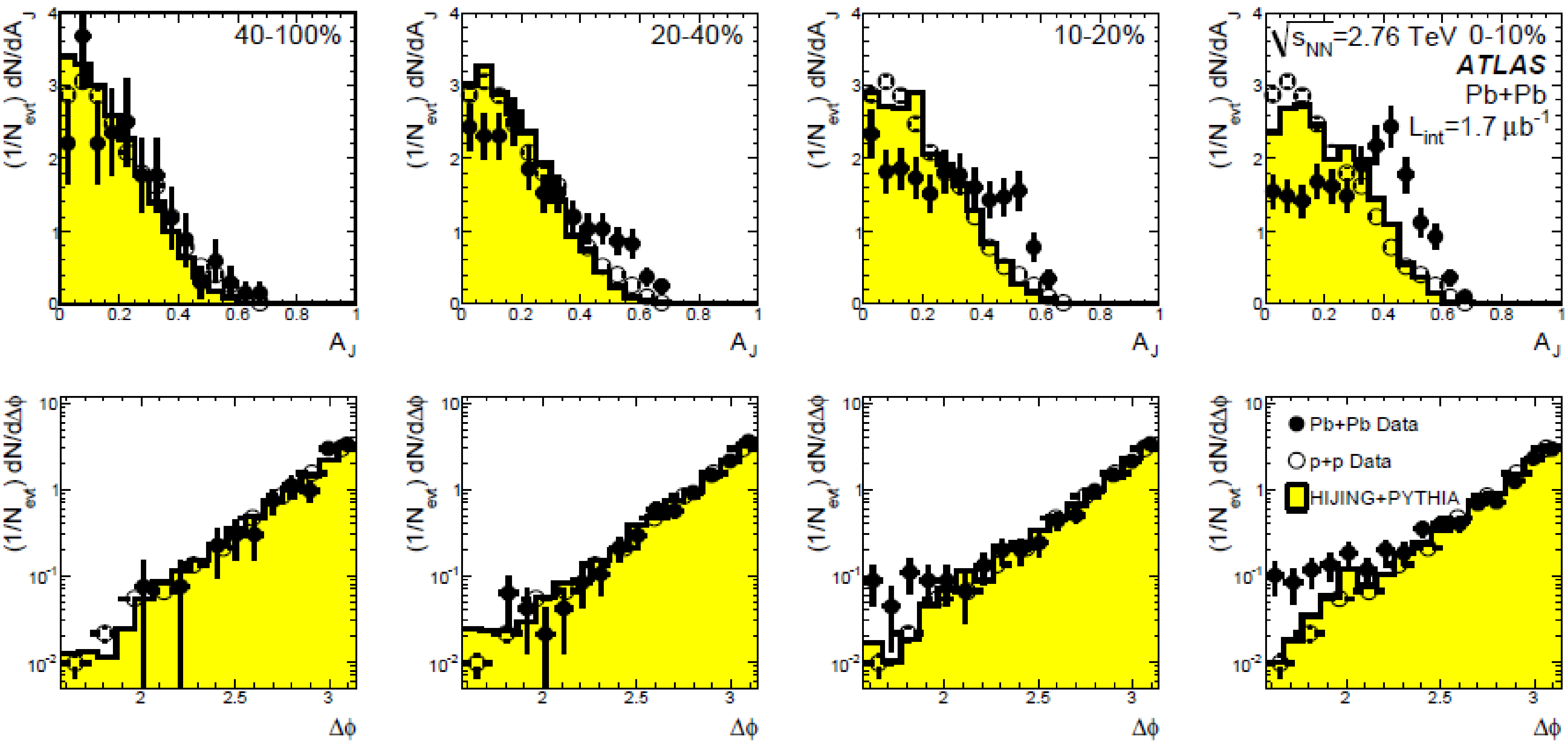
Measured di-jet asymmetry A_J as a function of the centrality

(1.7 μb^{-1})

$$A_J = \frac{E_{T1} - E_{T2}}{E_{T1} + E_{T2}}, \Delta\phi > \frac{\pi}{2}$$

Centrality bins defined with the ET in FCAL

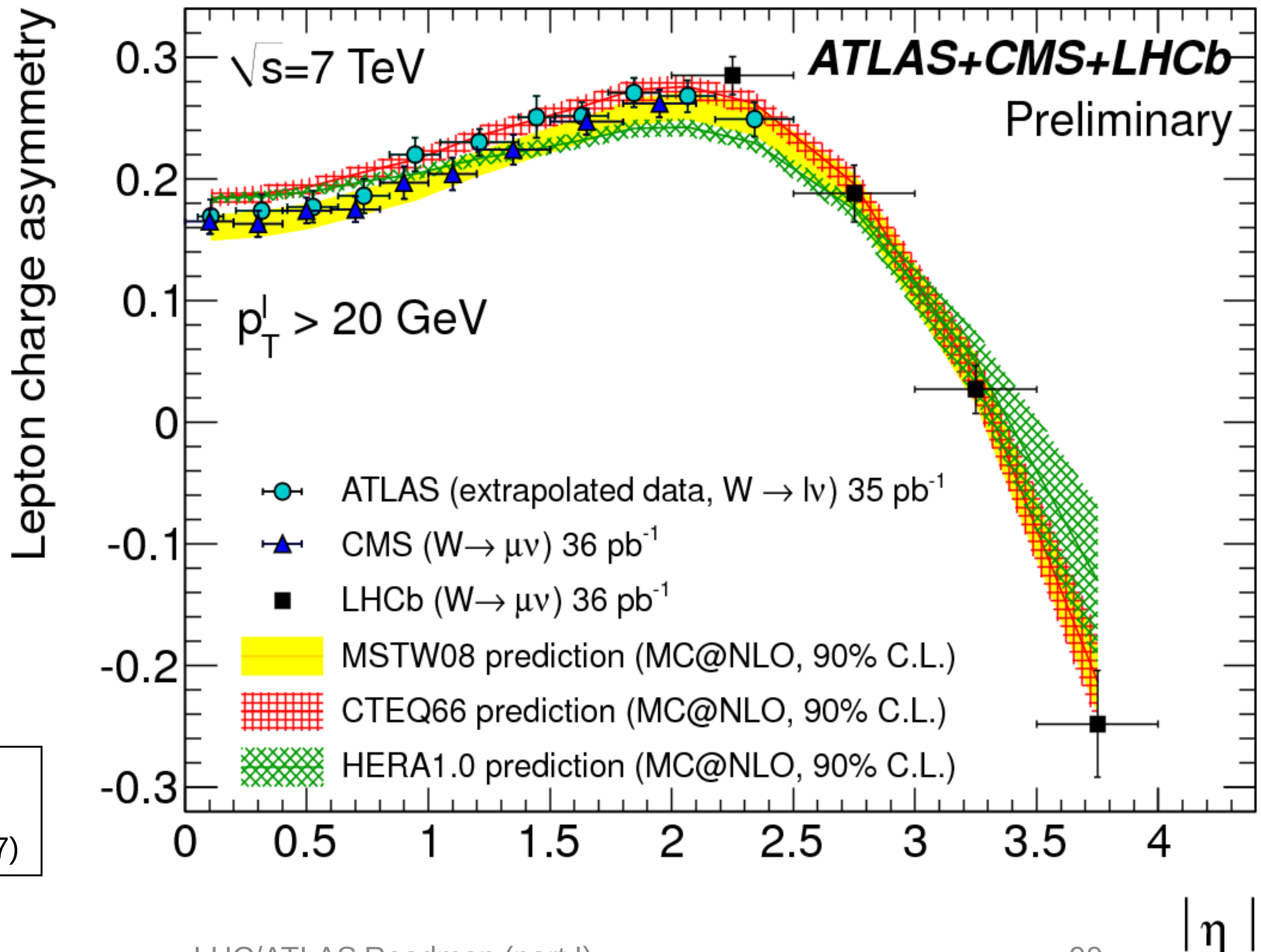




Such an effect could be the first direct indication of 'jet-quenching'

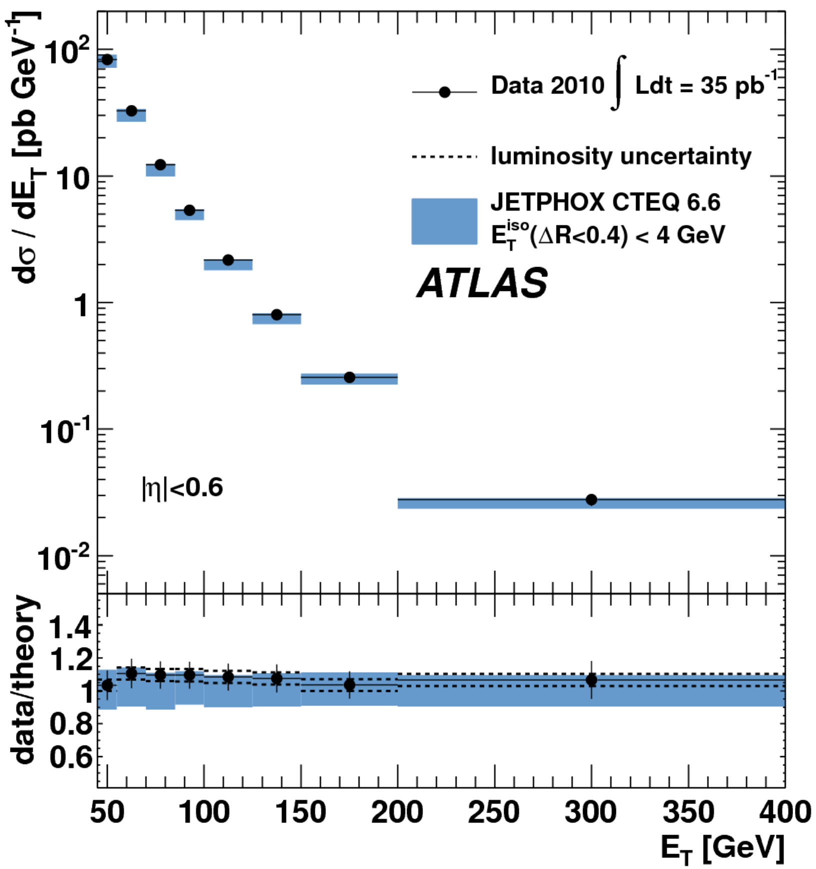
Lepton charge asymmetry from W decays in pp collisions at 7 TeV

$$A(\eta) = \frac{d\sigma/d\eta(W^+ \to \ell^+\nu) - d\sigma/d\eta(W^- \to \ell^-\bar{\nu})}{d\sigma/d\eta(W^+ \to \ell^+\nu) + d\sigma/d\eta(W^- \to \ell^-\bar{\nu})},$$



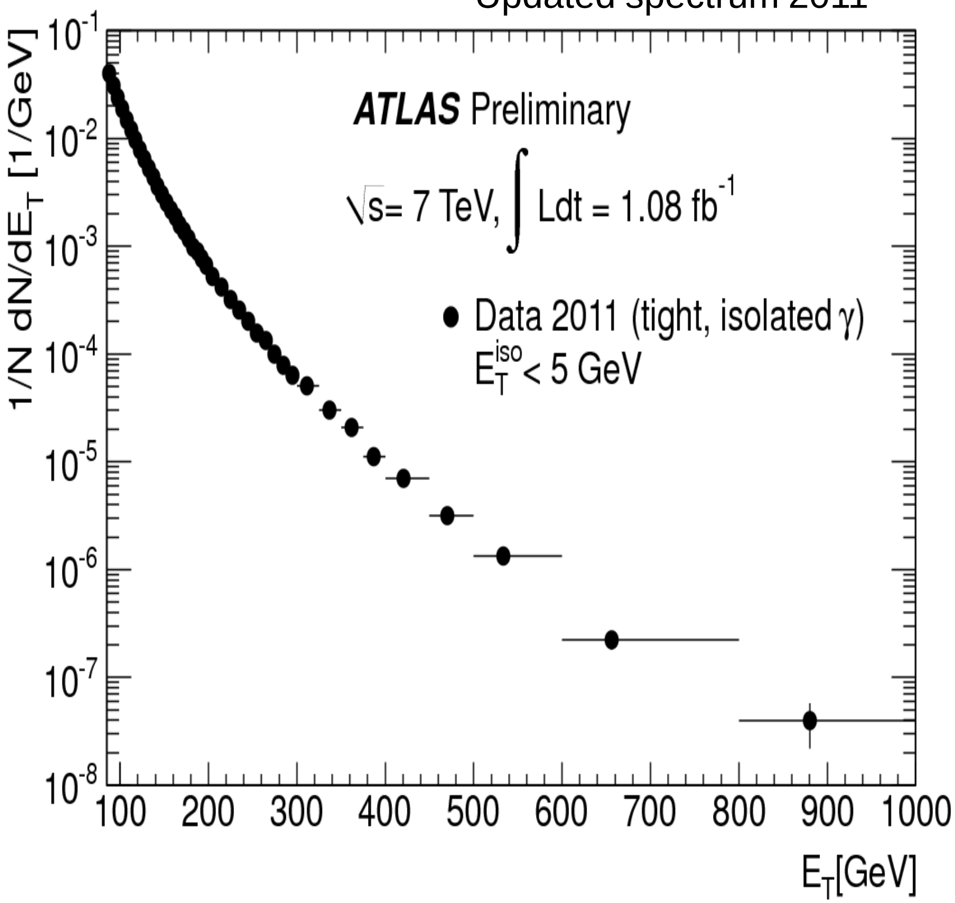
ATLAS-CONF-2011-129
LHCb-CONF-2011-039
CMS-EWK-10-006 (aXiv:1103.3407)

Example of inclusive isolated prompt photon cross-sections

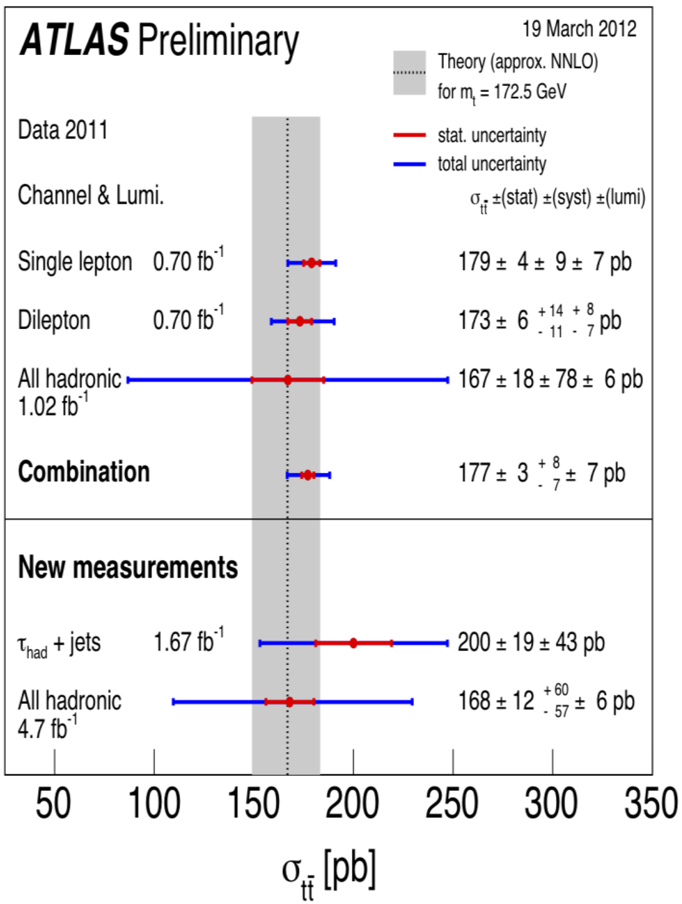


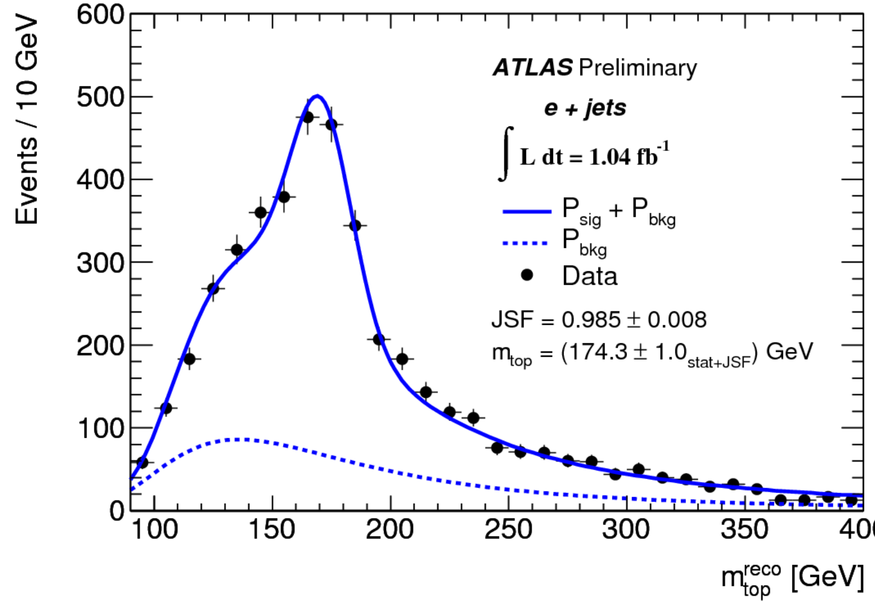
Phys. Lett. B706 (2011) 150

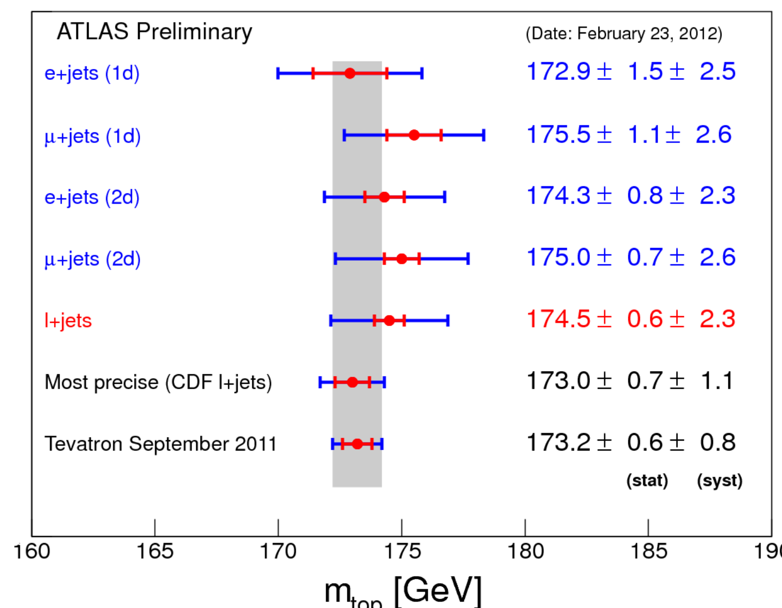
Updated spectrum 2011



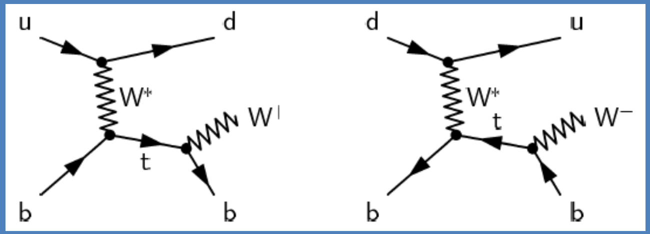
More details on top measurements...







Single top production

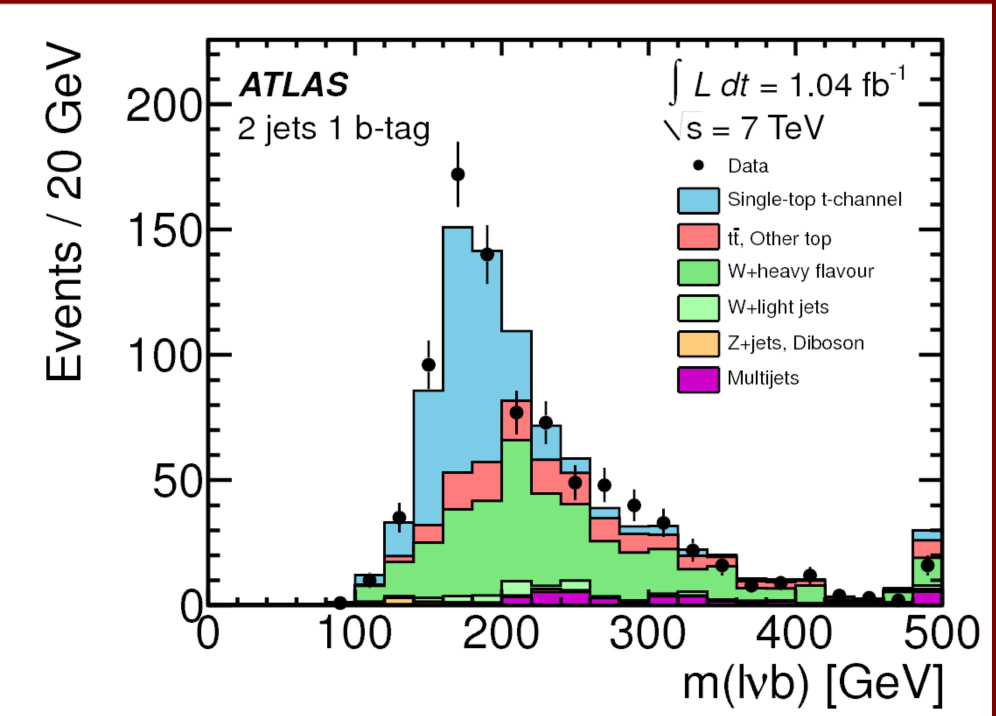


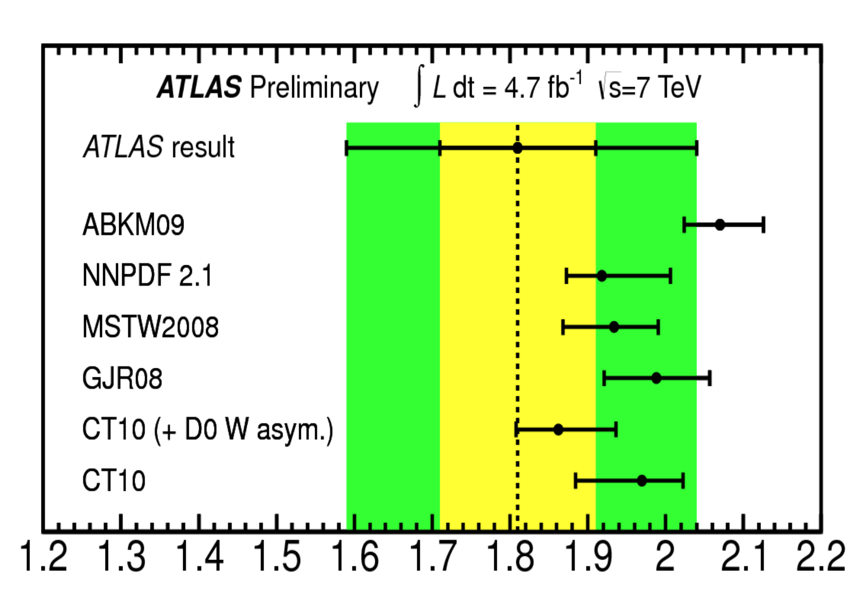
t-channel single-top production

Measured cross-section:

$$\sigma_t = 83 \pm 4\,(\text{stat.})\,^{+20}_{-19}\,(\text{syst.})\ \text{pb}$$

Expected from SM: ~ 65 ± 3 pb





top / anti-top ratio

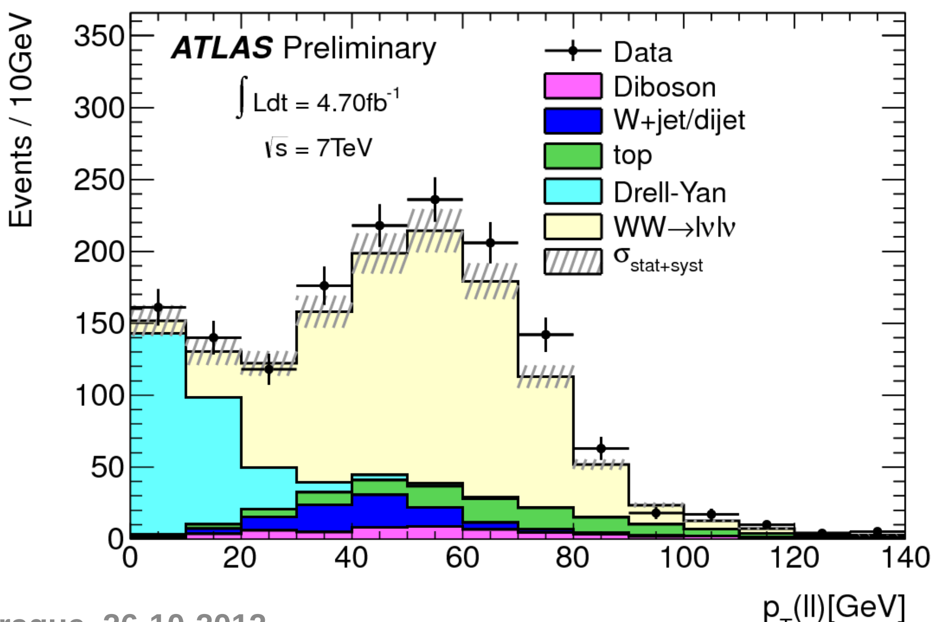
Submitted to Phys. Lett. B
arXiv:1205.3130v1[hep-ex]
and ATLAS-CONF-2012-056

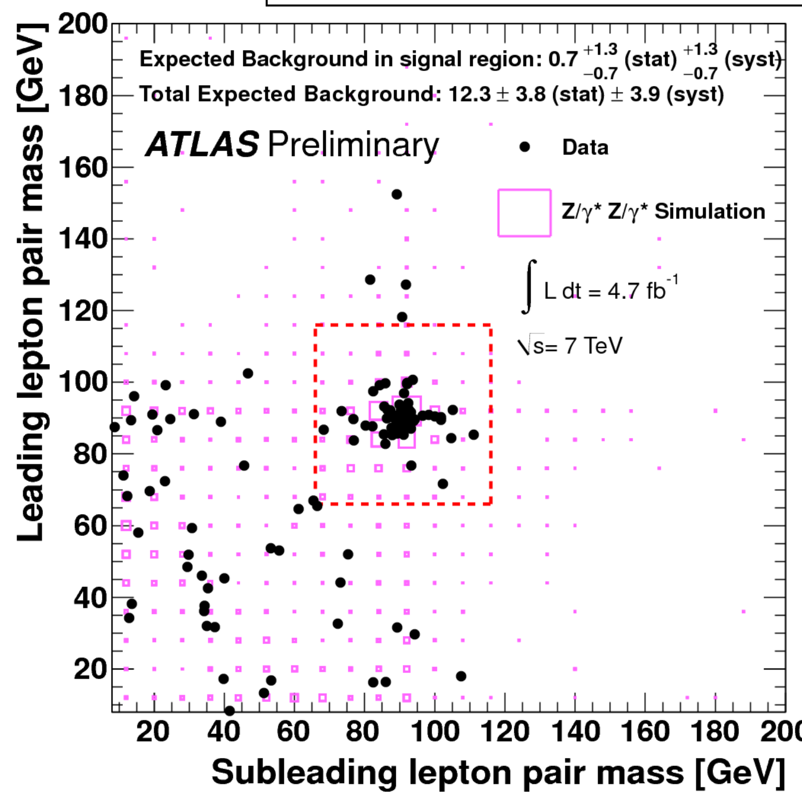
Electroweak di-boson production

Process	Final state	Measured total cross-section	Theory (NLO SM)
WW	lνlν	$\sigma^{tot}_{W^+W^-} = 53.4 \pm 2.1(\text{stat}) \pm 4.5(\text{syst}) \pm 2.1(\text{lumi})$ pb	45.1 ± 2.8 pb
ZZ	4l	$\sigma^{tot}_{ZZ} = 7.2^{+1.1}_{-0.9}$ (stat) $^{+0.4}_{-0.3}$ (syst) ± 0.3 (lumi) pb	$6.5^{+0.3}_{-0.2}$ pb
ZZ	llνν	$\sigma^{tot}_{ZZ} = 5.4^{+1.3}_{-1.2}$(stat.)$^{+1.4}_{-1.0}$(syst.) ± 0.2(lumi.) pb	$6.5^{+0.3}_{-0.2}$ pb

- ❑ **Backgrounds to Higgs searches**
- ❑ **Give access to triple gauge couplings and New Physics**

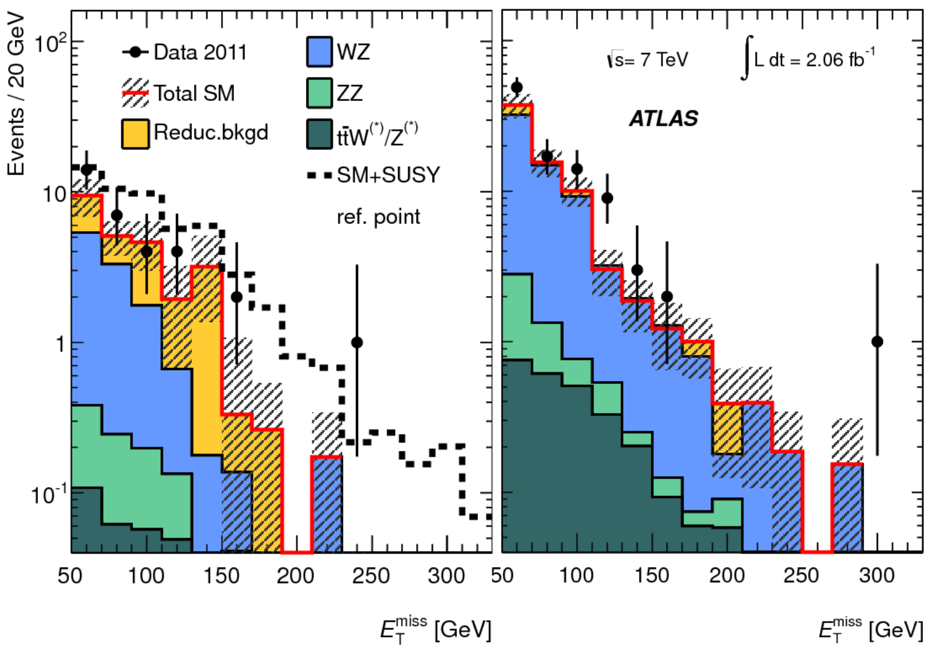
ATLAS-CONF-2012-025, 26, and 27



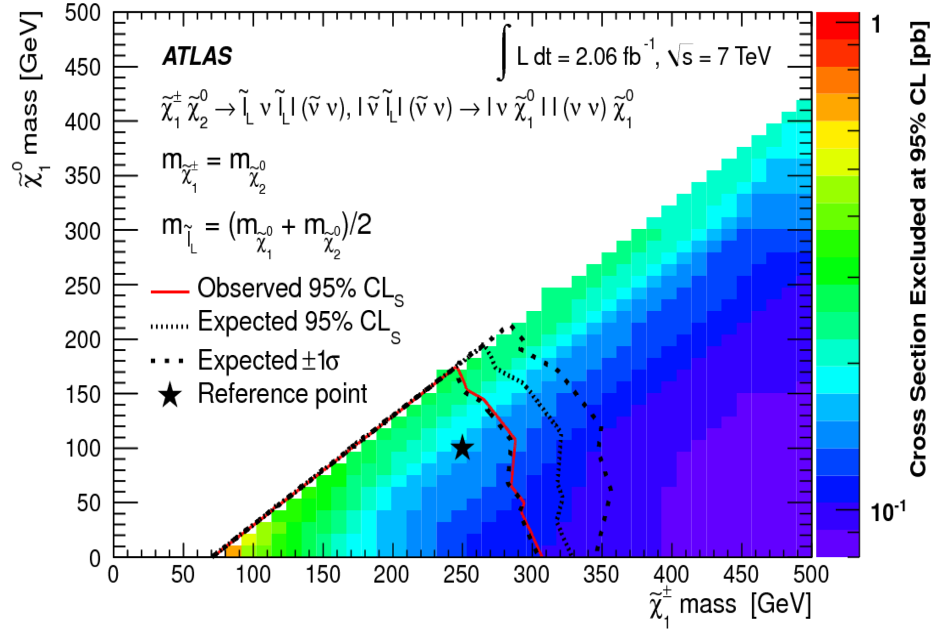


Searches for charginos/neutralinos

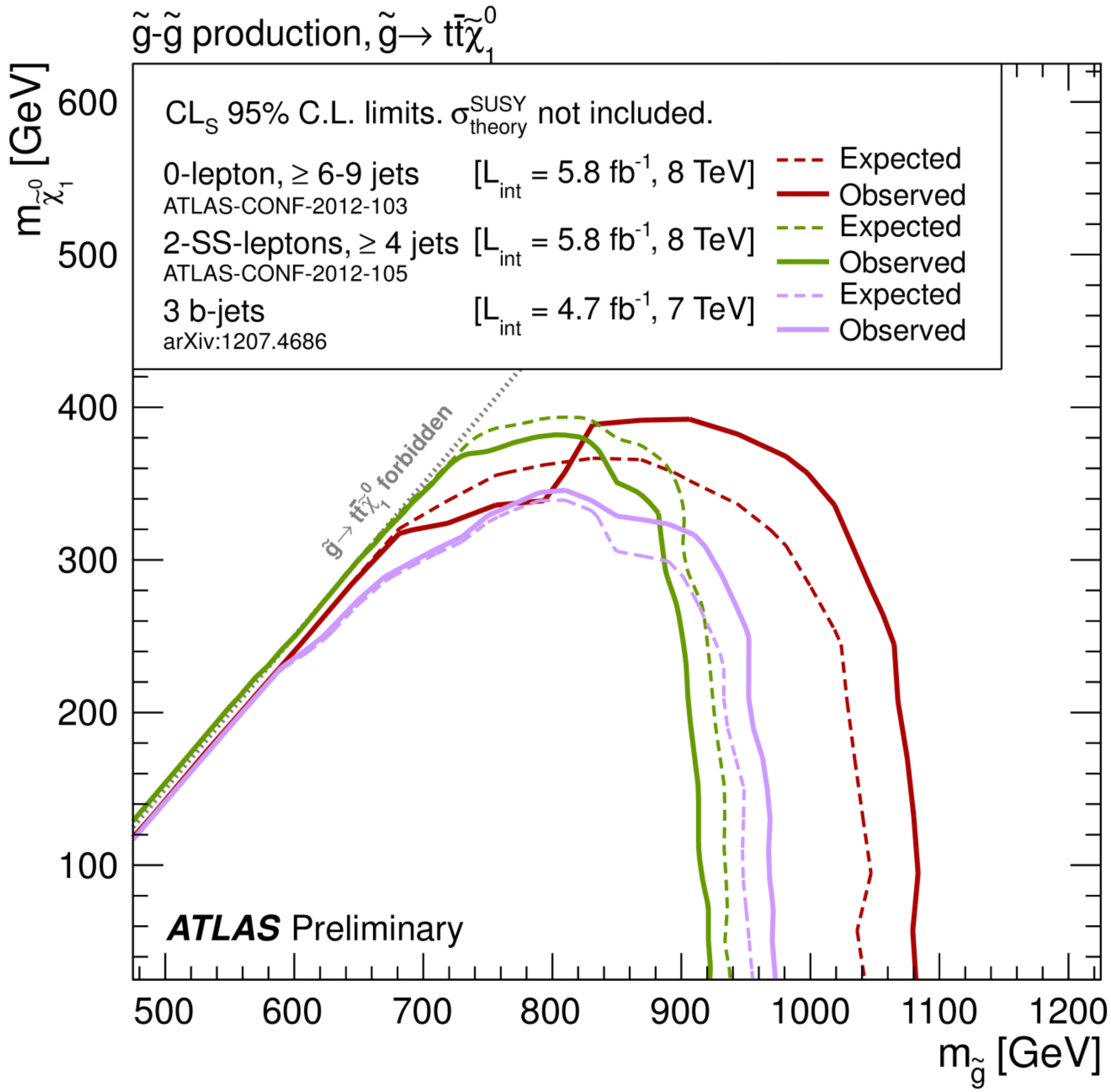
- Direct chargino/neutralino production cross section in the pb range
- ATLAS has searched for this in 3-lepton final state
- Limits in the $m(\chi^{\pm}_1/\chi^0_2)$ ~ 250 GeV region have been set



(Z-depleted and Z-enriched signal regions)



Accepted in Phys. Rev. Lett.
arXiv:1204.5638v1[hep-ex]

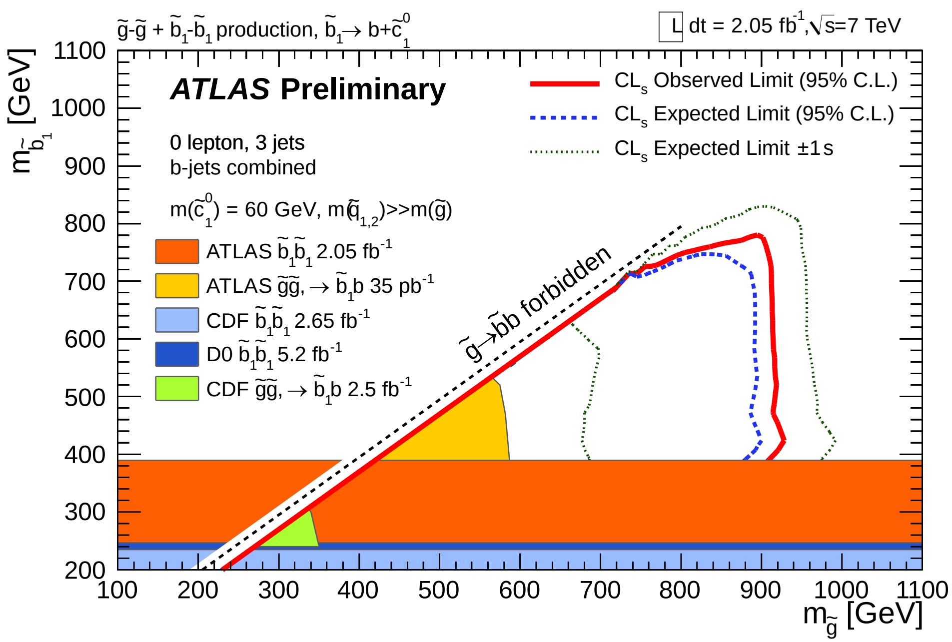

g̃-g̃ production, g̃→ tt̄χ̃⁰₁
CLs 95% C.L. limits. σ SUSY theory not included.
0-lepton, ≥ 6-9 jets [L int = 5.8 fb-1, 8 TeV]
ATLAS-CONF-2012-103
2-SS-leptons, ≥ 4 jets [L int = 5.8 fb-1, 8 TeV]
ATLAS-CONF-2012-105
3 b-jets [L int = 4.7 fb-1, 7 TeV]
arXiv:1207.4686
Expected
Observed
Expected
Observed
Expected
Observed
g̃→ tt̄χ̃⁰₁ forbidden
ATLAS Preliminary
m χ̃⁰₁ [GeV]
m g̃ [GeV]
100
200
300
400
500
600
500
600
700
800
900
1000
1100
1200

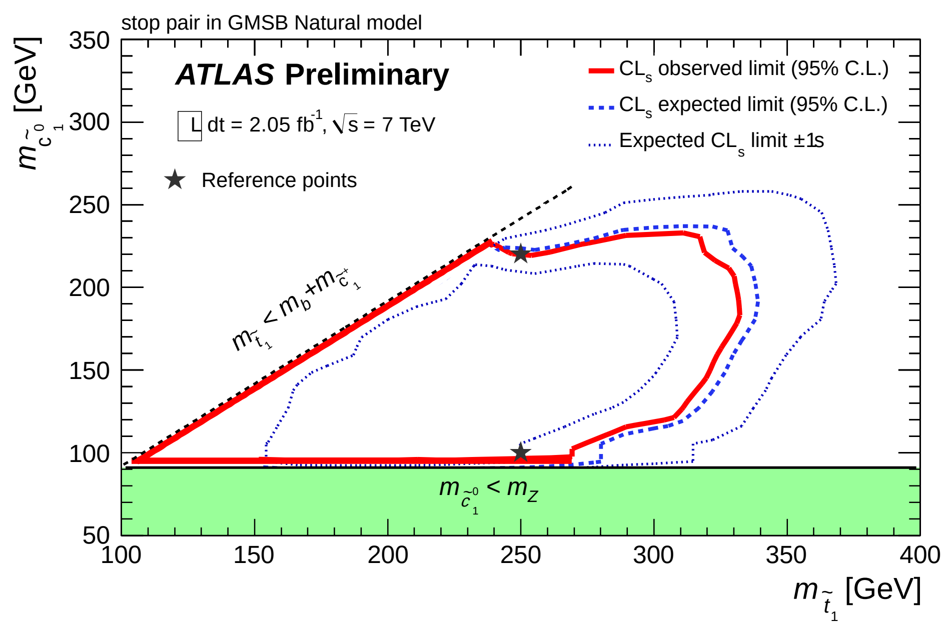
SUSY - 3rd generation squarks

- **Look for light stop and sbottom ("Naturalness"): from gluino decay + direct production**
  - **Gluino-mediated sbottom search in events w/ b-jets + 0,1-lepton + MET** [ATLAS-CONF 2012-003]
  - **Gluino-mediated stop search in events w/ SS dilepton + 4 jets + MET** [ATLAS-CONF 2012-004]
  - **Direct sbottom search in events w/ 2 b-jets + MET** [arXiv:1112.3832]
  - **Direct stop search in events w/ dilepton + b-jets (GMSB interpretation)** [ATLAS-CONF 2012-036]

Strong limits from search for gluino-mediated sbottom production in events with b-jets

First limits on direct stop pair production, assuming (a.o.) the decay chain: $t_1 \to t + \chi^0 \to t + Z(ll) + G$

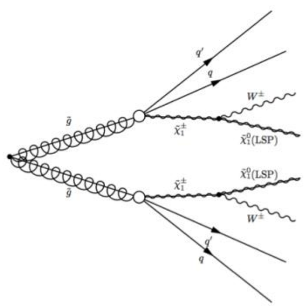




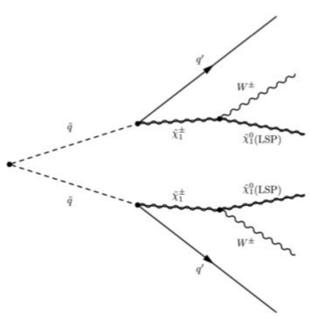
SUSY searches: “soft” leptons

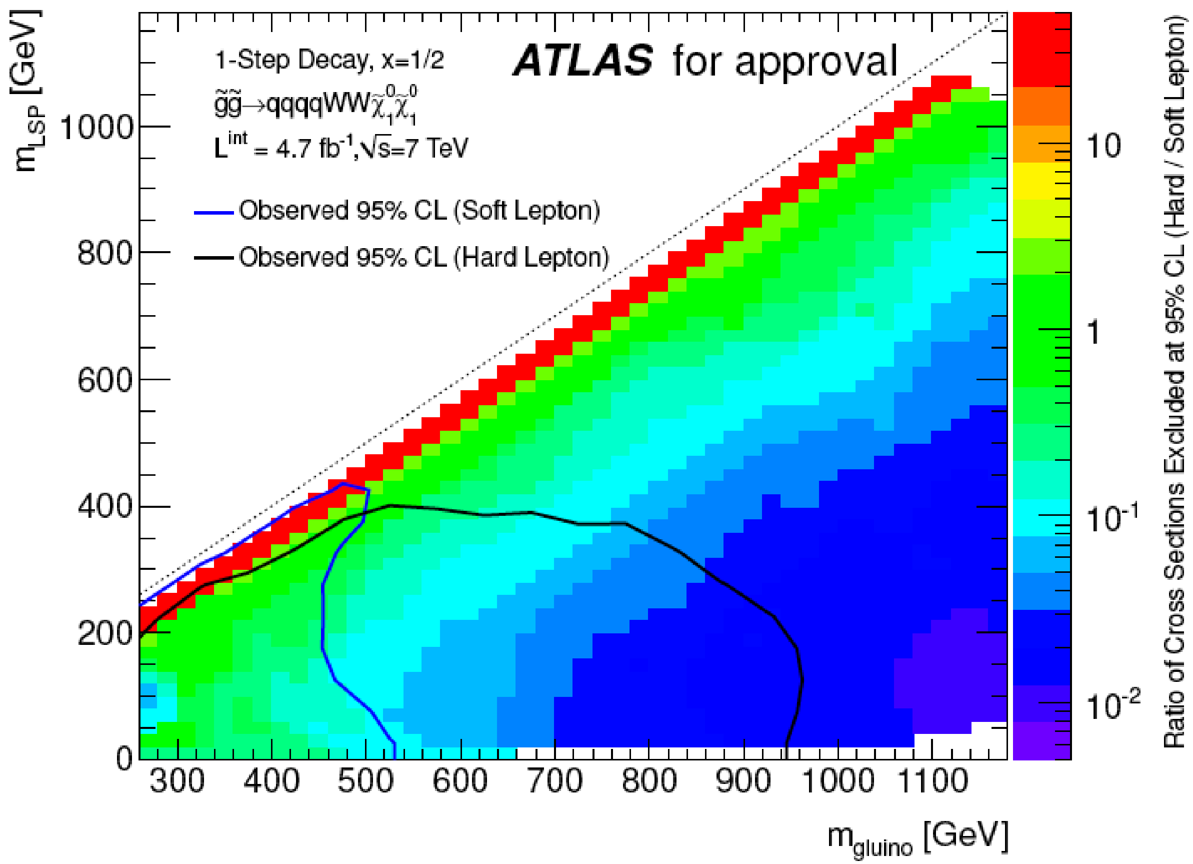
- **Dedicated search in “strong” production to deal with “compressed mass spectra (small DM)**

- **1-soft lepton + 2 jets + high MET**



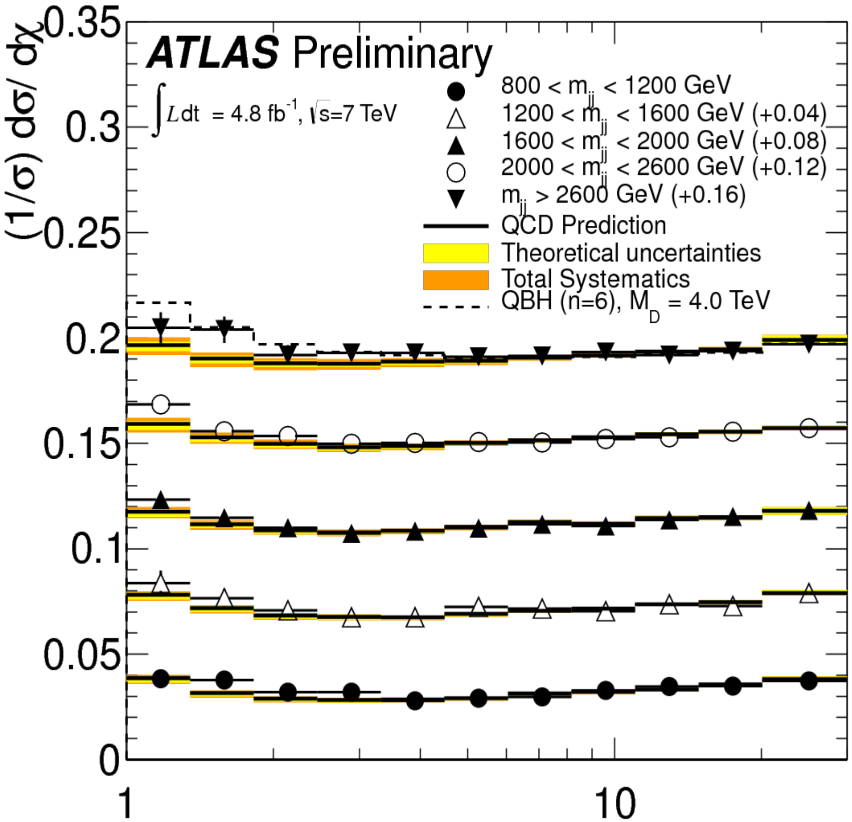
1-step simplified models leading to final states with leptons + jets + MET



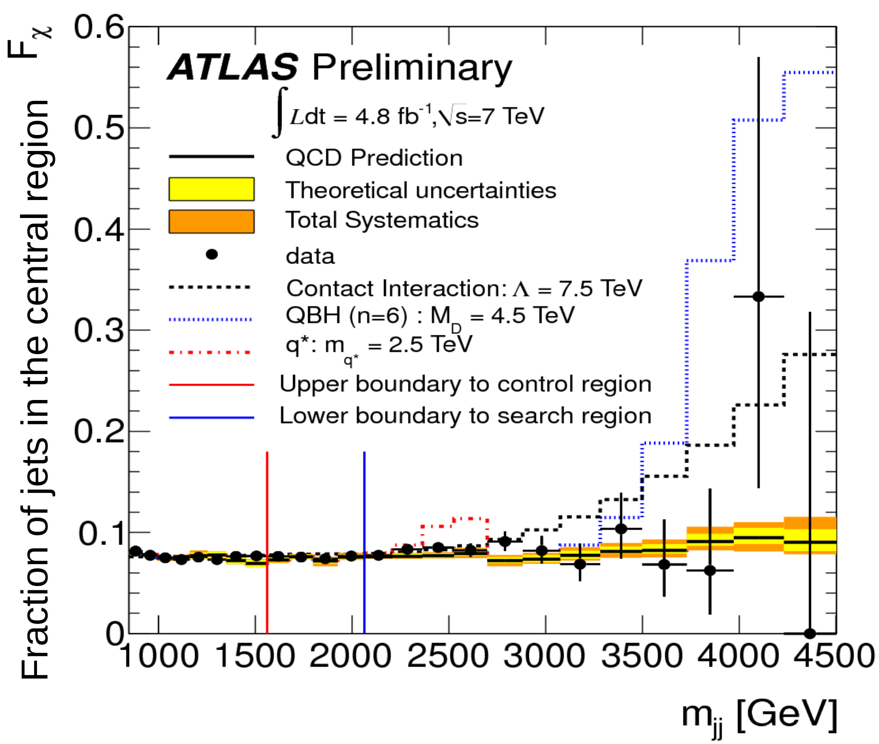


Search for deviations from QCD in the di-jet angular distributions

Deviations from the QCD expectation could reveal a substructure of the quarks ('compositeness' at scale Λ) in analogy to the famous Rutherford scattering 100 years ago



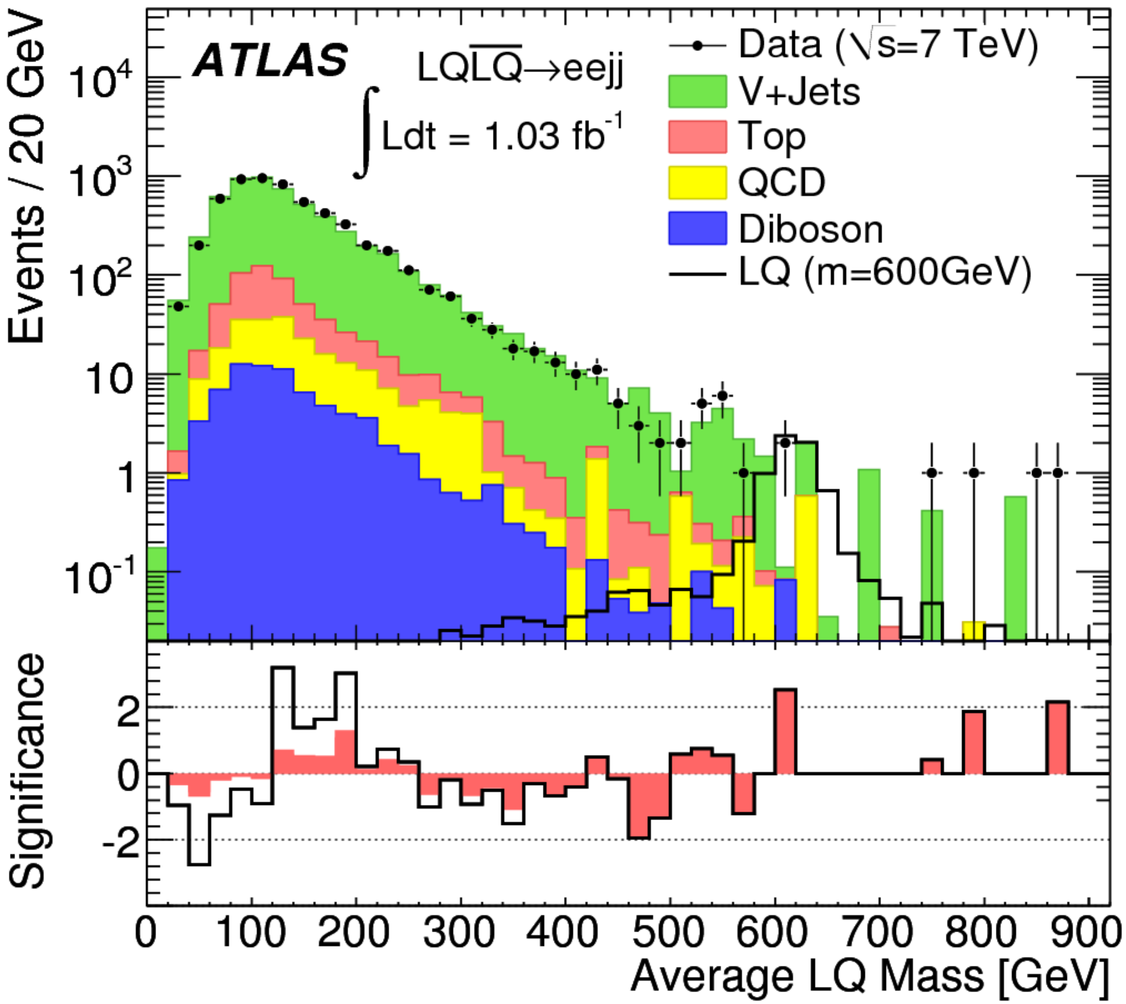
$$\chi = \exp\left(|y_1 - y_2|\right) = \frac{1 + \cos\vartheta^*}{1 - \cos\vartheta^*}$$



ATLAS-CONF-2012-038

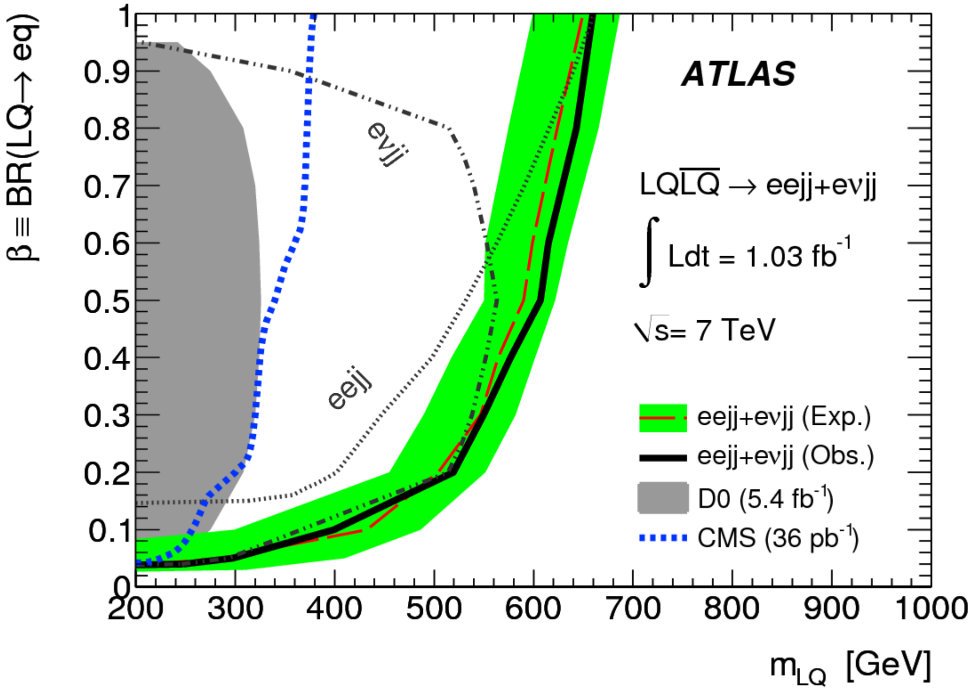
Search for Lepto-Quarks (LQ)

pp → LQ $\overline{LQ}$ → lljj or lνjj (l = e or μ)



Phys. Lett. B709 (2012) 158

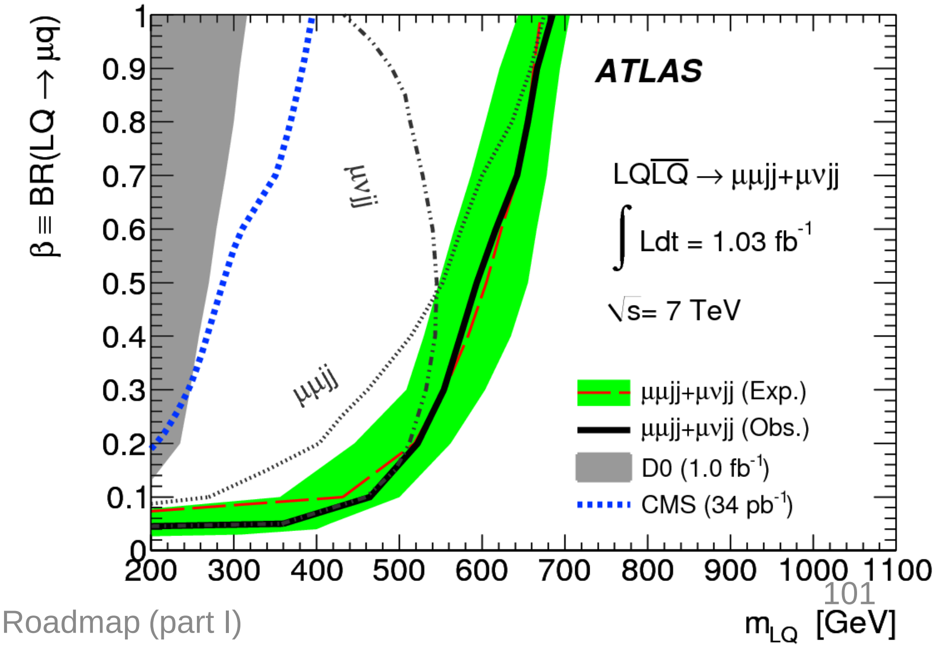
95% CL exclusion limits for Lepto-Quarks



1st generation LQ (electron-quark)

Phys. Lett. B709 (2012) 158

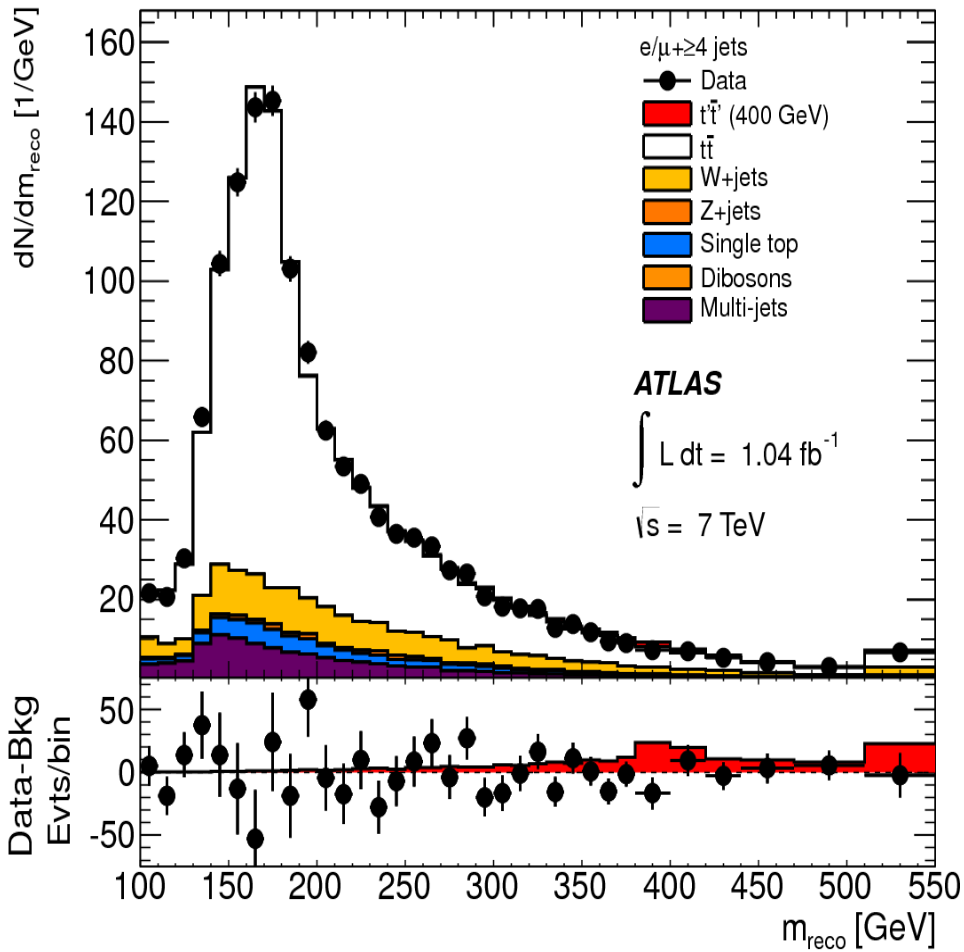
Sub. to European Physical Journal C
arXiv:1203.3172v1[hep-ex]

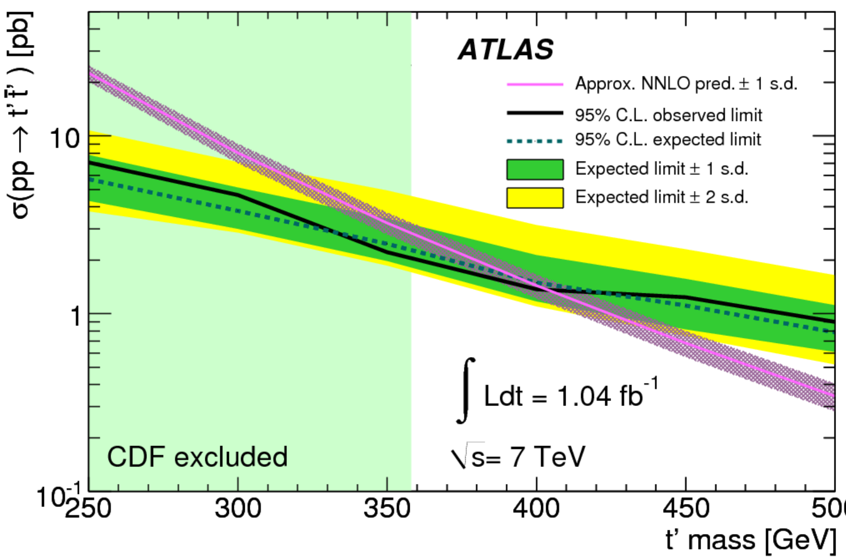


2nd generation LQ (muon-quark)

Search for New Heavy Quarks

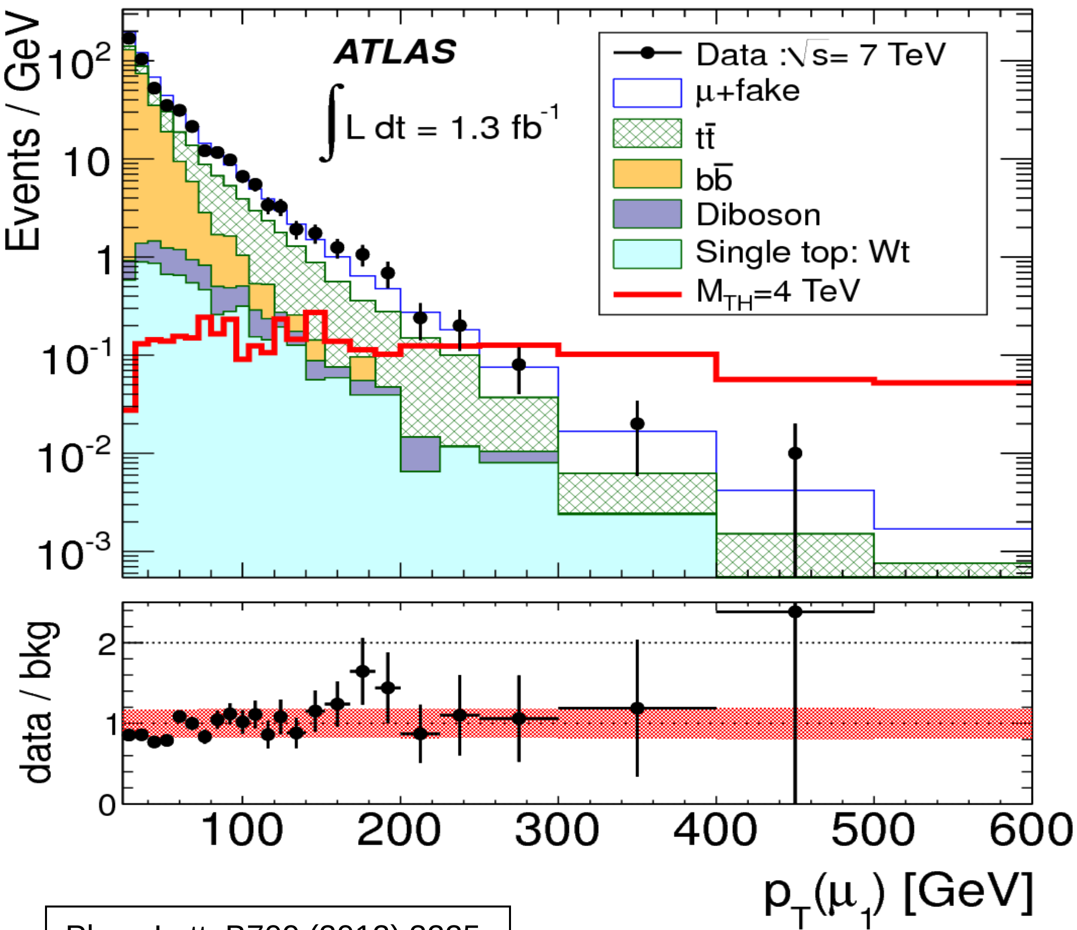
Example: pair-production of a heavy up-type quark (t') decaying into W + b





Sub. to Phys. Rev. Letters
arXiv:1202.3076v1[hep-ex]

Example 2: search for excess in same-sign di-muon states



Phys. Lett. B709 (2012) 3225

One example of many 95% CL exclusion plots: Non-rotating Black Holes with 2 or 6 extra dimensions