Performance of the LHC, ATLAS and CMS in 2011

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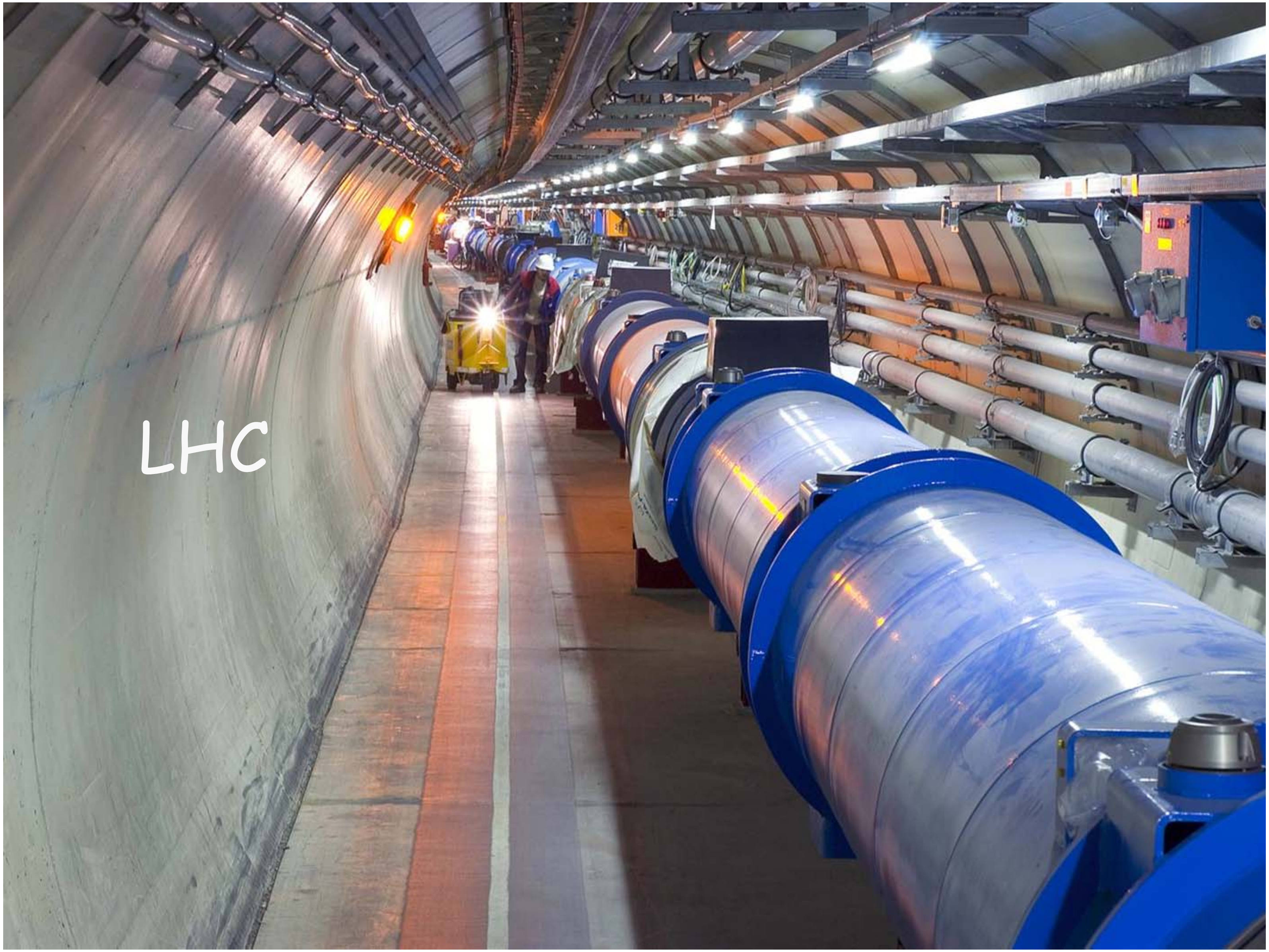
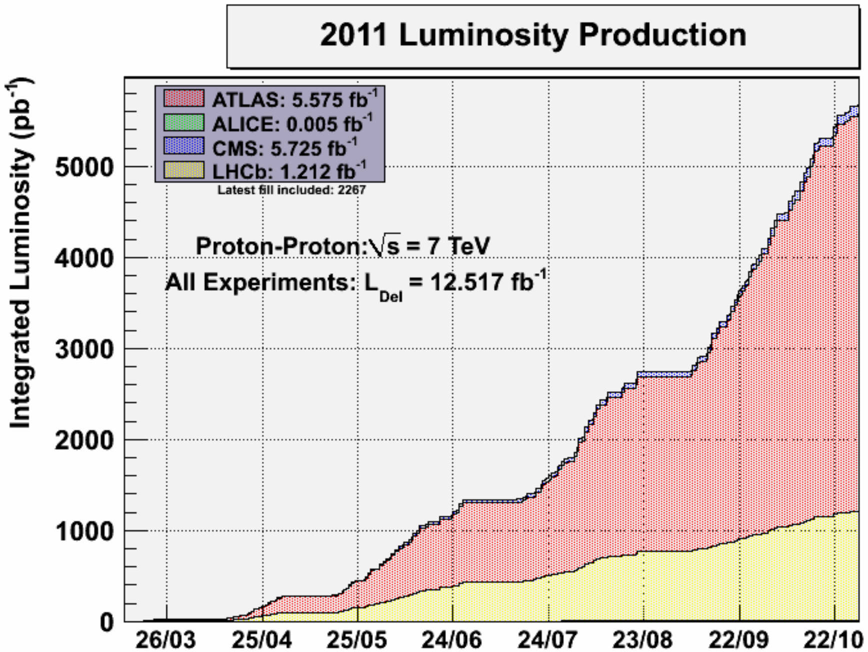

LHC

LHC performance: Beautiful !!
5.6 fb^{-1} delivered to ATLAS and CMS

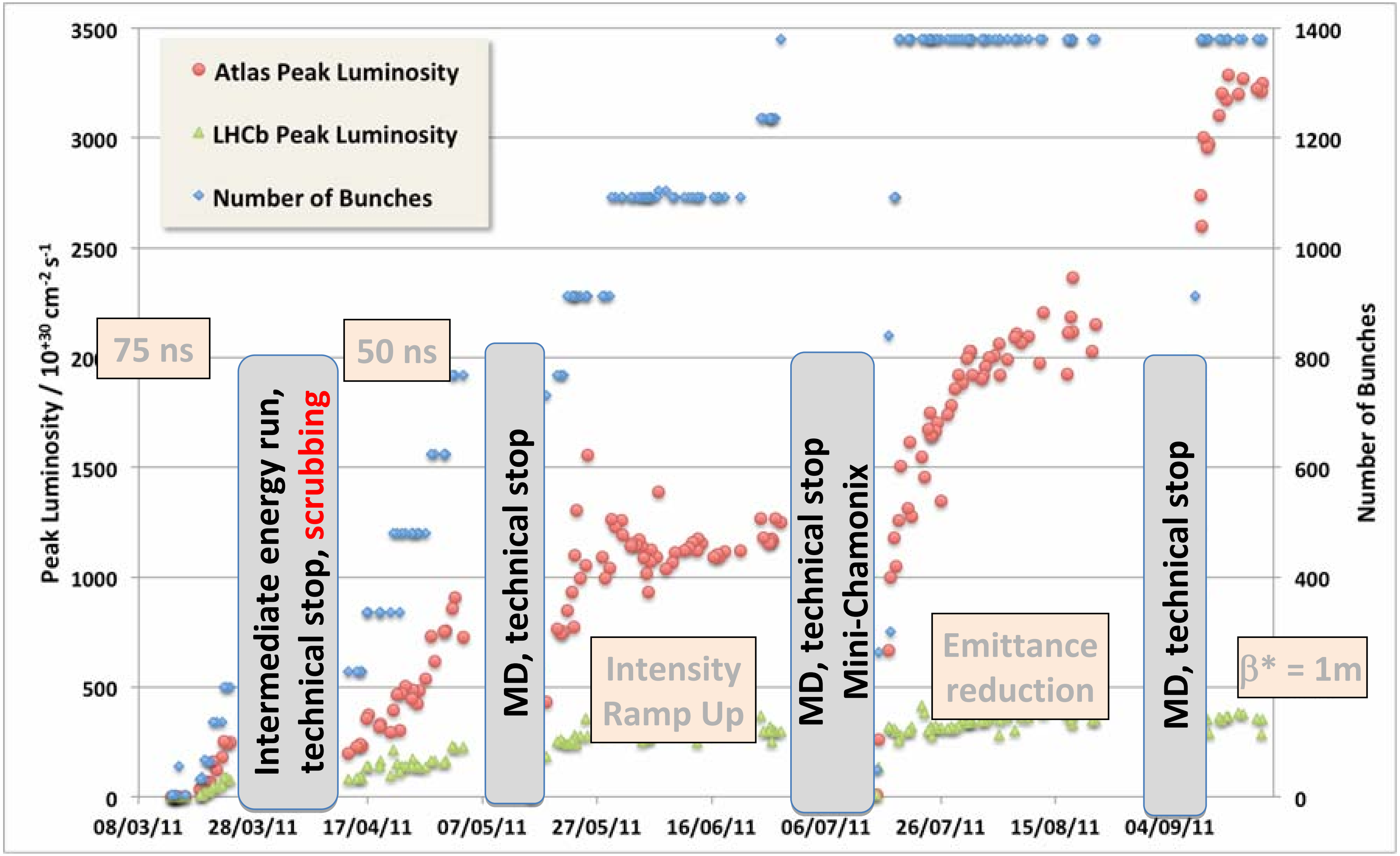


Parameter	2010	2011	Nominal
N (10^{11} p/b)	**1.2**	**1.5**	1.15
k (n bunches)	368	1380	2808
B. spacing	150	50	25
ε (μm rad)	**2.4-4**	**1.9-2.3**	3.75
β* (m)	3.5	1	0.55
L ($cm^{-2}s^{-1}$)	**2 10^{32}**	**3.6 10^{33}**	**10^{34}**
Stored Energy(MJ)	28	110	360

Crossing angle at IP 1,5 = ±120 microrads

Factor ~20 gain in Peak Luminosity wrt to 2010
thanks mainly to : number of bunches, beta*, emittance

Increase of peak luminosity over the year



From Paul Collier- LHCC/Sept 2011

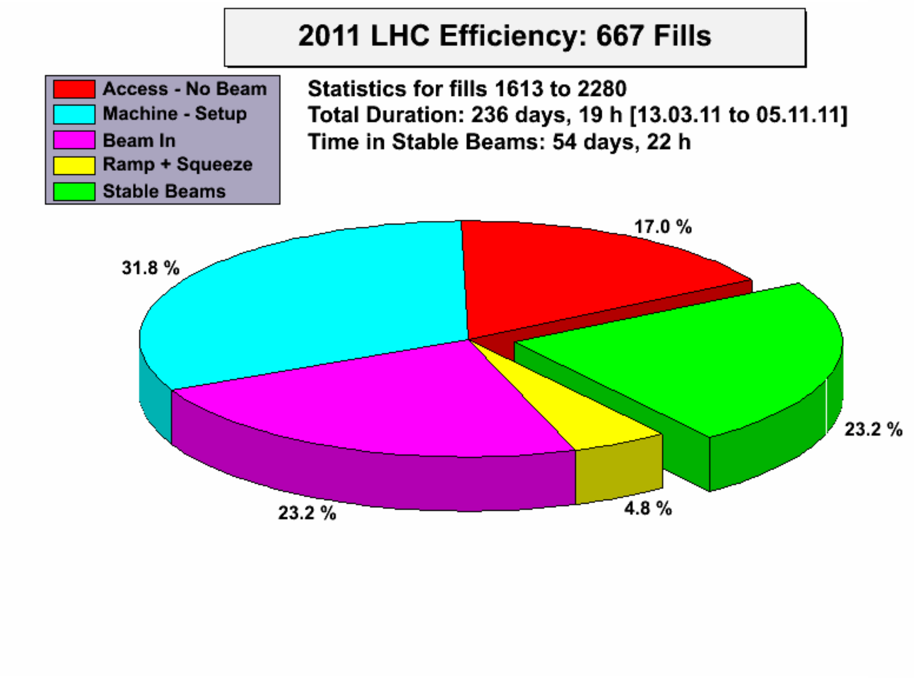
Limitations

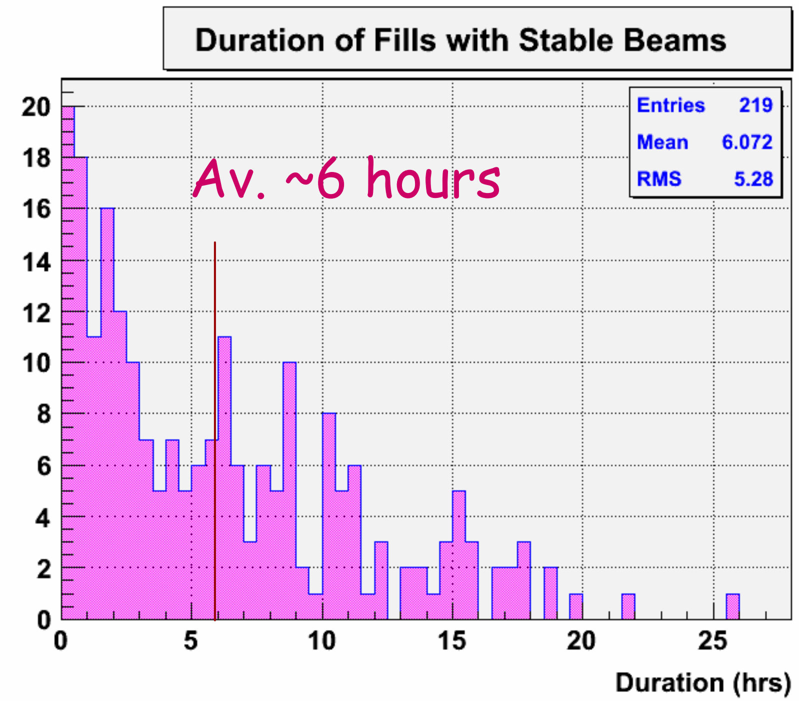
With 50 ns operation and with stored intensity of ~2×10^{14} protons (1380 bunches) a number of issues related to high intensity have started to surface:

- *Vacuum pressure increases (from "electron cloud effect")*
- *Radiation induced failures of critical tunnel electronics ("SEU"),*
- *Heating of the beam screen ,*
- *Heating of injection kickers, collimators,*
- *Losses due to (supposed) dust particles ("UFO")*
- *RF beam loading,*
- *Beam instabilities leading to emittance blow-up.*

Those effects have slowed down the pace of the intensity increase, and affected the ***machine availability****.*

Up time and fill duration

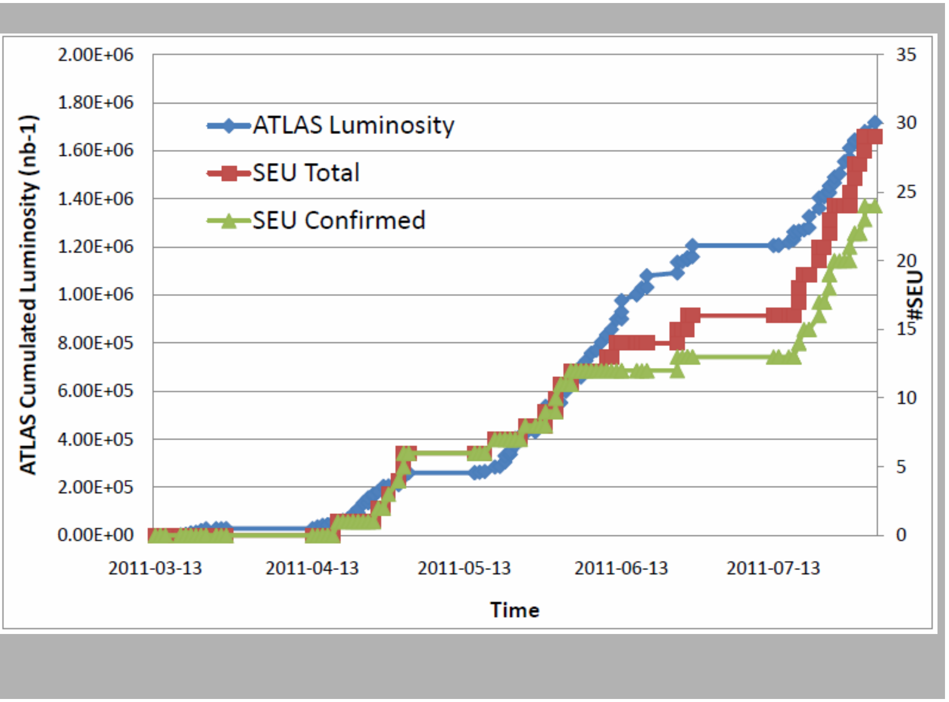


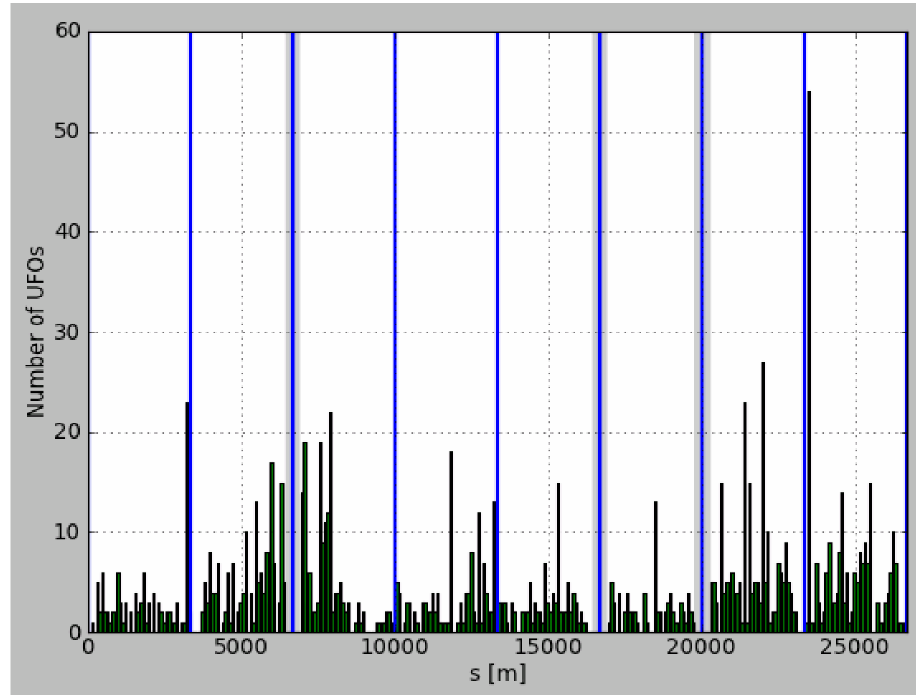


For ~50% of the time
there is beam in the machine

Optimum Fill duration would be about 12 hours
Average is around 6

SEU, UFO





Integrated number of SEU
Follows integrated luminosity

UFO at 3.5 TeV are ~evenly distributed
At 450 GeV they are concentrated around
injection kicker magnets

Luminosity normalisation

Precise measurement of:

- **size of the luminous region (VdM scan)**
- **beam intensity (BCT)**

$\}$ **--> <u>absolute luminosity calibration</u>**

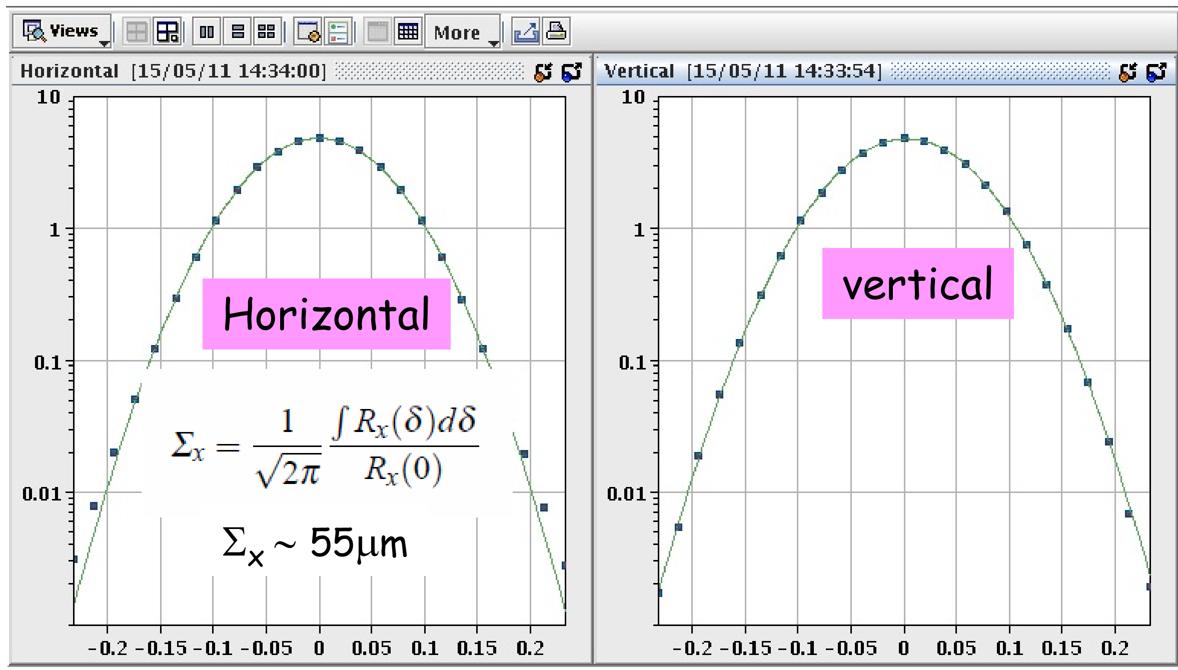
in a Reference run,where Experiment's lumi monitors are also recorded
Used to extrapolate to a whole data taking period.

$$\mathcal{L} = \frac{n_b f_r n_1 n_2}{2\pi \Sigma_x \Sigma_y}$$

n_b= nb of colliding bunches
n1,n2= nb of protons per bunch

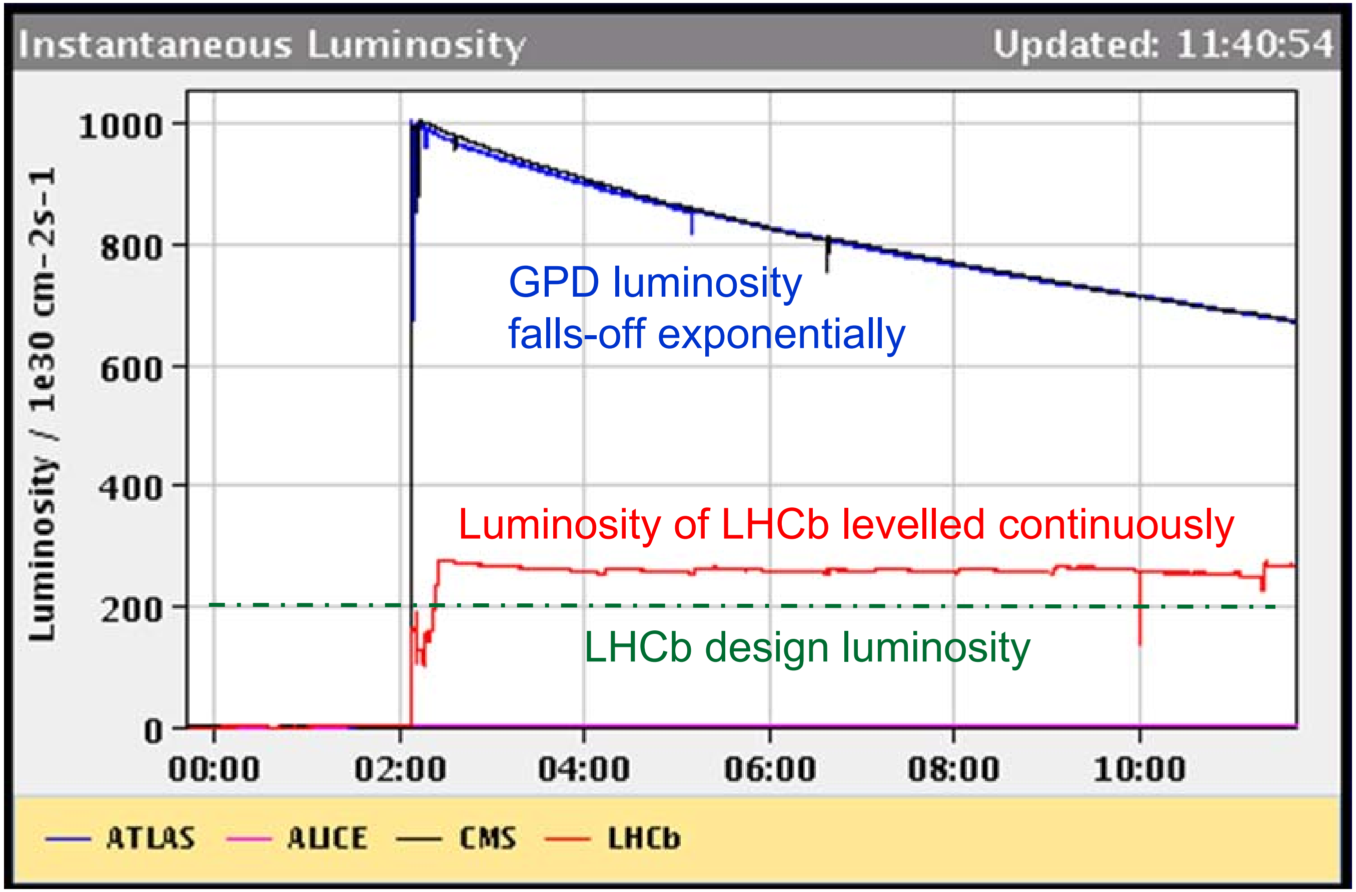
ATLAS	δL / L= 3.7 %
CMS	δL / L= 4.5 %

Dominant error from
Bunch charge current (n1xn2)



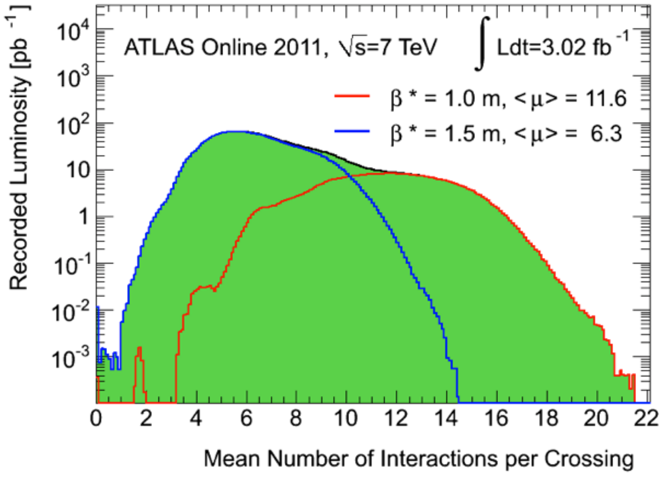
Exemple of counting rate R
during a Van der Meer scan

Luminosity leveling in LHCb



At IP8, beams are progressively moved in to maintain constant luminosity (around 2 to 3 10^{32})

Pile-up : relevant parameters



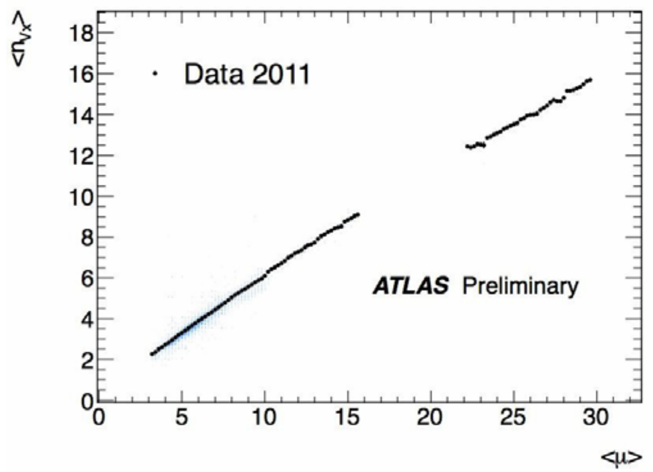
μ: luminosity-weighted mean number of interactions per crossing.

Calculated from the instant. luminosity as

Dispersion includes:

-bunch to bunch variation

-drop of L with time,



N_{VX}: number of reconstructed primary vertices for a given BC

In-time pileup : only due to collisions of a given BC

Out of Time Pile-up : superimposition of signals from preceding (and following) BC (null in average in ATLAS-LAr because of bipolar shaping)

Average value can be subtracted; of course fluctuations remain = "pile-up noise"

Special runs

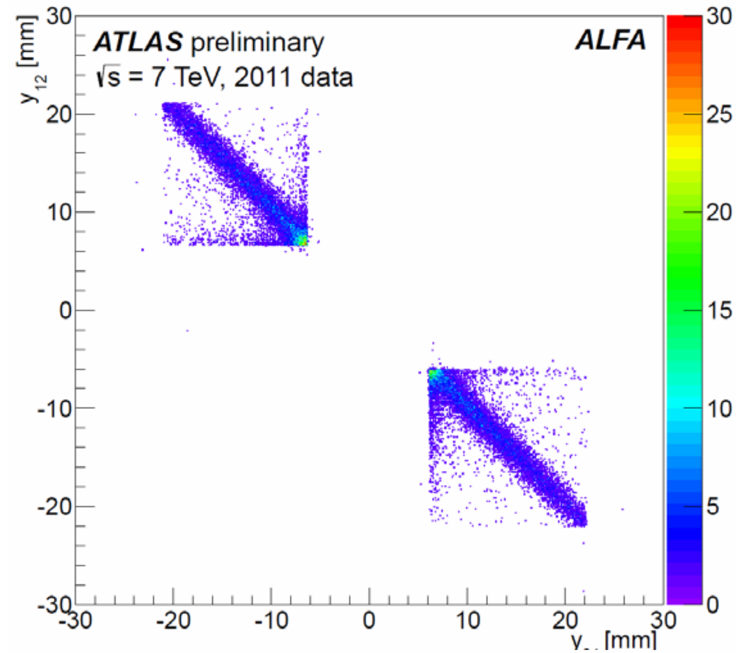
•Runs with 25 ns bunch spacing
Max reached :2100 bunches B1 and 1020 bunches B2, for scrubbing at 450 GeV
Collisions with short bunch trains, to assess trigger and pile-up conditions

•Runs with "fat bunches" (twice nominal intensity) to assess "high pile-up" in experiments
Reached $\langle\mu\rangle$ ~30

• Beta*=90 m runs (ultimate goal is 2650m to reach Coulomb interference region)
for <u>elastic scattering in ATLAS/ALFA and TOTEM</u>

ALFA: Detector (240m away) at 6.5 σ from the beam
About 1.5 millions elastic events recorded

Bunch scheme:
One bunch of 7E10 colliding.
13 bunches of 1E10 colliding.
One bunch of 7E10 non-colliding.

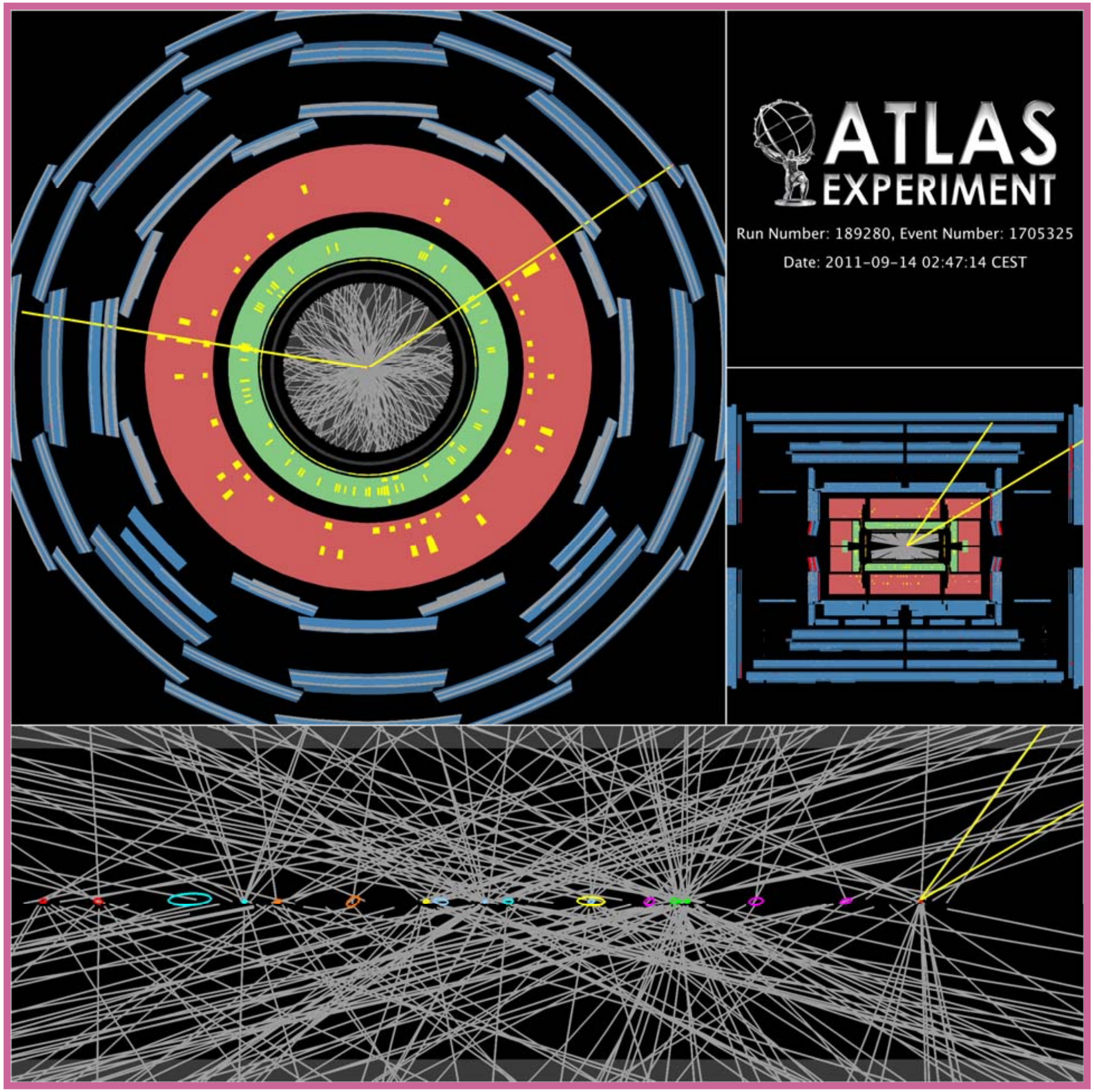


$$\theta_Y = \frac{Y}{L_Y} \quad \text{with} \quad L_Y = \sqrt{\beta_Y \beta_Y^*}\ \sin\Psi_Y$$

ATLAS…

$Z^0 \to \mu\mu$

with N_{vx}=20



ATLAS trigger at 3 10^{33}

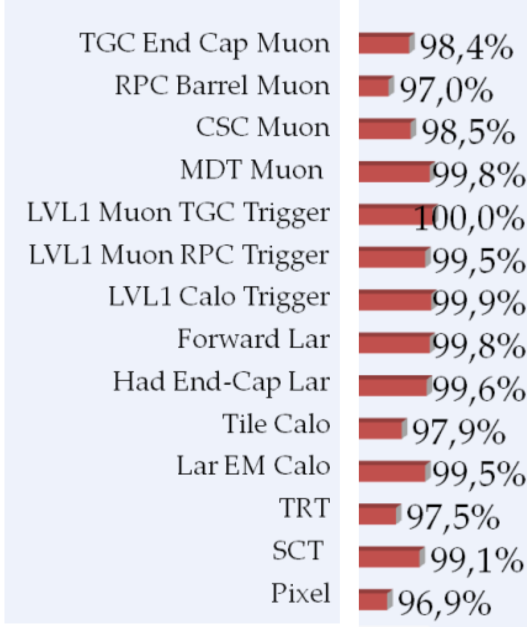
from 20 MHz
to ~ 300Hz on tape

About 4 10^{14} events "scrutinized" by trigger system !!

Trigger objects	Offline Selection (p_T thresholds)	Trigger Selection L1	Trigger Selection EF	L1 Rate (kHz) at 3 10^{33}	EF Rate (Hz) at 3 10^{33}
Single leptons	Single muon> 20 GeV	11 GeV	18 GeV	8	100
	Single electron > 25 GeV	16 GeV	22 GeV	9	55
Two leptons	2 muons> 4 GeV	11 GeV	15,10 GeV	6	5
	2 electrons, > 15GeV	2x10 GeV	2x12 GeV	2	1.3
	$2\tau \rightarrow h$> 45, 30 GeV	15,11 GeV	29,20 GeV	7.5	15
Two photons	2 photons,> 25 GeV	2x12 GeV	2x20 GeV	3.5	5
E_T^{miss}	E_T^{miss}> 170 GeV	50 GeV	70 GeV	0.6	5
Multi-jets	5 jets, > 55 GeV	5x10 GeV	5x30 GeV	0.2	9
Single jet plus E_T^{miss}	Jetp_T> 130 GeV& E_T^{miss}> 140 GeV	50 GeV& 35 GeV	75 GeV& 55 GeV	0.8	18
Total rate (peak)	In total more than 350 lines in menu…			55 kHz	550 Hz

ATLAS : Data quality/efficiency

Channels "alive"



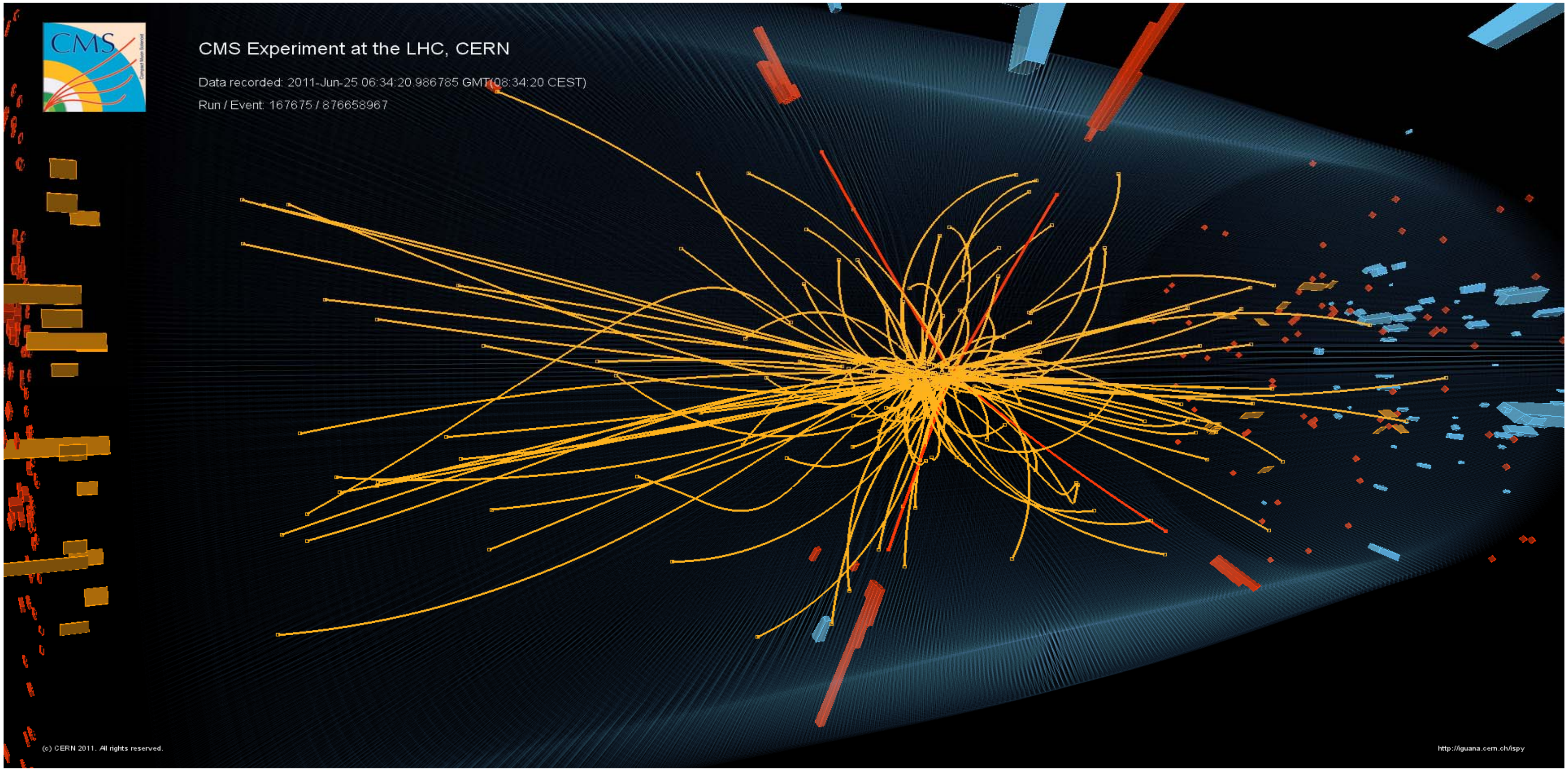
Sub-system "operationnal"

Inner Tracking Detectors			Calorimeters				Muon Detectors				Magnets	
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.9	99.8	100	96.3	98.6	98.9	99.7	99.8	99.8	99.8	99.7	99.3	99.0

Luminosity weighted relative detector uptime and good quality data delivery during 2011 stable beams in pp collisions at √s=7 TeV between March 13th and June 29th (in %). (after reprocessing)

DAQ efficiency : 5.25 / 5.62 (93.5%)
Calibration loop : 48 hours
Processing at Tier0 : 3000 CPU cores (~20 sec/evt for <mu>= 15)
Reprocessing campaign in Aug/Sept:
0.9 Gevents processed in Tiers 1

CMS…

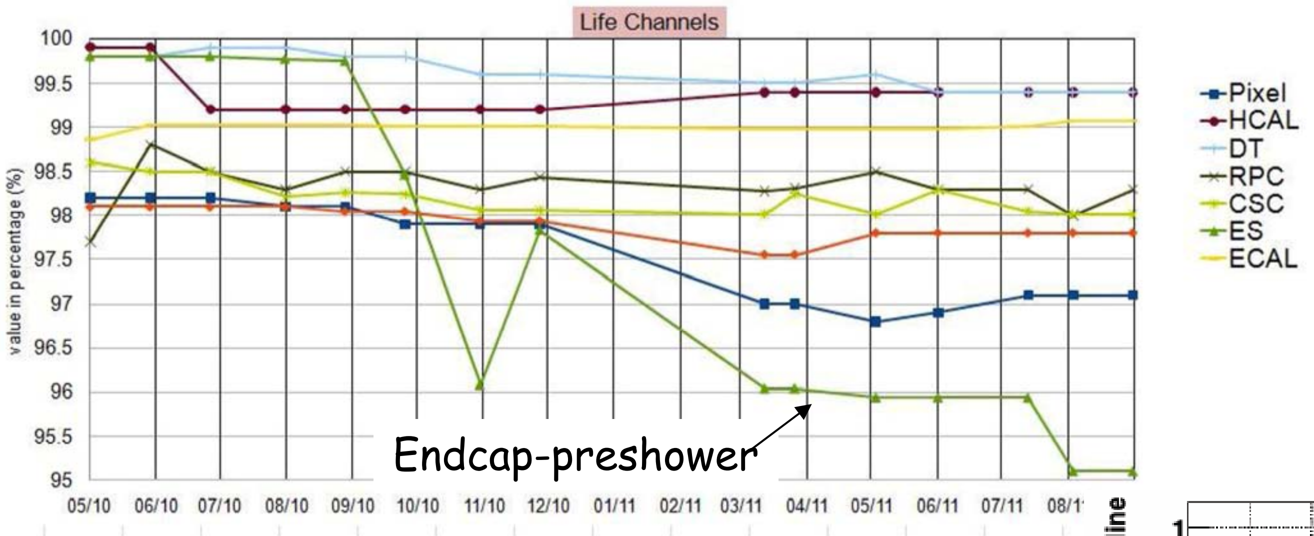


4-electron event
(ZZ candidate)
-tracks and EM clusters in red

CMS trigger

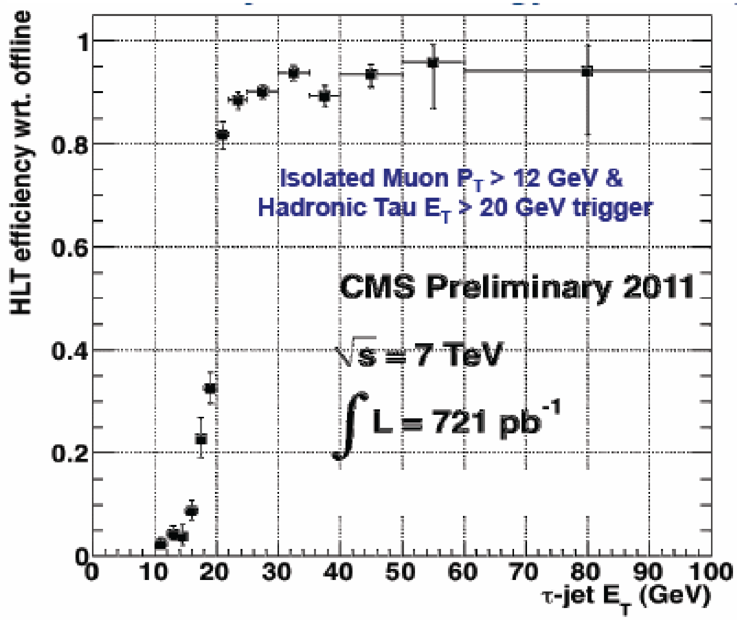
Trigger objects	Offline Selection (p_T thresholds in GeV)	Trigger Selection		L1 Rate (kHz) at 3×10^{33}	HLT Rate (Hz) at 3×10^{33}
		L1 (GeV)	HLT (GeV)		
Single leptons	1 mu (e) > 35 (70)	14 (20)	24 (32)	6 (6)	34 (10)
Two leptons	2 mu (e)> 20, 10	2x3.5 (12,5)	17, 8	5 (7)	8 (5)
	mu & e > 20, 10	12,5 (0,12)	17,8 (8,17)	2 (2)	4 (9)
	$2\tau \rightarrow$ h> 50	2x44	2x45	3	2
Two photons	2 photons> 40, 30	12,5	26,18	7	8
E_T^{miss}	E_T^{miss}> 150	30	120	4	3
Multi-jets	4 jets, > 80	4x28	4x70	2	9
1 jet + E_T^{miss}	Both > 100	E_T^{miss}>30	80, 80	4	9
3 jets + e or mu	Jets > 40, e/mu > 30/20	e/mu > 20/14	J=30, 25/17	7/5	3/1
Peak [avg]rate	In total more than 400 paths in Menu			80[70]	400[300]

CMS:Data quality/efficiency,Trigger turn on

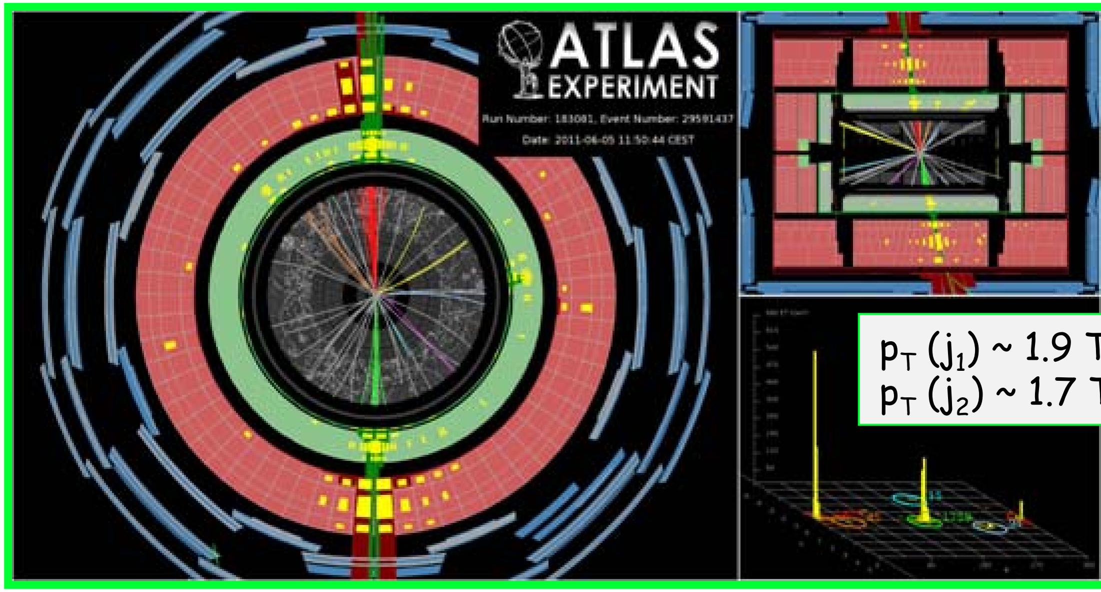


- LVL1 rate ~ 80 kHz (start of fill)
- 10 k HLT CPU cores
  for > 400 single and multi-objects path
- 400 Hz recording

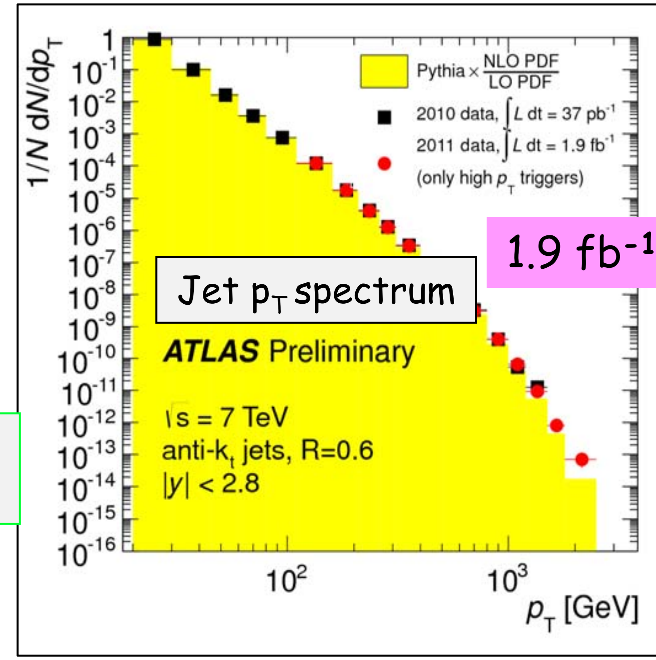
Muon>12 GeV
& hadronic tau



ATLAS : Jets and QCD



p_T (j_1) ~ 1.9 TeV
p_T (j_2) ~ 1.7 TeV

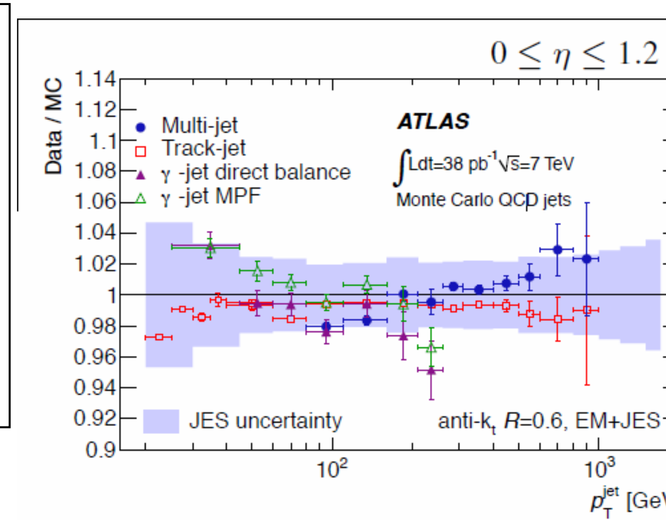


Jet p_T spectrum

1.9 fb^{-1}

Jets
- Reconstructed with anti-kT algo, R=0.6 (often R=0.4)
- Vectorial sum of clusters of calorimeter cells, corrected for hadronic/electromagnetic response, and E-loss in dead material

Energy scale
- From single hadrons measurement, in situ(E/p) and test beam
- 2.5% uncert.(2010) in wide kinematic range ; ultimate Goal 1%
- Validated using in situ methods(γ-jets, multijet balance, track-jets,..)



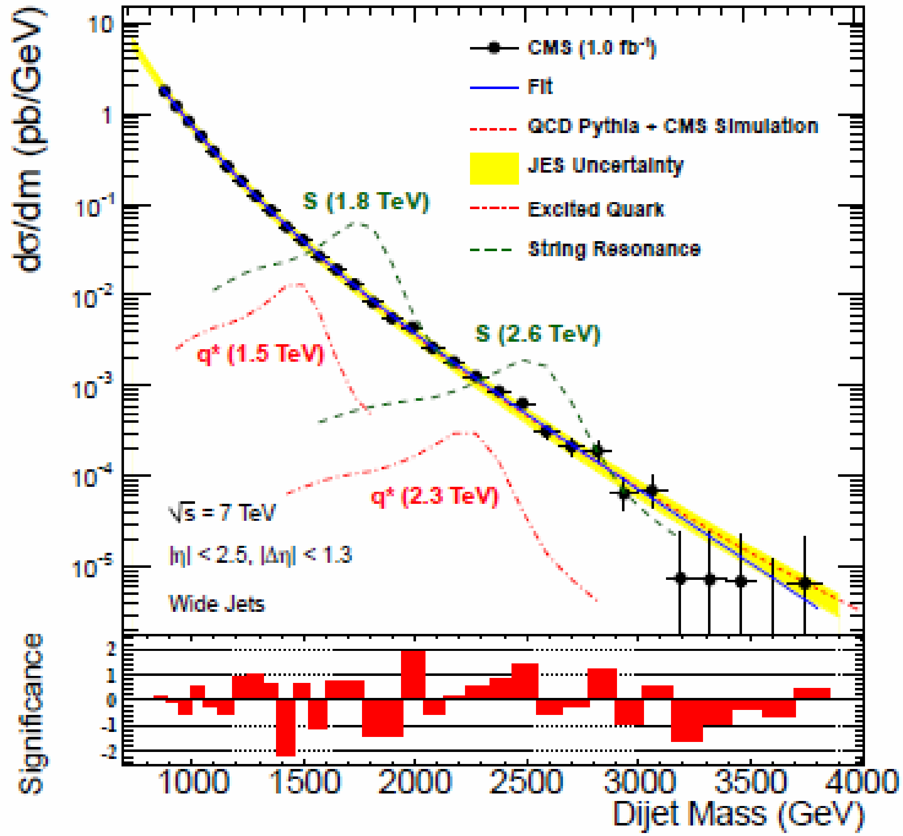
CMS: di-jets and limits on Q*

1 fb^{-1}

<u>Jets</u>
Reconstructed with anti kT R= 0.5
From <u>Particle Flow</u> clusters.
(smaller jets added afterwards
"jet grooming")
<u>Invariant mass of 2 jets of higher pT</u>

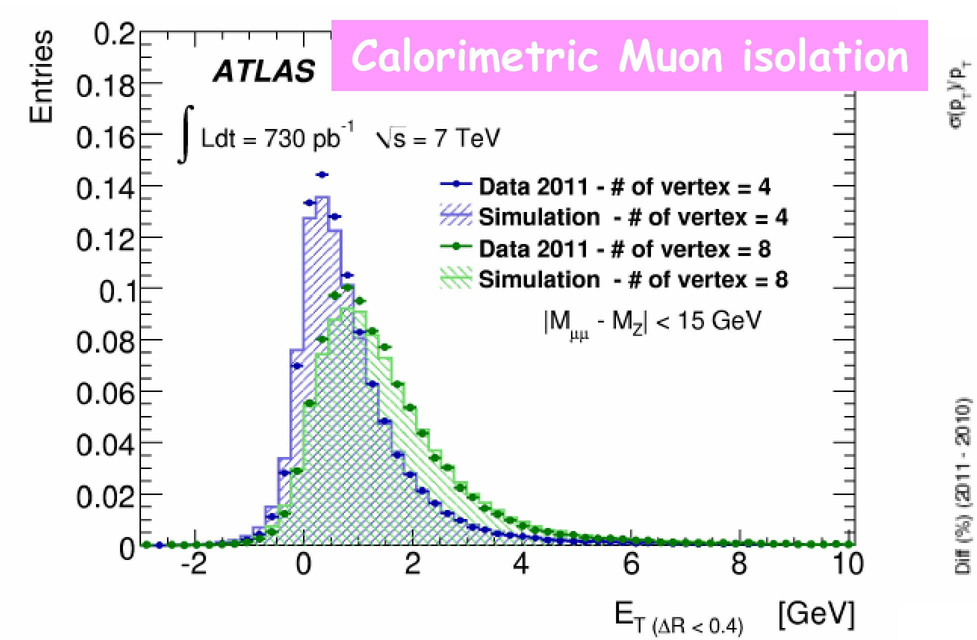
Good agreement with PYTHIA
(kfactor=1.33)(with CTEQ6L1 PDFs)

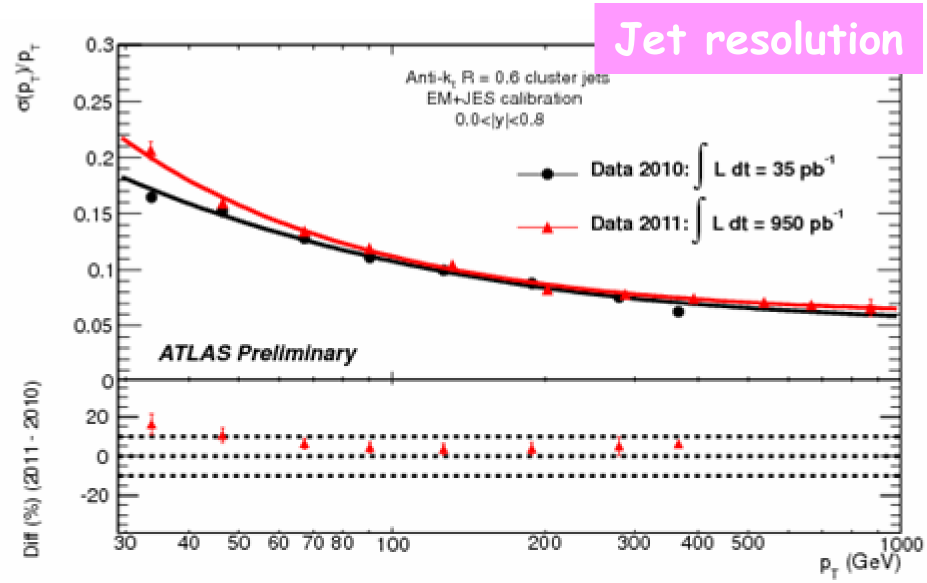
<u>Fit of smooth function</u> allows to exclude :
-Excited quarks < 2.49 TeV (2.68 exp.)
-Axigluons < 2.47 TeV (2.66 exp.)
-W' < 1.51 TeV (1.40 exp.)



Impact of pile-up-ATLAS

- Do not expect a significant impact on tracking, nor muons, nor even electrons and photons
- Except **isolation**
- But sizable impact on **jets ($+E_T^{miss}$)**



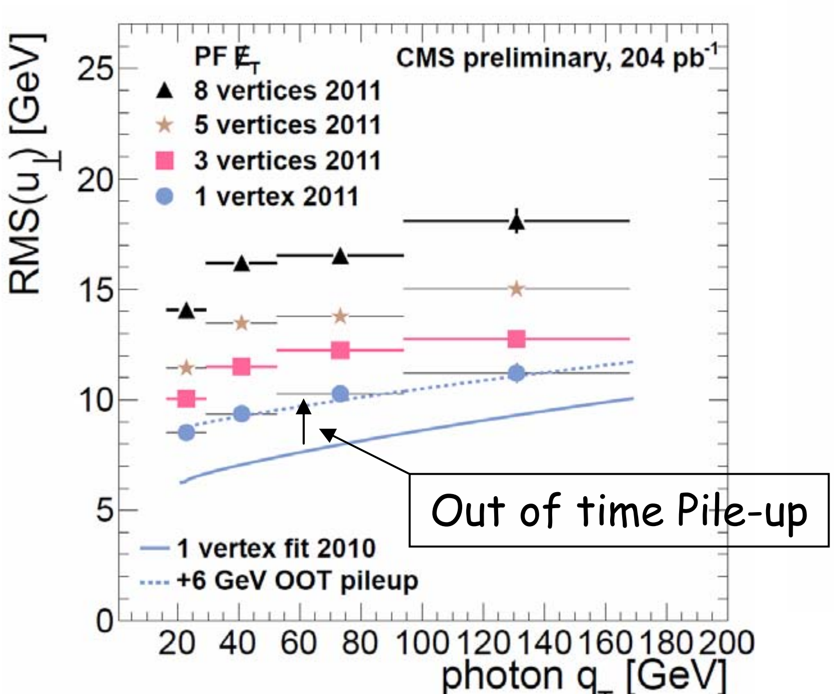


- Ambient average value can be subtracted
- Width increases by factor ~2 from 1 to 12 VXs

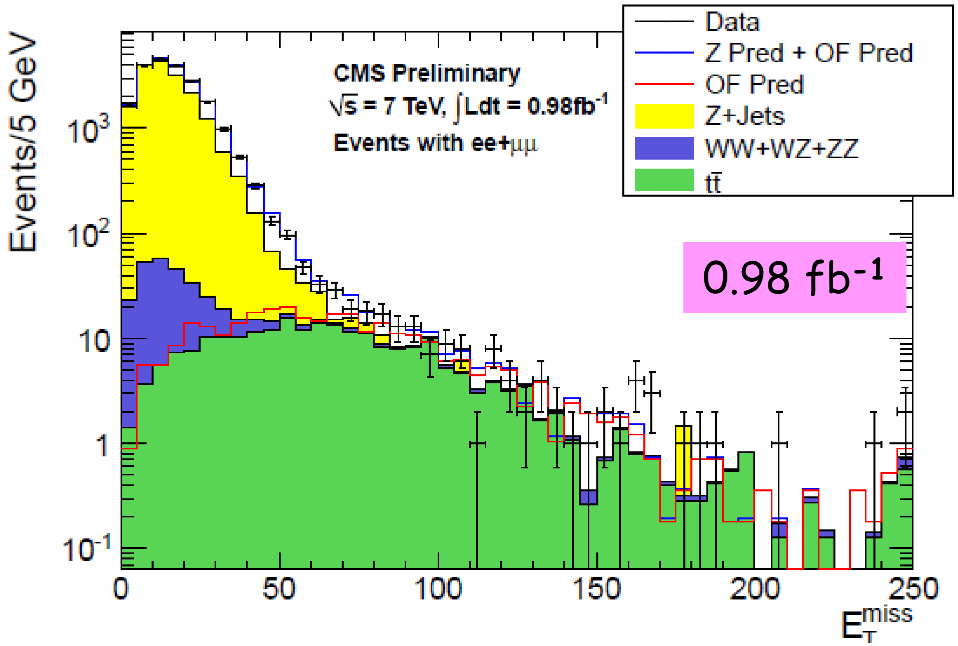
- At most 10% worsening of <u>resolution</u> at low energy without any pile-up correction.
- <u>E-scale</u> uncertainty increased temporarily (FWD jets)

Impact of Pile-up on Missing ET- CMS

Photon-jet events



Z+2-jets events



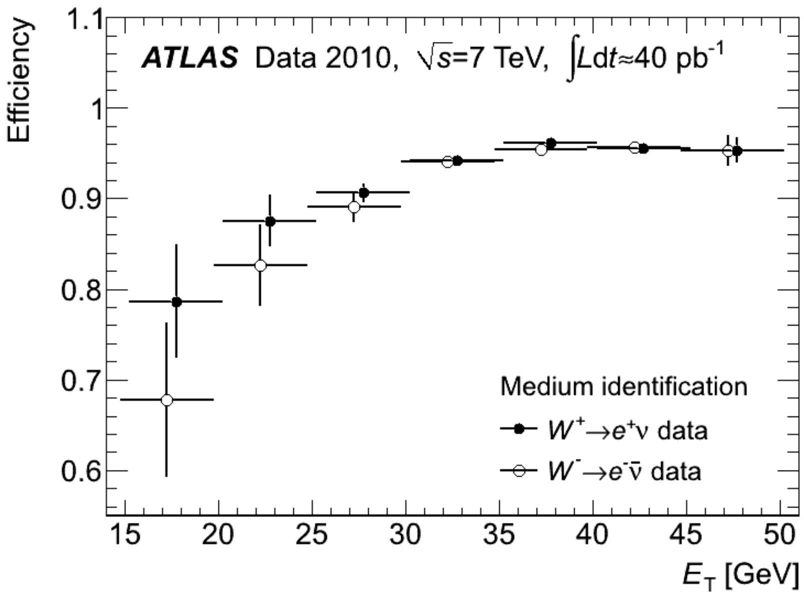
Resolution of component transverse to photon direction significantly worsened by pile-up.
No corrections yet

- Etmiss tail above ~70 GeV dominated by t-t bar(red histo)
- No "spill-out" from "genuine " Z+jets"

EWK Physics in ATLAS

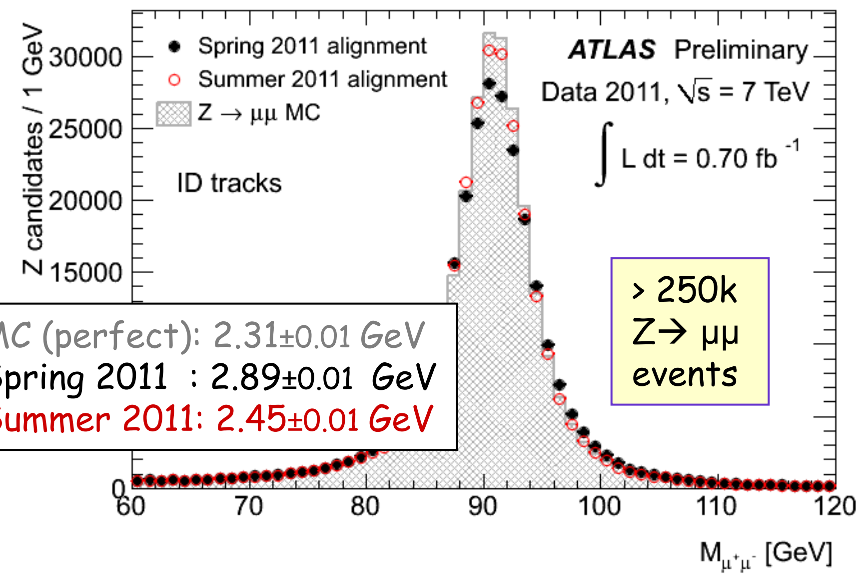
Present dataset (~ 5.2 fb^{-1}) contains:
~ 100k top-pair events (with ≥ 1 lepton)
~ 3 M Z → ee, μμ events
~ 35 M W → eν, μν events

Also a " Gold mine"
for calibration of Physics objects
low/medium energy leptons
Low/medium energy jets/Etmiss



Electron efficiency:
More work needed at low pT !

Improving the Z→μμ mass resolution

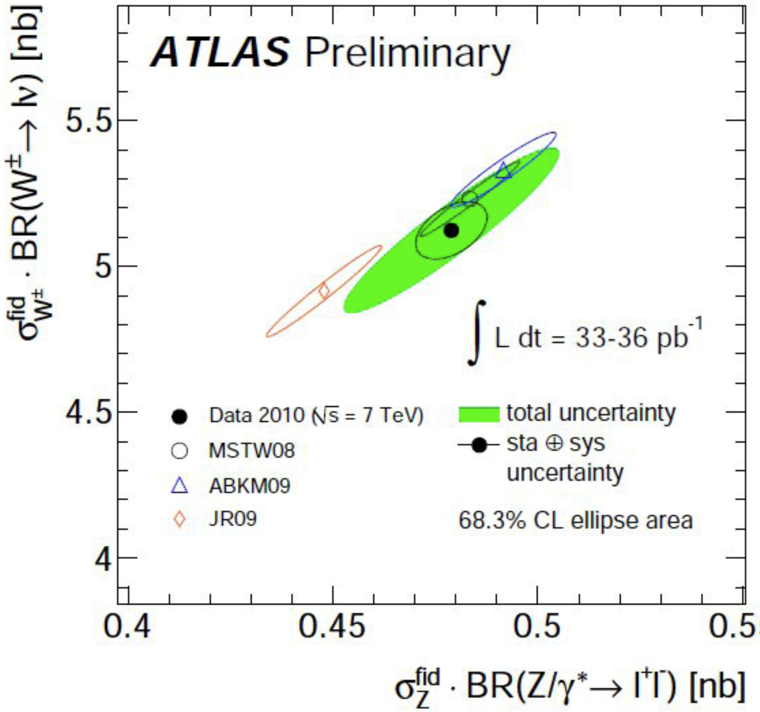


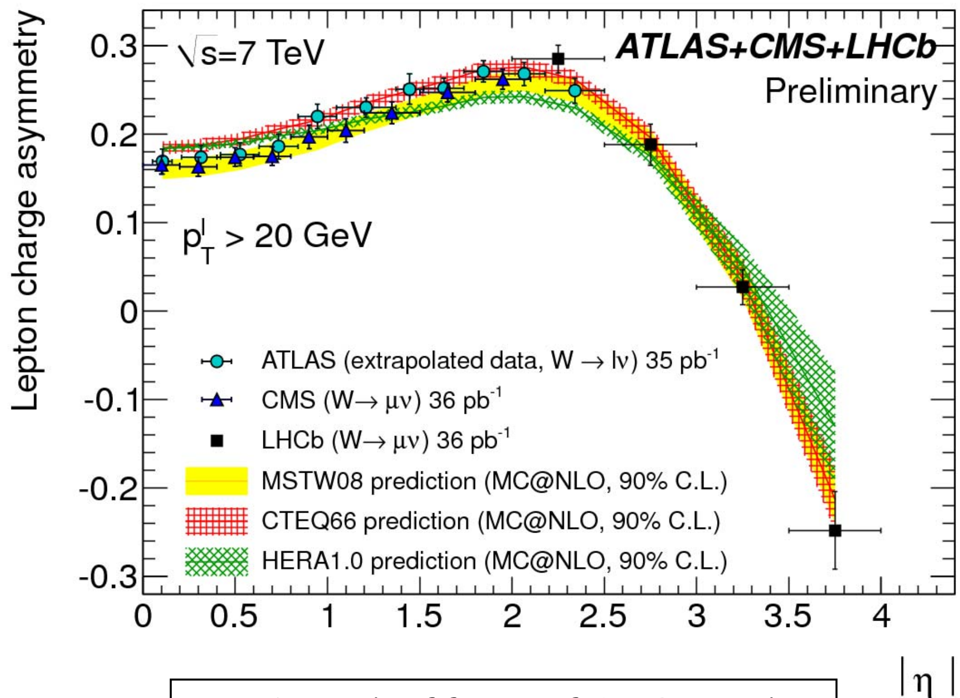
MC (perfect): 2.31±0.01 GeV
Spring 2011 : 2.89±0.01 GeV
Summer 2011: 2.45±0.01 GeV

> 250k
Z→ μμ
events

Z→μμ resolution also used for MS alignment.
Alignment today: barrel=50,EC=100,goal=40μm

EWK Physics: W/Z cross-section in ATLAS and asymmetry from ATLAS, CMS, LHCb



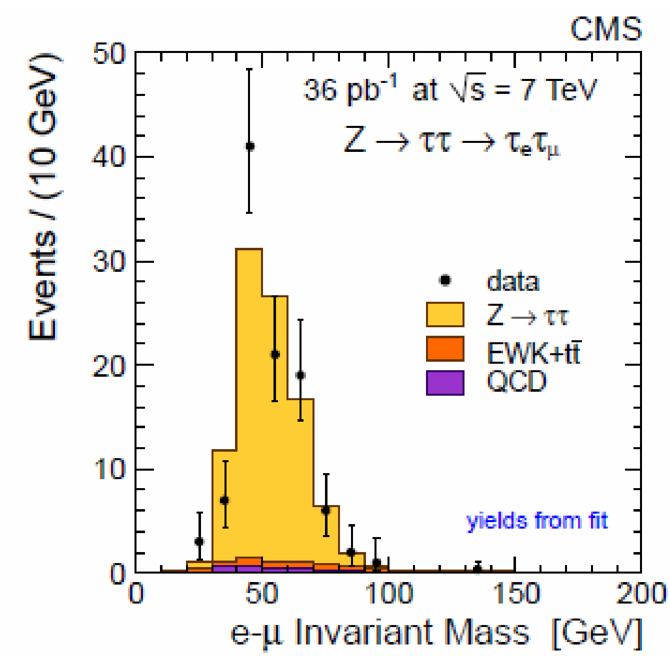


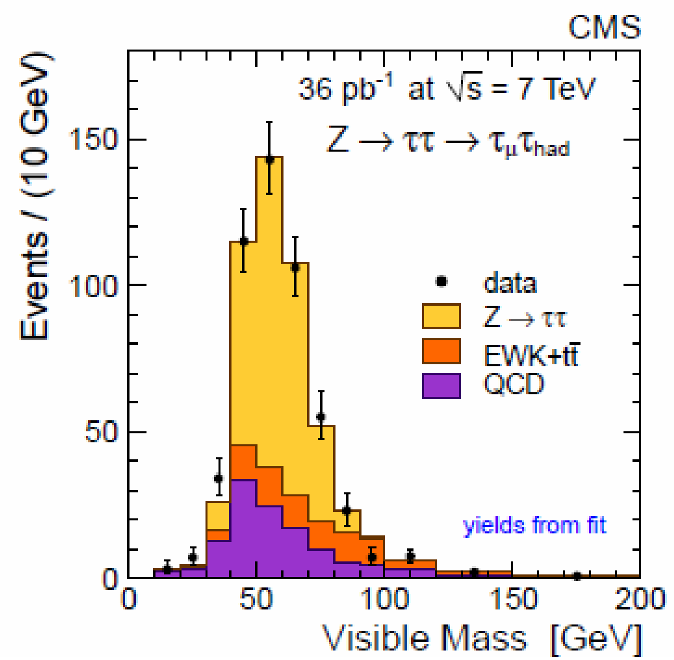
Combined effect of PDFs and W polarisation ⊗ (V-A)W decay

Both measurements have quantitative implications on PDFs already with 40 pb^{-1}

EWK Physics: Exemple of $Z \to \tau\tau$ in CMS

2010 data
Best modes are e-μ and μ-had
Electrons and muons required to be isolated Eiso/Elep< ~0.1 in Δ R=0.3
Hadronic mode: at least one charged hadron, Large isolation cone ΔR=0.5
PTlept>15 GeV, PThad>20 GeV
MT(lept,ETmiss)< 50 GeV





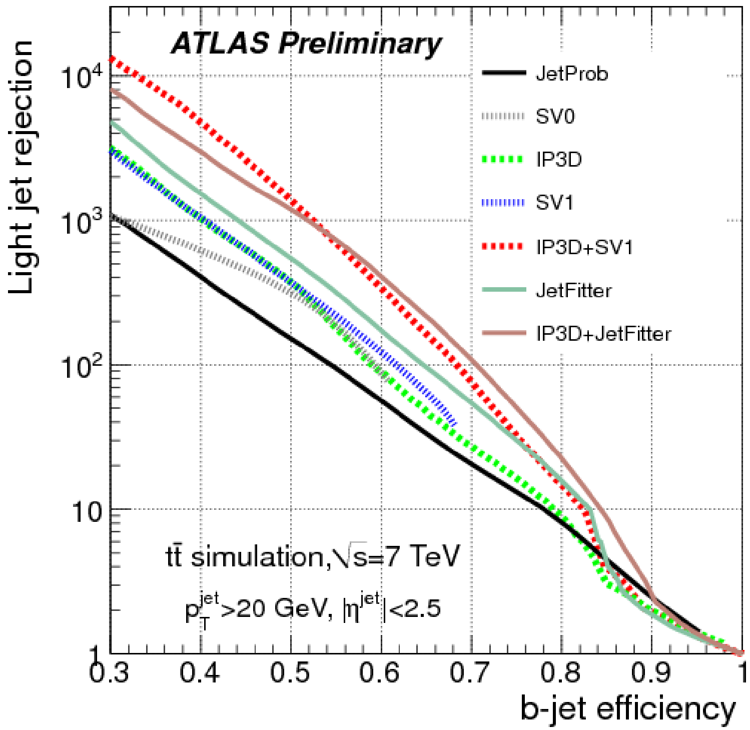
σ. BR(nb)= 1.00 ±0.05(stat)±0.08(syst)±0.04(Lumi)

Similar in ATLAS (not shown)

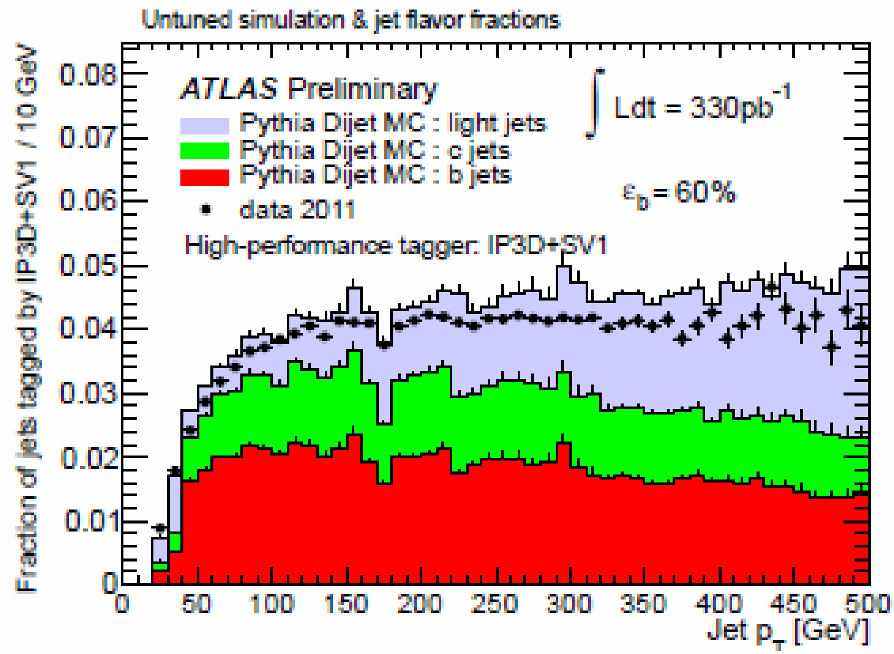
Fully compatible with $Z \to \mu\mu$ and $Z \to ee$

B-tagging : a key to top, Higgs,..ATLAS exemple

IP3D + SV1 an "advanced" tagging method validated with 2011 data



Best performance for jets around 100 GeV



IP3D: impact parameter in rϕ and z

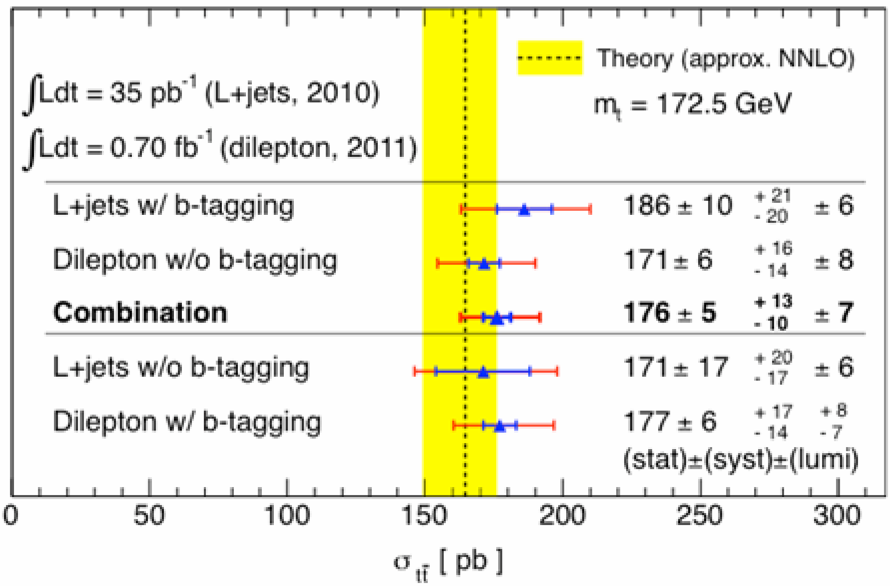
SV1 : secondary vertex + "vertex mass"+..

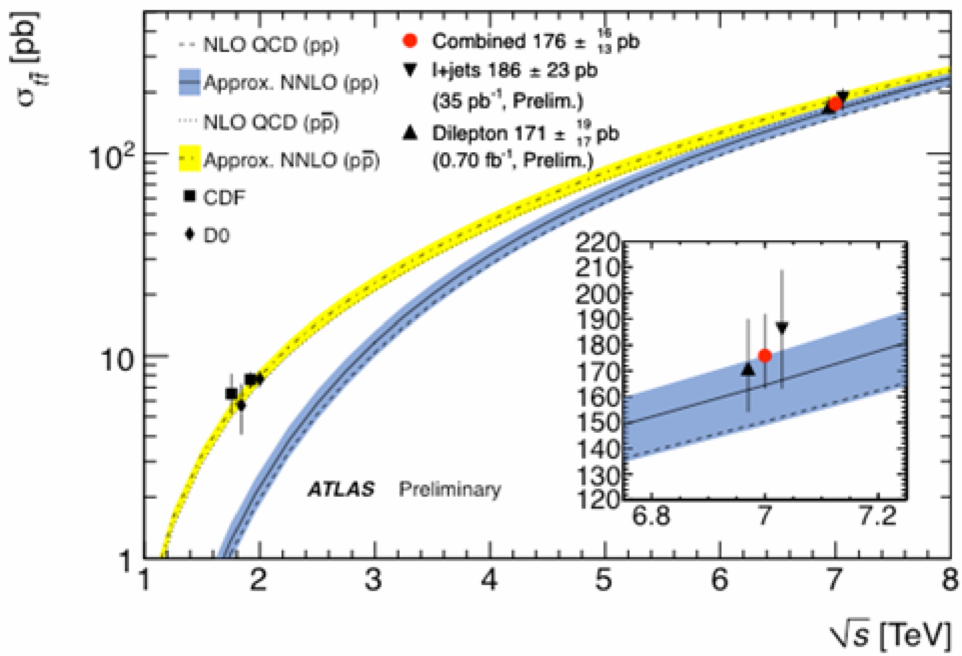
Likelihood ratio of PDF representing b-jets and light jets

($\sigma_{b\text{-jets}}/\sigma_{\text{-incl}}$ ~4%)

At 60% efficiency,IP3D+SV1 has a rejection ~4 times larger than SV0

t-t bar cross-section and mass





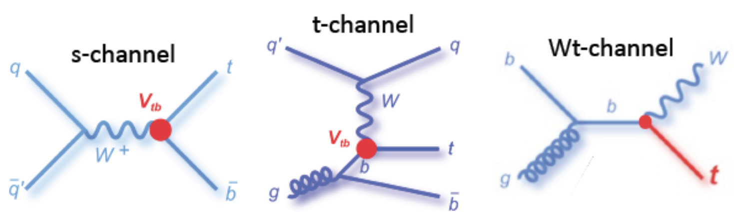
ATLAS	σ = 176±5(stat)+13-10±7 pb
CMS	σ = 164±3±12±7 pb

- Mtop systematics dominated by ISR/FSR and b-jet Escale
- Only < 1 fb^{-1} analysed

ATLAS	Top mass: M= 175.9 ± 0.9 ± 2.7 GeV
CMS	Δm (t-tbar)= -1.20±1.21(stat)±0.47(syst) GeV

Average Tevatron
Mt= 173.2±0.6± 0.9 GeV

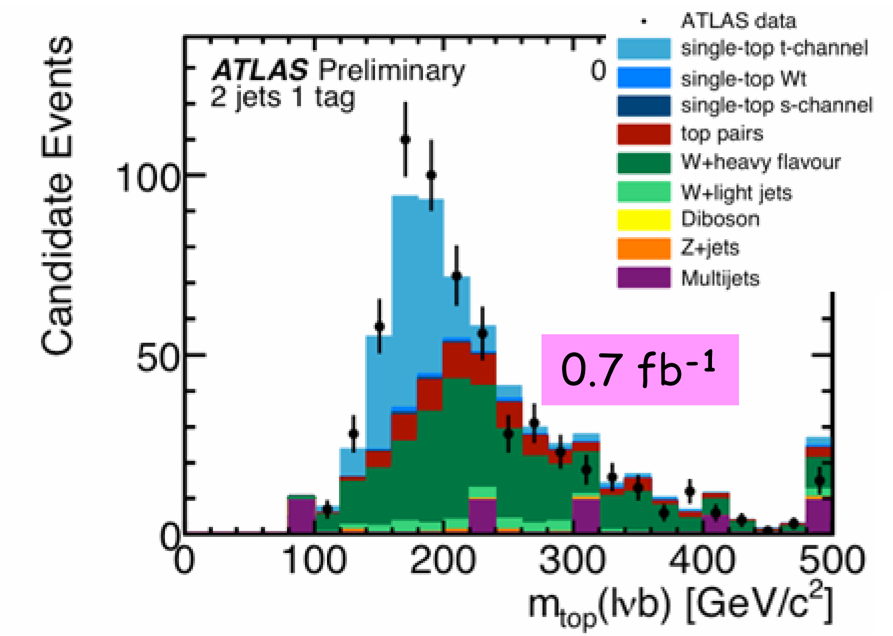
ATLAS: single top in t-channel



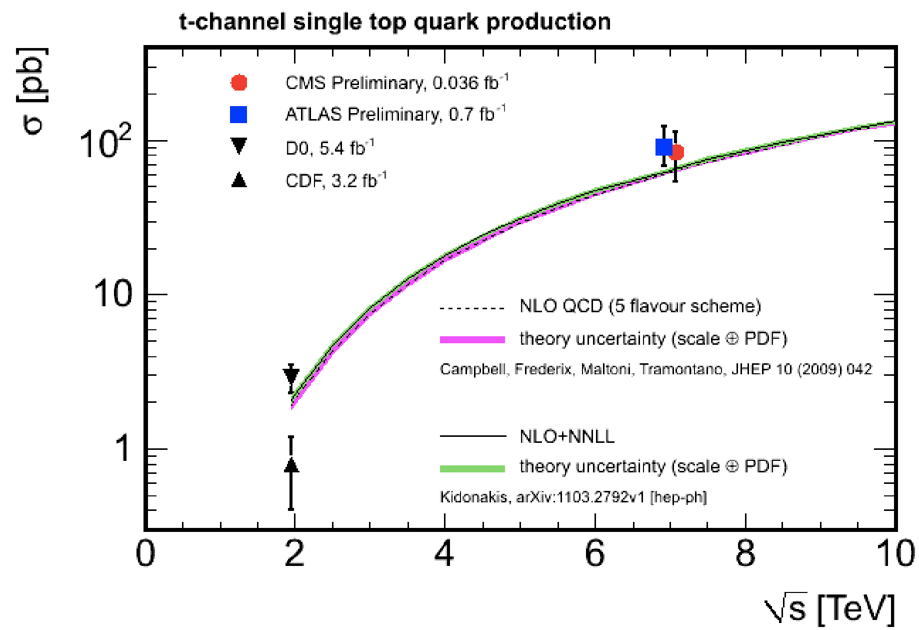
For M_t = 172.5 GeV	σ_{tb}	σ_{tqb}	σ_{tW}
$p\bar{p}$ @ 1.96 TeV	1.04 ± 0.04 pb	2.26 ± 0.12 pb	0.28 ± 0.06 pb
pp @ 7 TeV	4.6 ± 0.3 pb	64.6 +3.3 -2.6 pb	15.7 ± 1.4 pb

- Challenging measurement: small cross section, signal difficult to separate from the other SM processes
- Allows to directly measure Vtb, and the b-density in the proton
- Search for New Physics

Require 1 lepton, 1b-jet + 1 or 2 extra jets

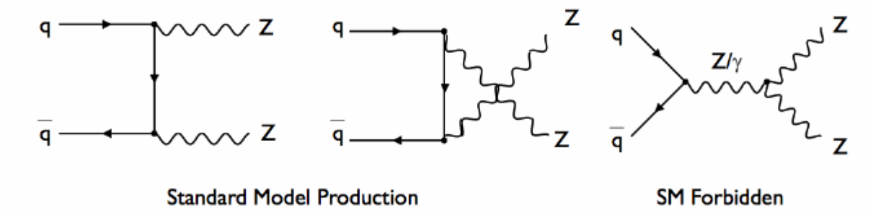


$$\sigma_t = 90^{+9}_{-9}(\text{stat})\,^{+31}_{-20}(\text{syst})$$

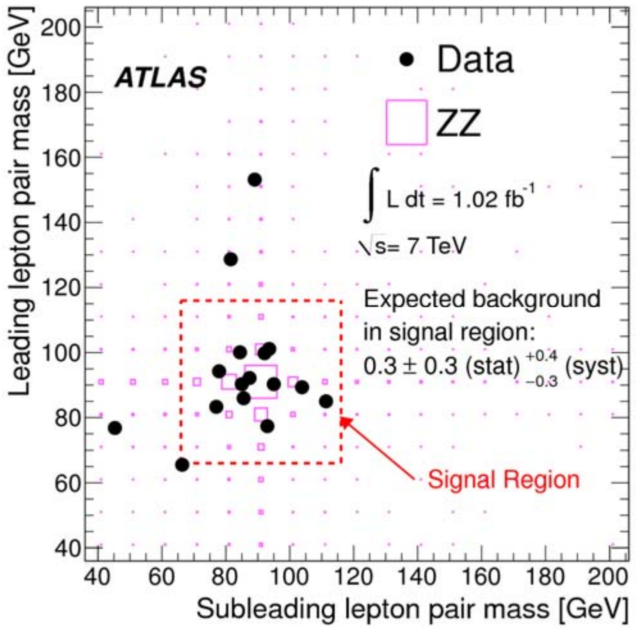


Di-boson production : exemple of ZZ in ATLAS (1 fb^{-1})

3 channels: 4e, 4μ, 2e2μ
Require 4 leptons pT>15 GeV,|η|<2.4
2 inv.mass comb 66<M<116
Impact parameter d/σ < 10
<u>12 events observed</u> (2/4e, 8/4μ, 2/eμ)
0.3 evt BKG expected

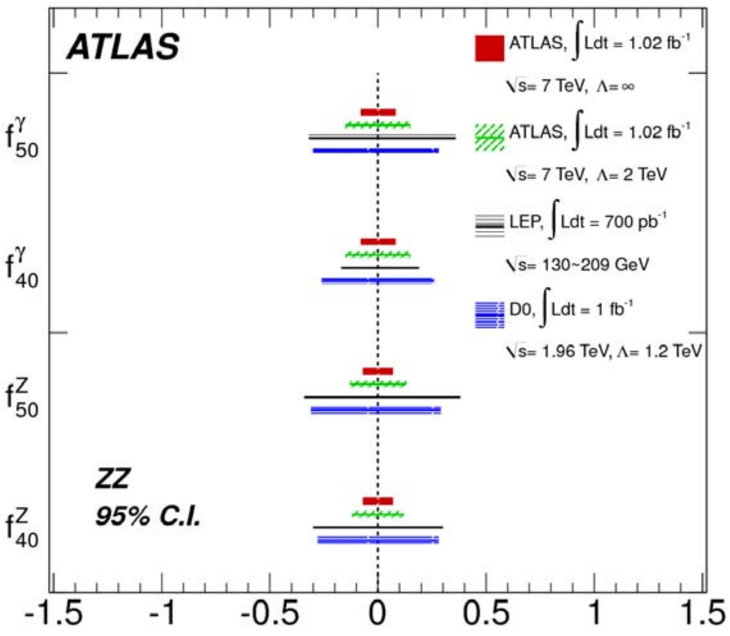


Anomalous trilinear coupling induces increased Xsection→limit



$$\sigma^{fid}_{ZZ\to\ell^+\ell^-\ell^+\ell^-} = 19^{+6}_{-5}\ (\mathrm{stat})\ ^{+1}_{-2}\ (\mathrm{syst}) \pm 1\ (\mathrm{lumi})\ \mathrm{fb}$$

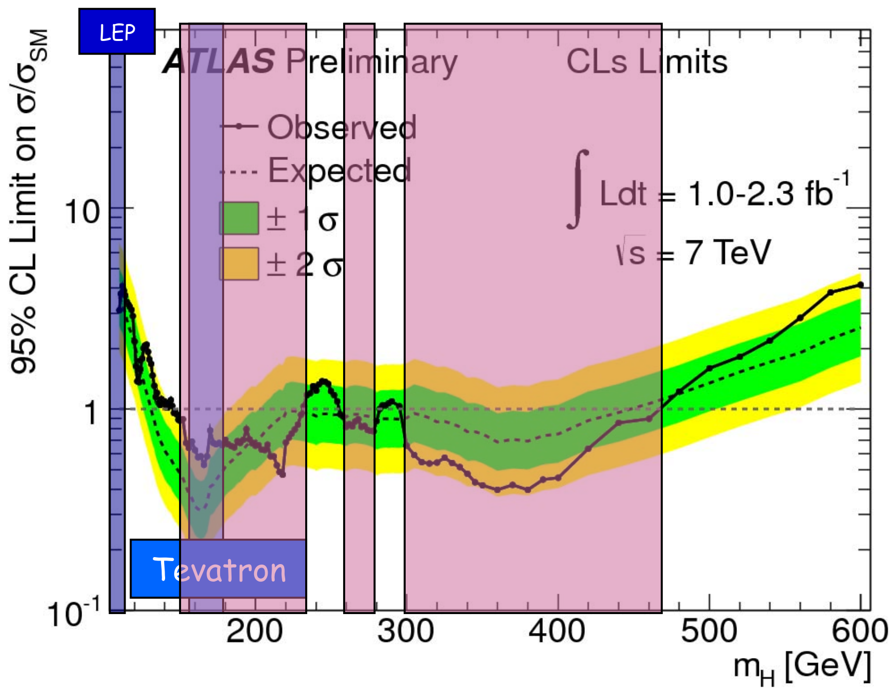
Best TGC limit

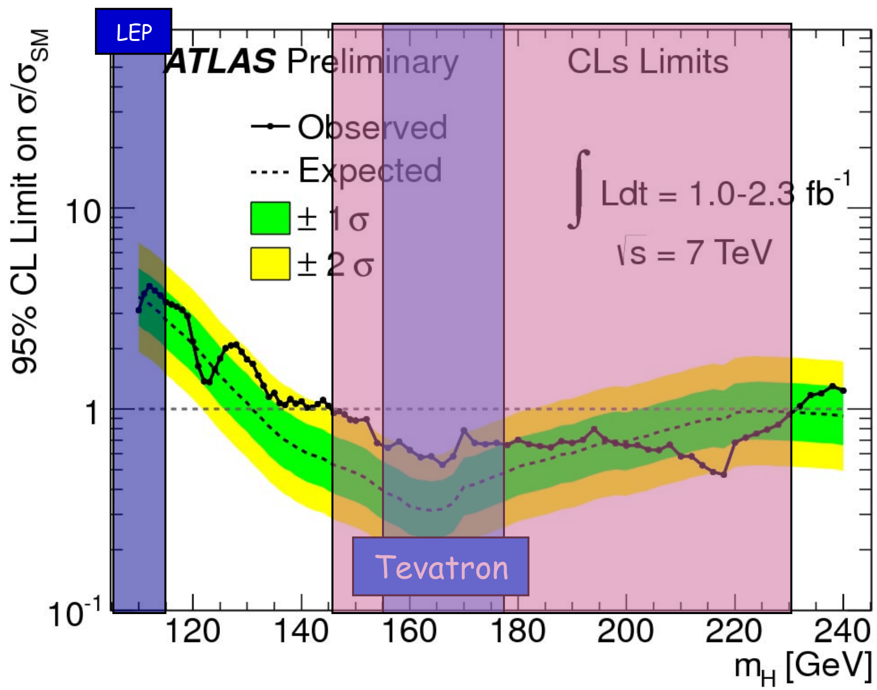


Range of Higgs →γγ , Higgs→4 leptons X-sections

ATLAS Higgs seach → combined constraints from:

H→γγ , H→ ττ
W/ZH→ lbb+X
H→ $WW^{(*)}$→ lνlν
H→ $ZZ^{(*)}$ → 4l, H→ ZZ → llνν
H→ ZZ → llqq



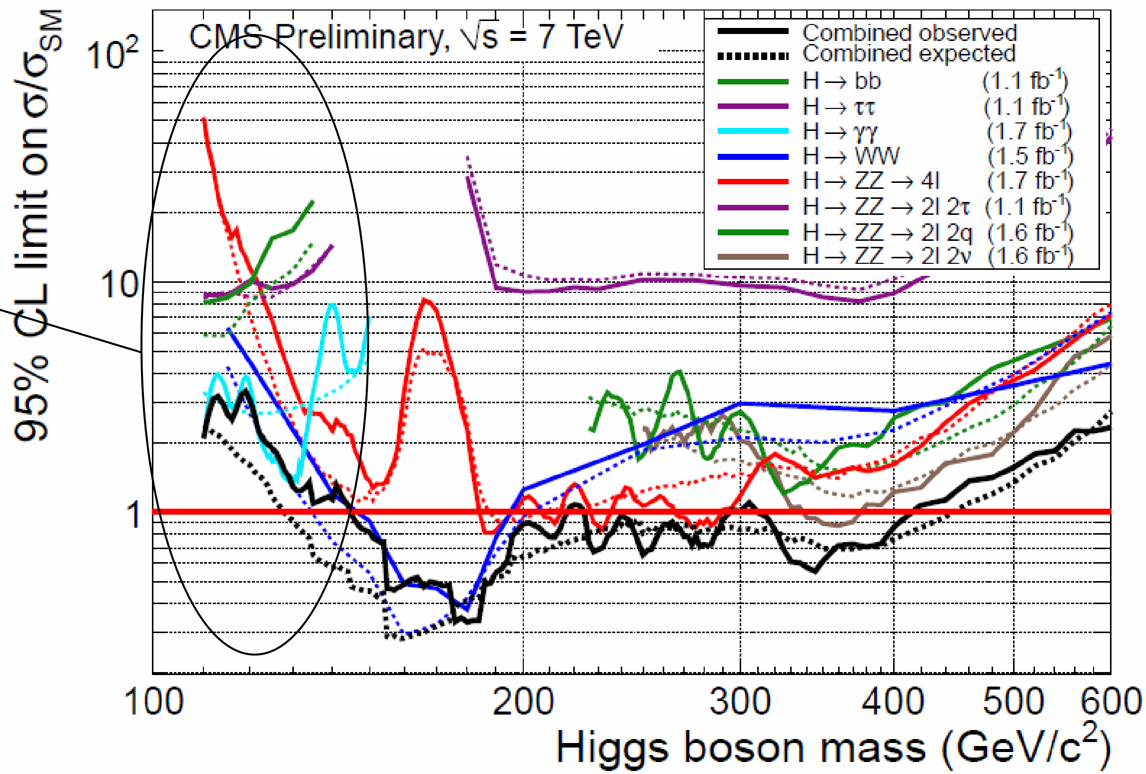


Excluded by ATLAS at 95% CL : 146-466 GeV, except 232-256, 282-296 GeV
Expected if no signal at 95% CL : 131-447 GeV

CMS Higgs search

Excluded by CMS at 95% CL : 145-400 GeV, except 216-226, 288-310 GeV
Expected if no signal at 95% CL : 130-440 GeV

For M_H<140 GeV,
the main channels are
$\gamma\gamma$
$\tau\tau$
ZZ* 4 leptons
VH, $H \to bb$

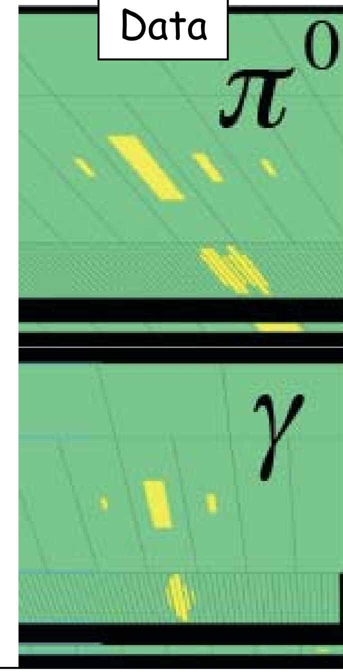


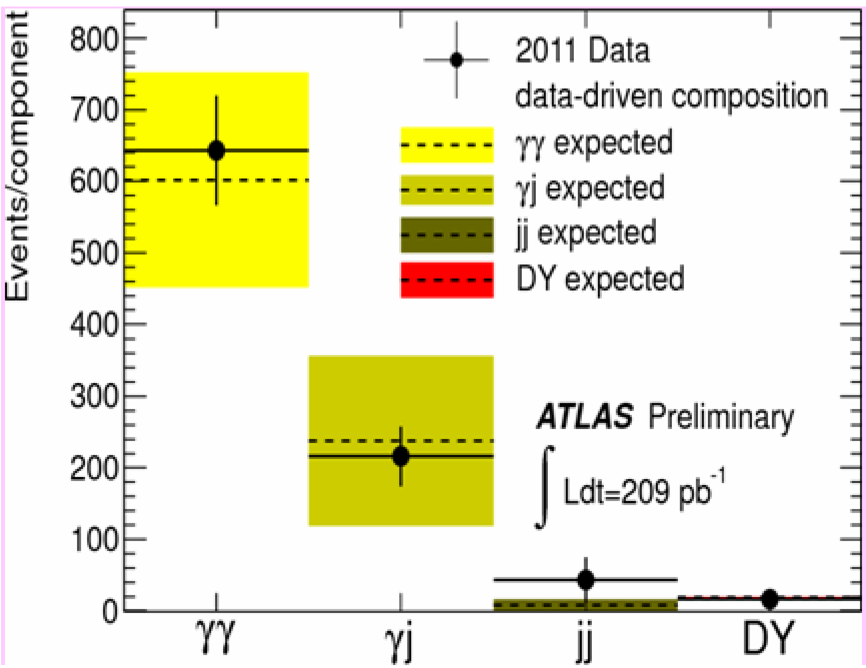
- The best-motivated low-mass region (EW fit: m_H < 161 GeV 95% CL) still open to exploration
- Main channels for low mass range: $H \to \gamma\gamma$, $H \to \tau\tau$ W/ZH→ lbb+X $H \to$4leptons

ATLAS-CMS Combination will be shown later during the Conference

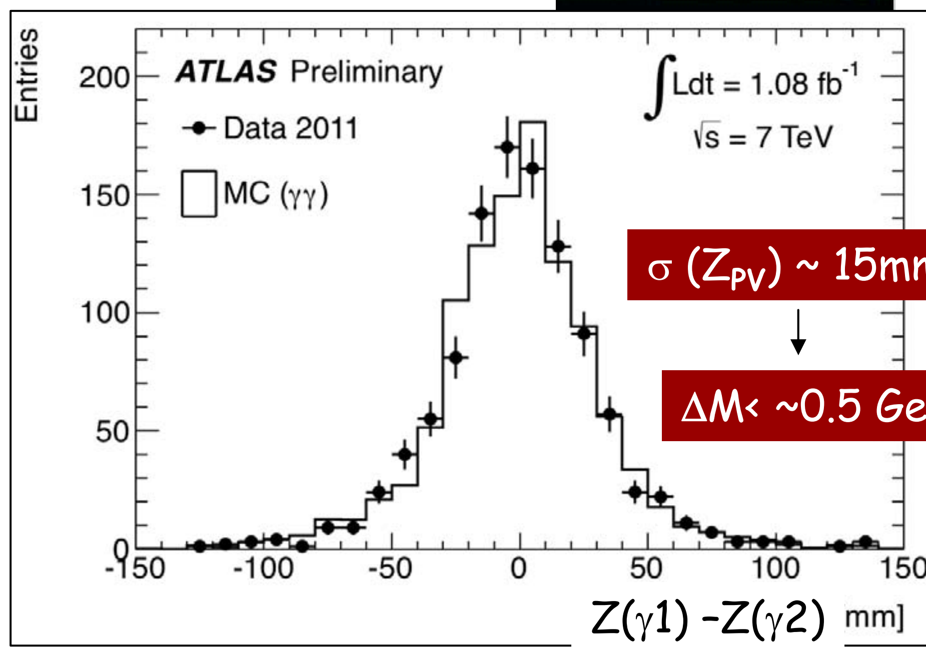
Atlas performance for $H \to \gamma\gamma$ (I)

- High granularity LAr "accordion" EM calorimeter
  $\to$Photon direction
  $\to$Photon/π^0 additional rejection
- Calorimetric isolation (5GeV E_T)
  ("ambient" PU subtracted from iso energy)





~75% prompt γγ , 25% γ-jets



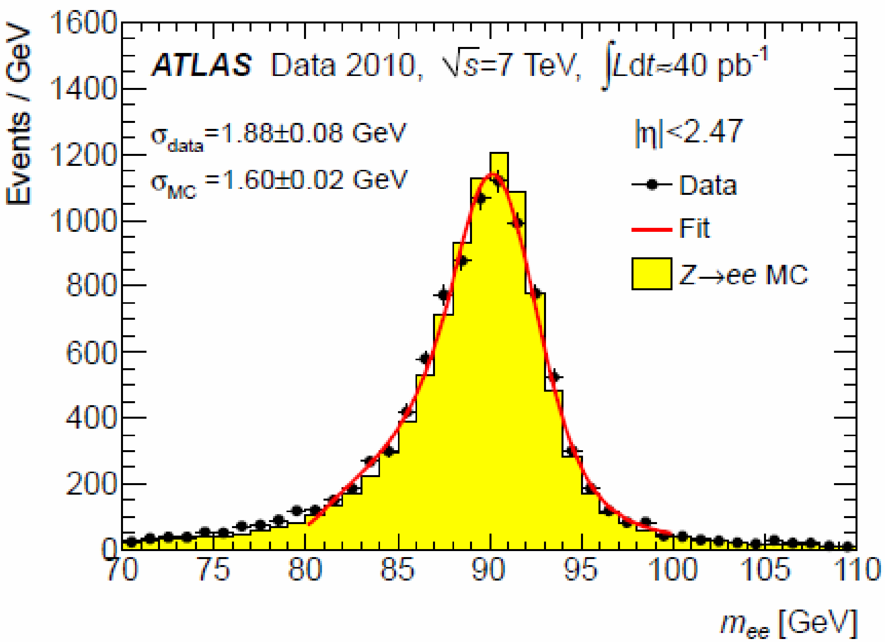
σ (Z_{PV}) ~ 15mm

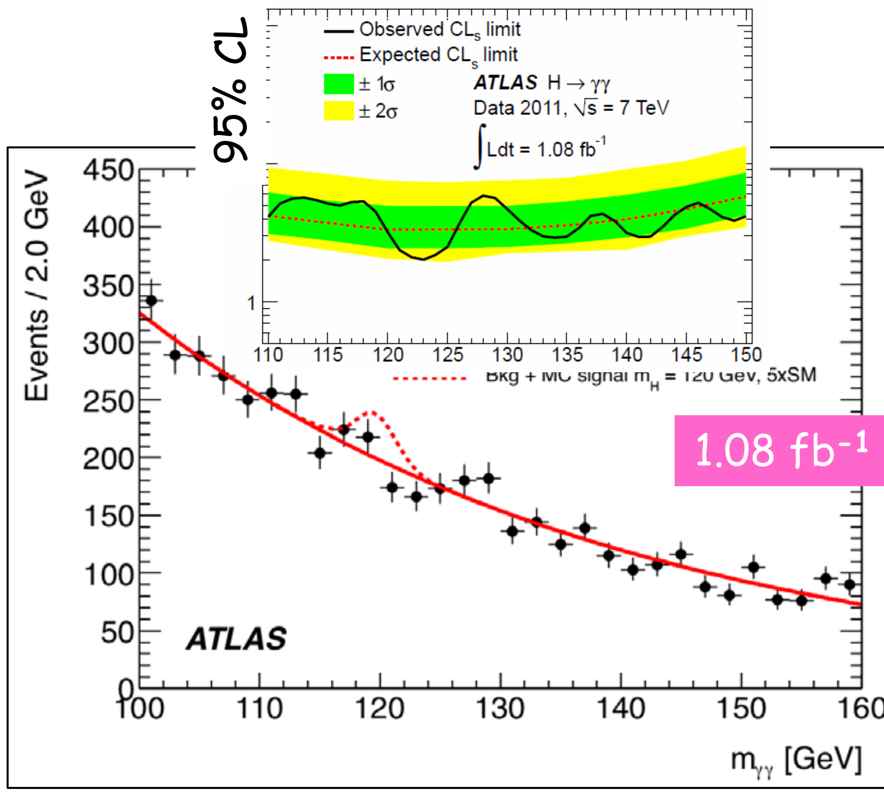
ΔM< ~0.5 GeV

Atlas performance for H $\rightarrow \gamma\gamma$ (II)

High stability $\rightarrow$ "easy calibration"
Z sample$\rightarrow$ cell weights (within +-2%)
as a function of η (material effect?)

$\sigma_{\gamma\gamma}$ ~ 1.7 GeV (mH=120 GeV)





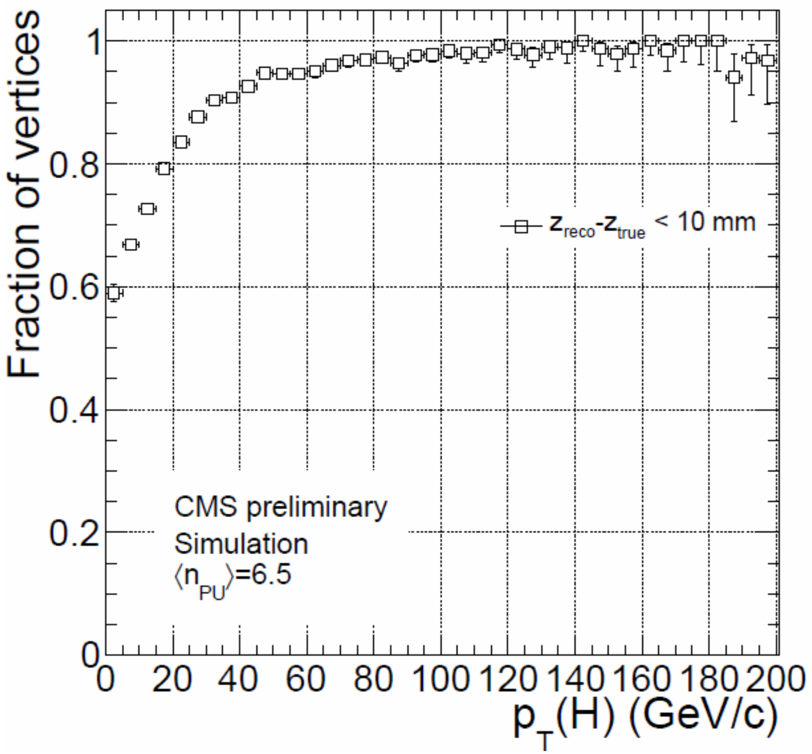
Constant term (2010/35 pb^{-1})
-Barrel : 1.1 ± 0.5%
-End-caps 1.8 ± 0.6%
with 100 times more data$\rightarrow$ work toward reaching nominal (0.7%)

CMS performance for H$\rightarrow \gamma\gamma$ (I)

- Vertex selected on the basis of Σp_T^2 (tracks at the vertex) and P_T balance between ($\gamma\gamma$) and tracks

- If a photon is converted, use it for Vertexing

For <μ>= 6.5, in average
83% of the selected vertices are within 10 mm from true vertex
(ie with small/negligible contribution to invariant mass)
For <μ>=12,improved algo in progress

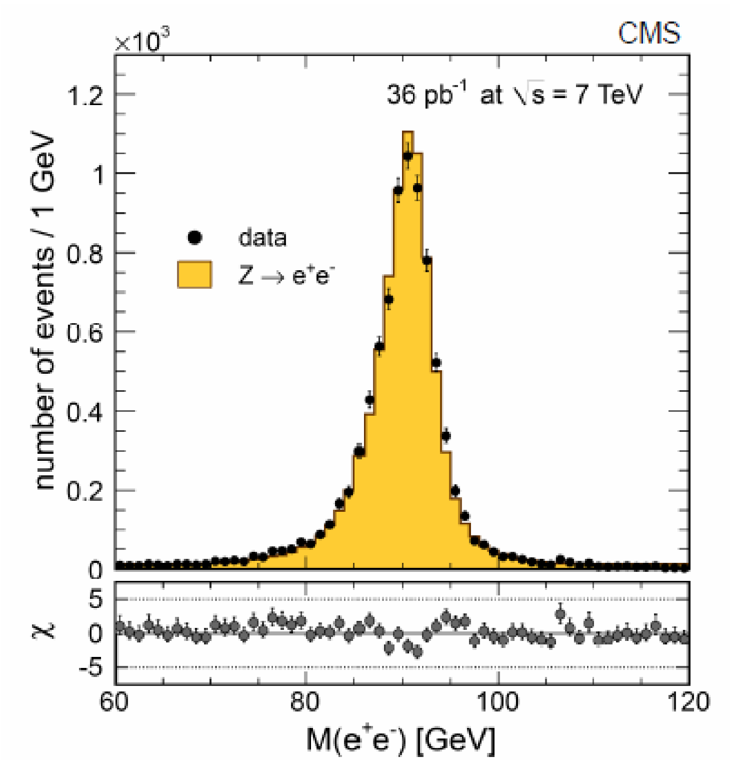


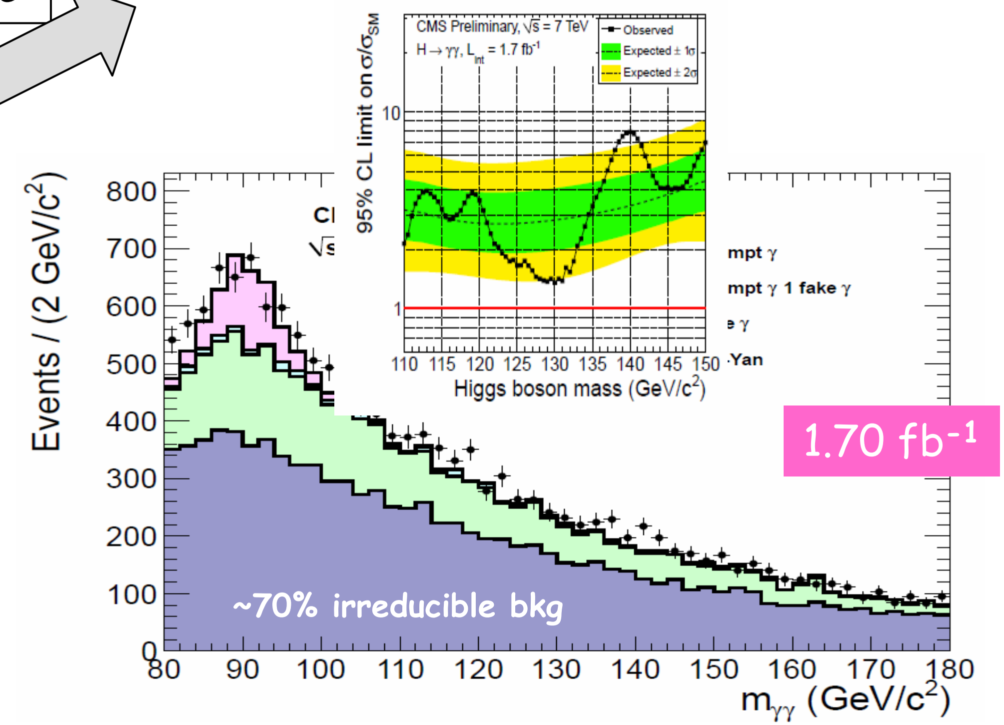
Photon isolation
-use of ECAL & HCAL energy in cone complicated by pile-up
-use of $\Sigma|pT|$ of tracks from vertex, complicated by wrong vertex assignment (pu as well)
efficiency ranges from 60% to 90%,being lower where bkg is higher

CMS performance for H→ γγ (II)

- Calibration complicated by slight dependence of BGO cristal transparency on luminosity "history"
- In 2010 variation within 1%(4%) in B/EC
- Corrected by Laser to 0.3%(1%) in B/EC

<u>Mass resolution</u>: larger spread /ATLAS :
-~1.5 GeV for B-B , and >94% in 9 cristals
-~ 3 GeV for B-EC

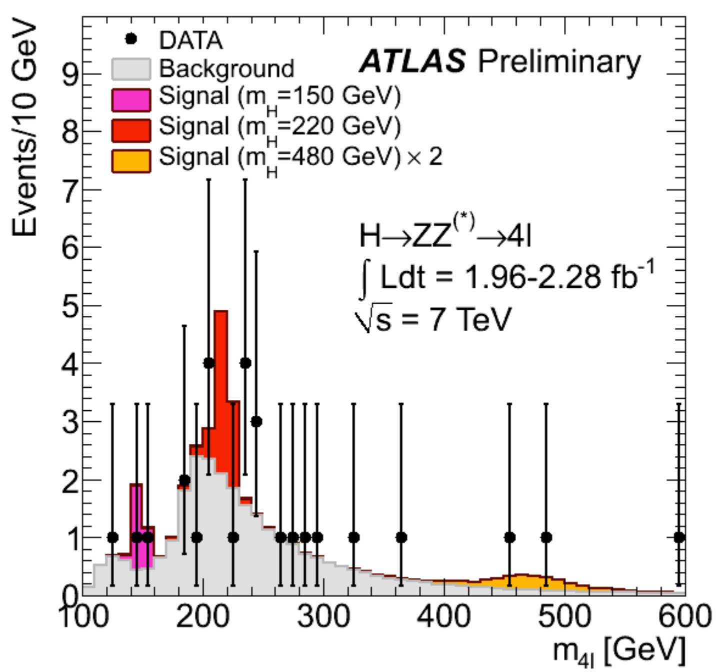


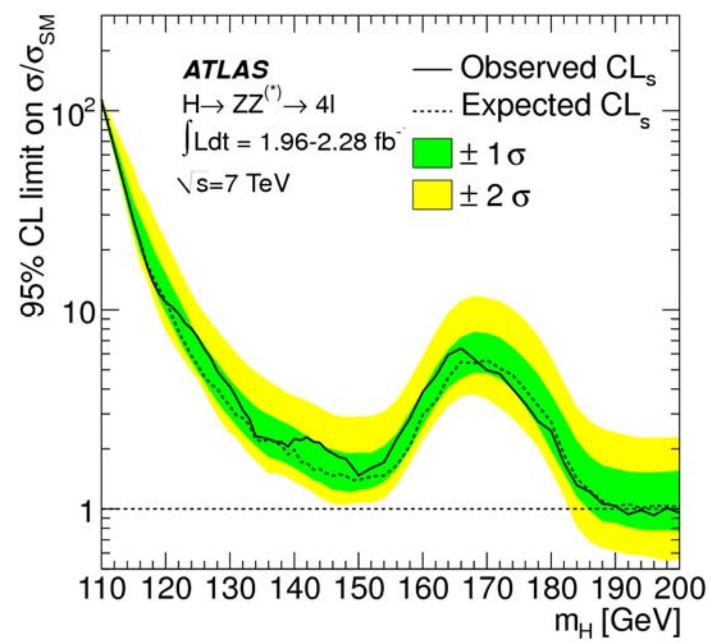


Combining efficiency, background rejection, M resolution,..the performances of the two detectors,for this channel, are at present quite close from each other

Higgs $\rightarrow$ 4 leptons in ATLAS with ~2 fb^{-1}

$H \rightarrow ZZ^* \rightarrow$ 4 leptons combines <u>low background and precision mass reconstruction</u>
Drawback is the small combined branching ratio
Key point is the reconstruction efficiency for low pT leptons (down to ~5 to 7 GeV)
Background(ttbar,Zbb) removed by isolation and impact parameter requirement



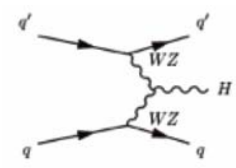


- A total of 27 events are selected by the analysis algorithm: 6ee, 9eμ, 12μμ
- Expected: 28±4

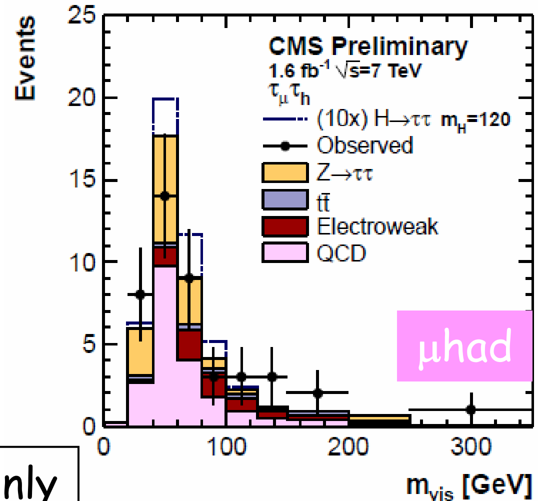
The sensitivity degrades rapidly when M_H goes below ~130 GeV.
Expected $H \rightarrow 4l$ cross-section:
4.4 (2.9) fb for MH= 150(130) GeV

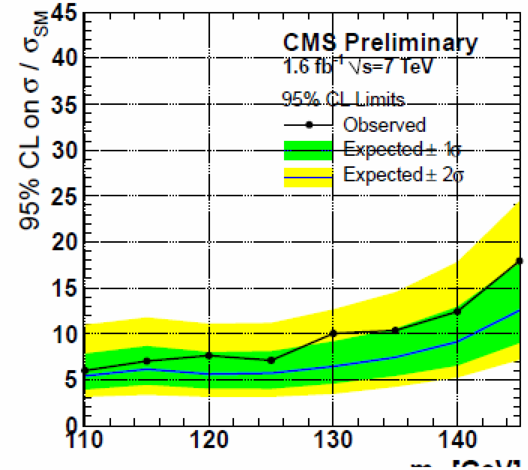
Higgs →ττ in CMS with 1.6 fb^{-1}

eμ, μhad, ehad

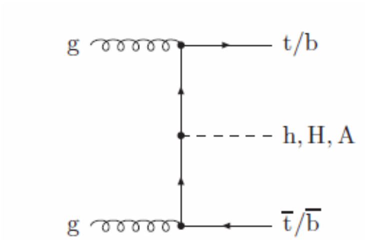


2 VBF jets→SM Higgs

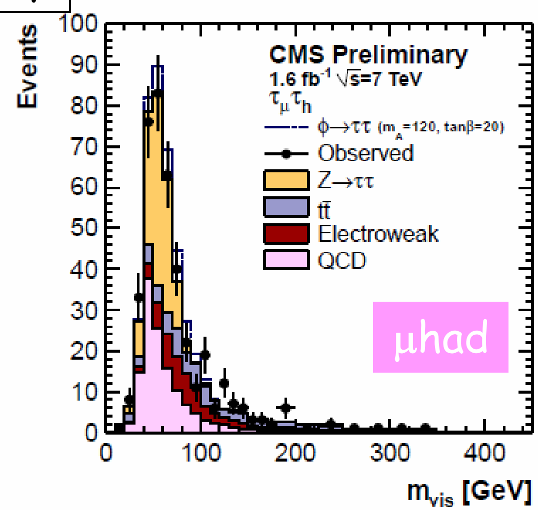


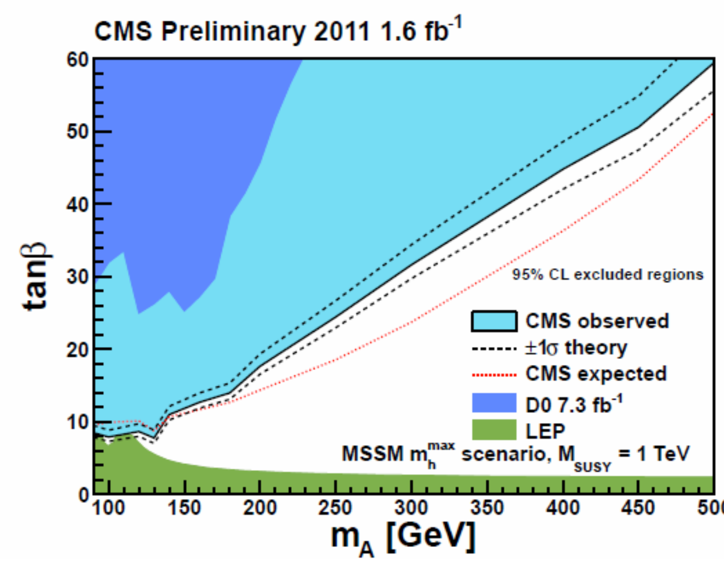


Compatible with BKG only



1 B-tag jet
→MSSM Higgs

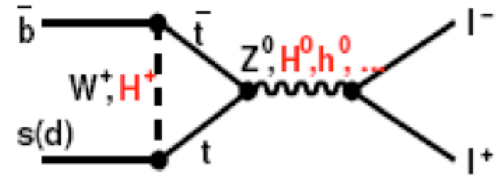


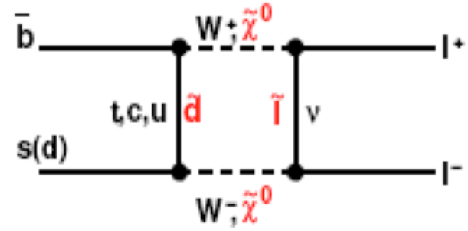


- Very useful complement to γγ for SM Higgs
- Start closing down parameter space (low M_A) for MSSM

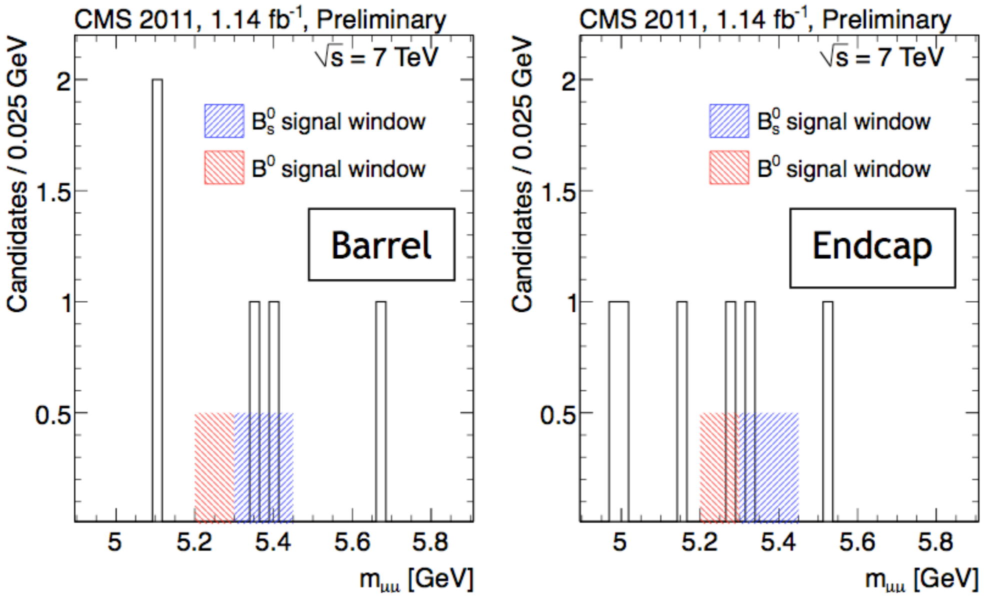
CMS SUSY exemple of $B_s \to \mu\mu$

•Decays highly suppressed in the SM
BR($Bs \to \mu\mu$): $(3.2\pm0.2)\times10^{-9}$,
$Bd \to \mu\mu$: $(1.0\pm0.1)\times10^{-10}$
Indirect sensitivity to new physics
MSSM : BR prop to $(\tan\beta)^6$





Require high pT (~4 GeV) and isolation of muons,
and L/σ (flight)>15 (20/EC)
Mass resolution ~36(85) MeV (in Barrel/EC)

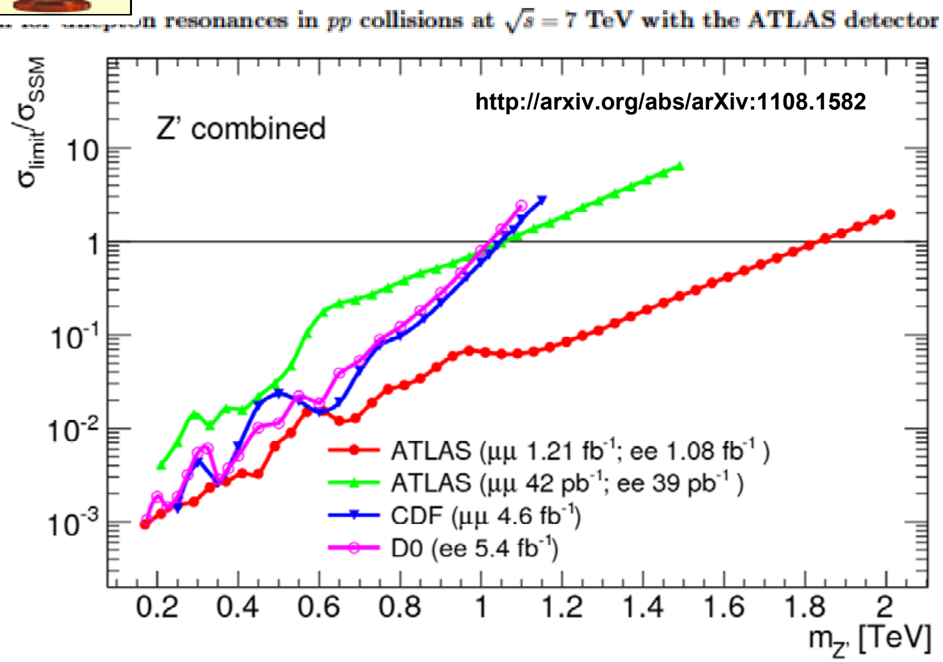


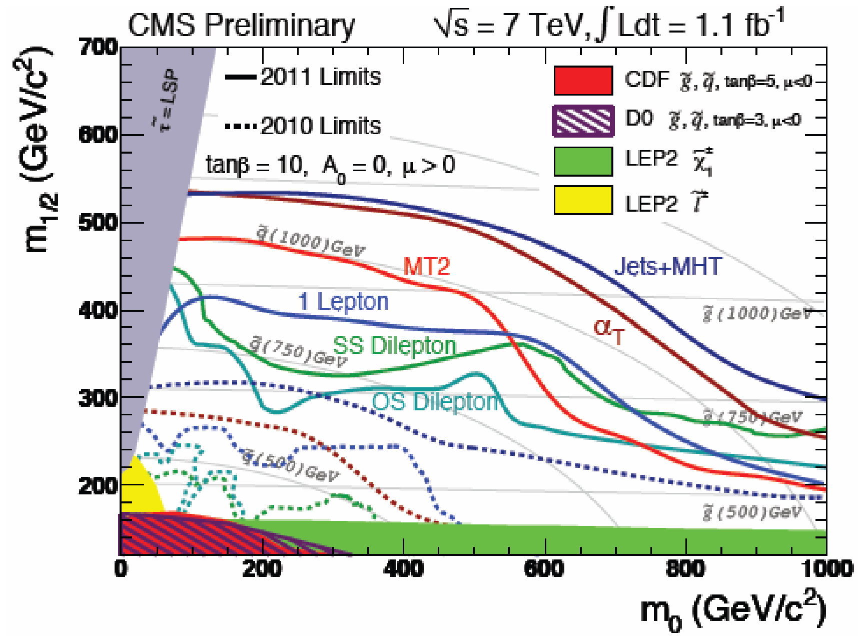
1.14 fb^{-1} CMS BR Limits at 95% CL
$Bs \to \mu+\mu- < 1.9\times10^{-8}$
$Bd \to \mu+\mu- < 4.6\times10^{-9}$

LHCb BR Limits at 95% CL
$Bs \to \mu+\mu- < 1.5\times10^{-8}$

With 4 times the statistics and improved analysis+ATLAS SM limit is not far away…

Searches : Z' and SUSY JETs+MET





Wrt Tevatron, ATLAS with $1fb^{-1}$
-high mass reach considerably increased
Z'_{SSM} > 1.83 TeV with 1.08 fb^{-1}
-surpass sensitivity at low mass as well

•Jets +ETmiss has best sensitivity
Huge gain/Tevatron
•Several CMSSM benchmark points already excluded

1.07 TeV squarks and gluinos excluded by ATLAS as well in a "simplified" model with equal squark and gluino masses

Conclusions

- After some difficult time the LHC is now running steadily at $\sqrt{s}$ =7 TeV and L >3×10^{33} $cm^{-2}s^{-1}$. Over 2011 it delivered 5.6 fb^{-1} to both ATLAS and CMS
- With this inst lumi and 50ns bunch spacing,the average number of collisions per crossing is now over 12. The detectors (incl trigger and reconstruction) have demonstrated excellent performance in these already difficult conditions.

- Analyses of EWK bench mark channels show very good agreement between data and the Standard Model
- With the accumulated data sets, precision physics (M_{top},M_W,…) can now start

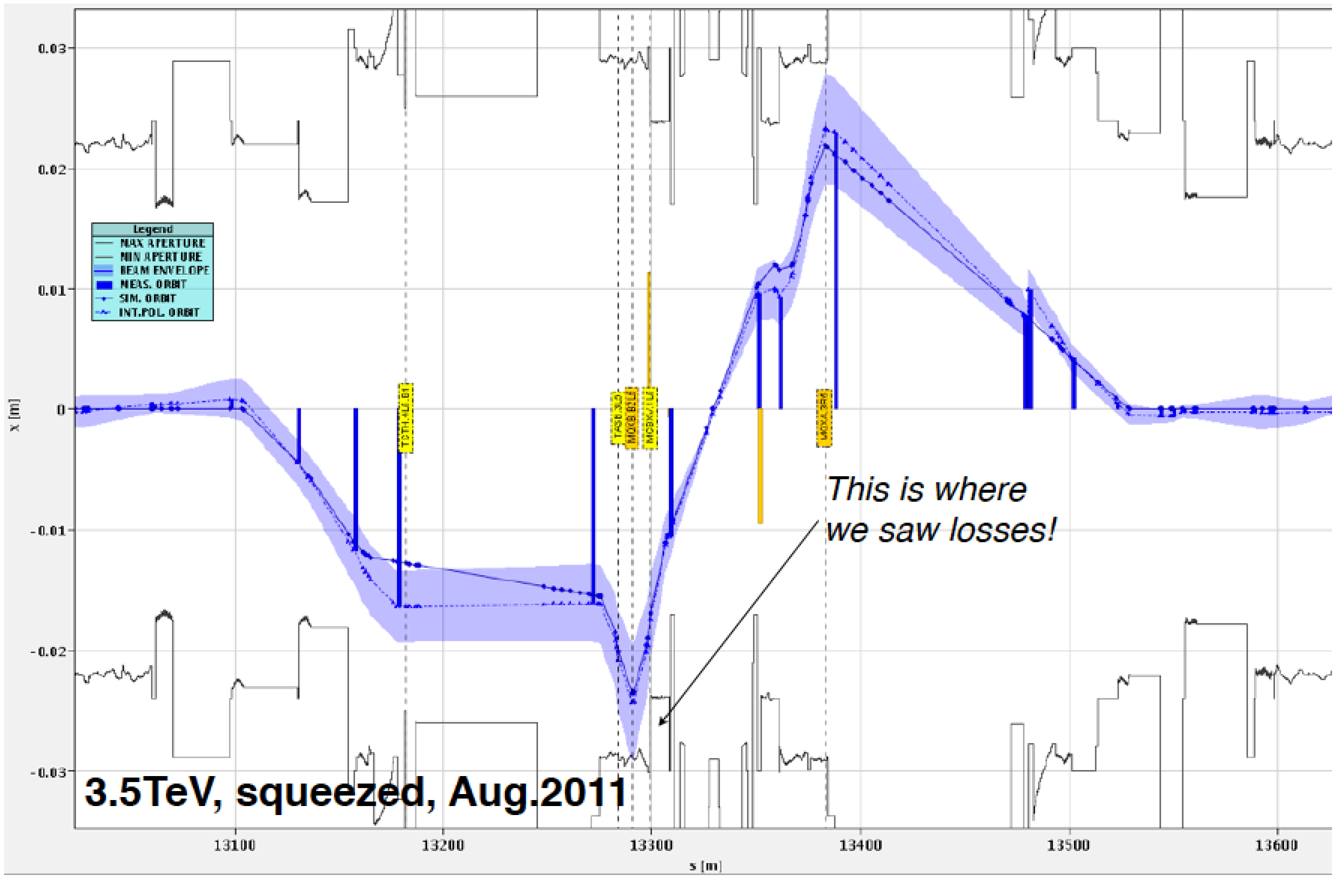
- No phenomenon "beyond standard Model" has so far shown-up. But this exploration is only beginning

- The "hot-topic" of 2011 (and 2012..) is the search for the SM Higgs. A very broad high mass range has been excluded, but the best motivated region (114-140) is still fully open,
- Getting the best from data in this difficult range requires pushing the "objects" reconstruction, and the physics analyses to their ultimate performance

We look forward hearing many updates, new clues, new results,…during this Conference

SPARES

Triplet



Crossing-angle +- 120 Microrad,benefitting from large Aperture margin in triplets

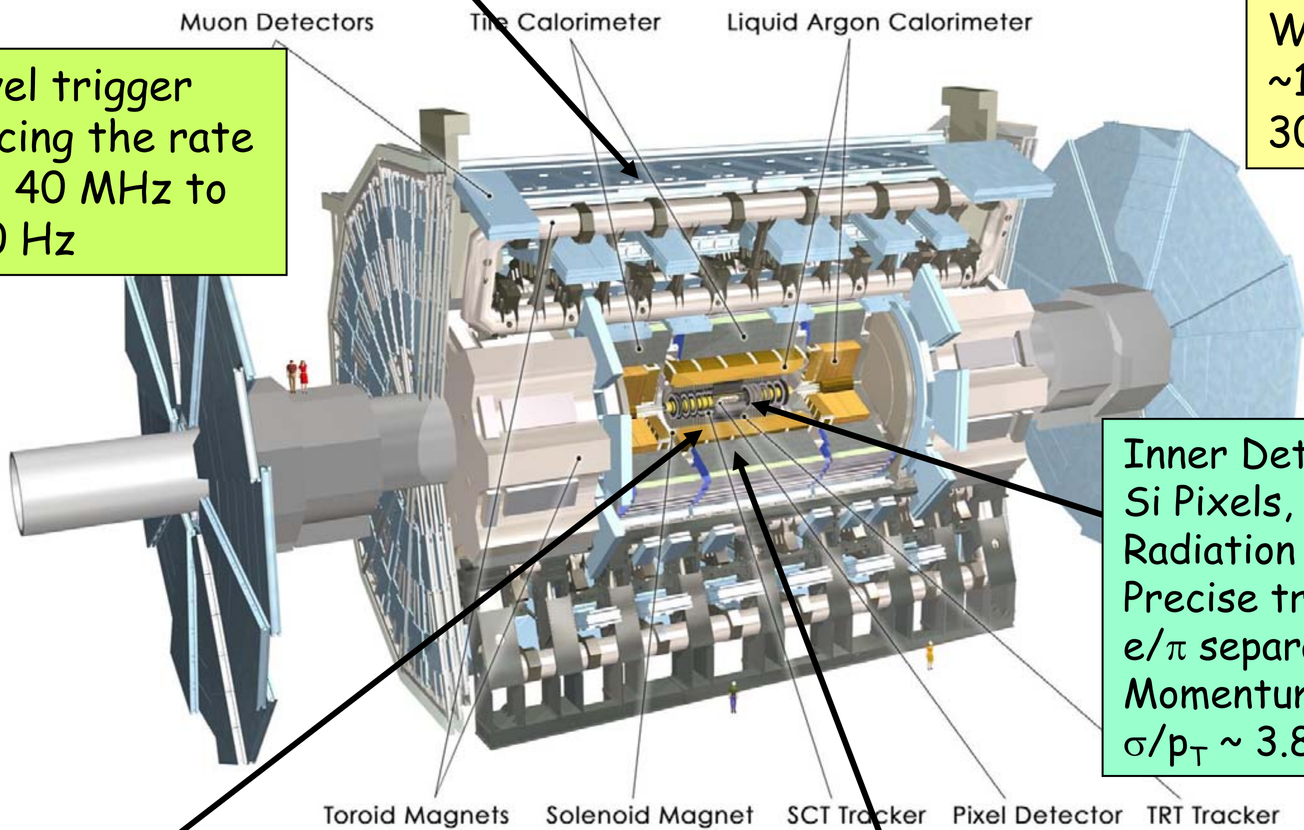
Parameters after Sept MD

	2010	2011	Nominal
Energy [TeV]	**3.5**	**3.5**	**7**
β* [m] (IP1,IP2,IP5,IP8)	**3.5, 3.5, 3.5, 3.5**	**1.0, 10, 1.0, 3.0**	**0.55, 10, 0.55, 10**
Emittance [μm] (start of fill)	**2.0 – 3.5**	1.5 – 2.2	**3.75**
Transverse beam size at IP1&5 [μm]	**60**	**23**	**16.7**
Bunch population	**1.2×10^{11} p**	1.4×10^{11} p	**1.15×10^{11} p**
Number of bunches	**368**	**1380**	**2808**
Number of collisions (IP1 & IP5)	**348**	**1318**	**-**
Stored energy [MJ]	**28**	**110**	**360**
Peak luminosity [$cm^{-2}s^{-1}$]	**2×10^{32}**	3.3×10^{33}	**1×10^{34}**
Max delivered luminosity (1 fill) [pb^{-1}]	**6.23**	**116**	**-**
Longest Stable Beams fill [hrs]	**12:09**	**25:59**	**-**

Muon Spectrometer ($|\eta|<2.7$) : air-core toroids with gas-based muon chambers
Muon trigger and measurement with momentum resolution < 10% up to $E_\mu \sim 1$ TeV

Length : ~ 46 m
Radius : ~ 12 m
Weight : ~ 7000 tons
~10^8 electronic channels
3000 km of cables

3-level trigger reducing the rate from 40 MHz to ~200 Hz



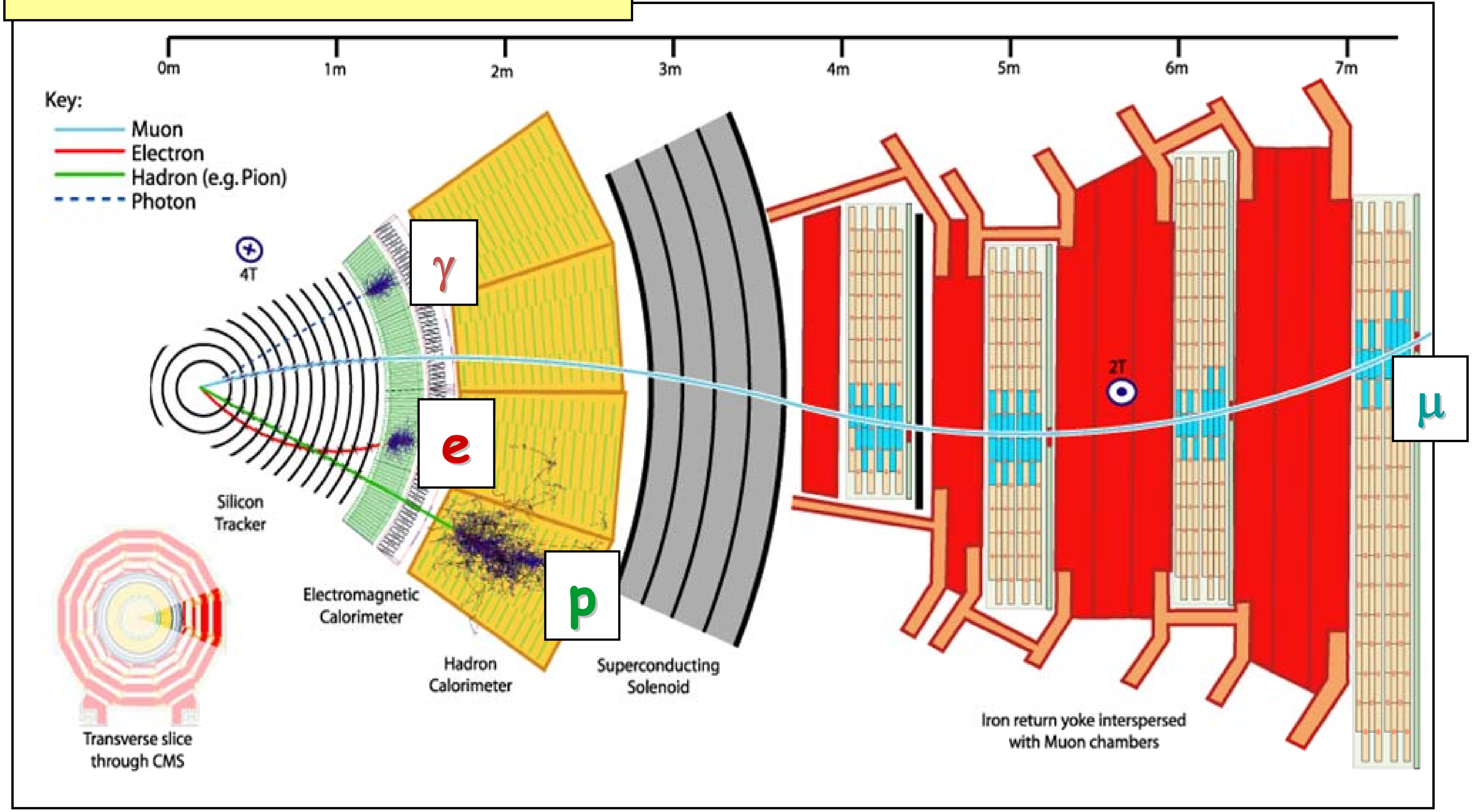
Inner Detector ($|\eta|<2.5$, B=2T):
Si Pixels, Si strips, Transition Radiation detector (straws)
Precise tracking and vertexing, e/π separation
Momentum resolution:
$\sigma/p_T \sim 3.8\times10^{-4}\, p_T (\mathrm{GeV}) \oplus 0.015$

EM calorimeter: Pb-LAr Accordion
e/γ trigger, identification and measurement
E-resolution: $\sigma/E \sim 10\%/\sqrt{E}$

HAD calorimetry ($|\eta|<5$): segmentation, hermeticity
Fe/scintillator Tiles (central), Cu/W-LAr (fwd)
Trigger and measurement of jets and missing E_T
E-resolution: $\sigma/E \sim 50\%/\sqrt{E} \oplus 0.03$

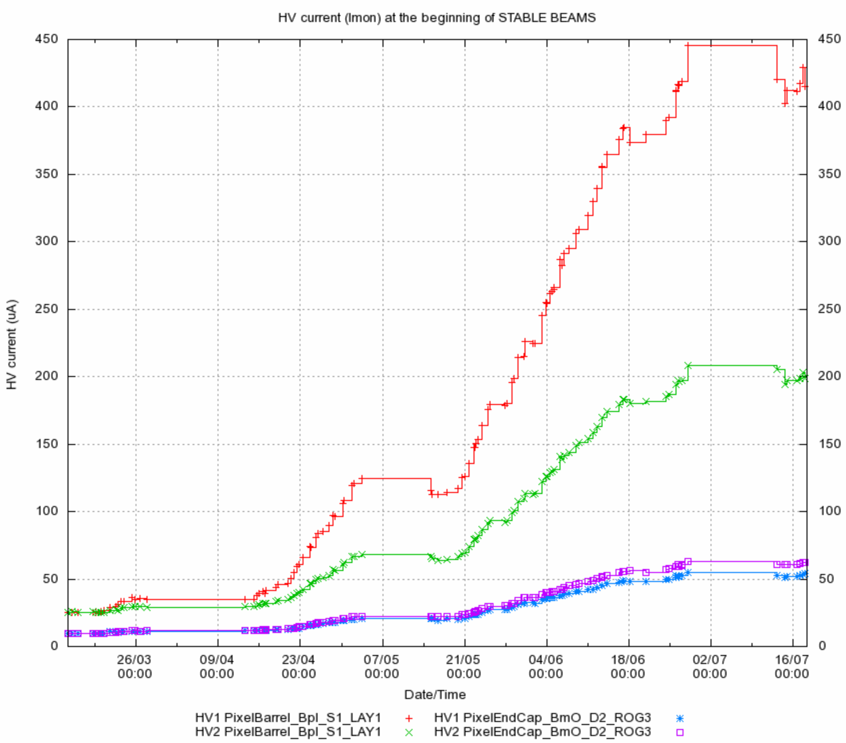
CMS slice

Slice of a CMS sector

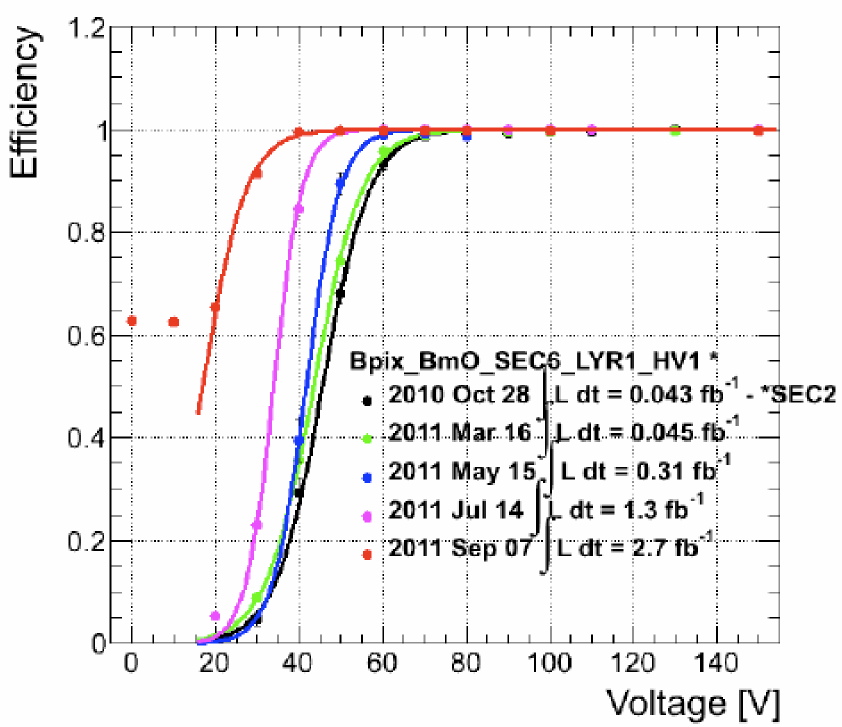


CMS pixels

CMS pixels operated at warm (for the time being)
for technical reasons→radiation effects more visible



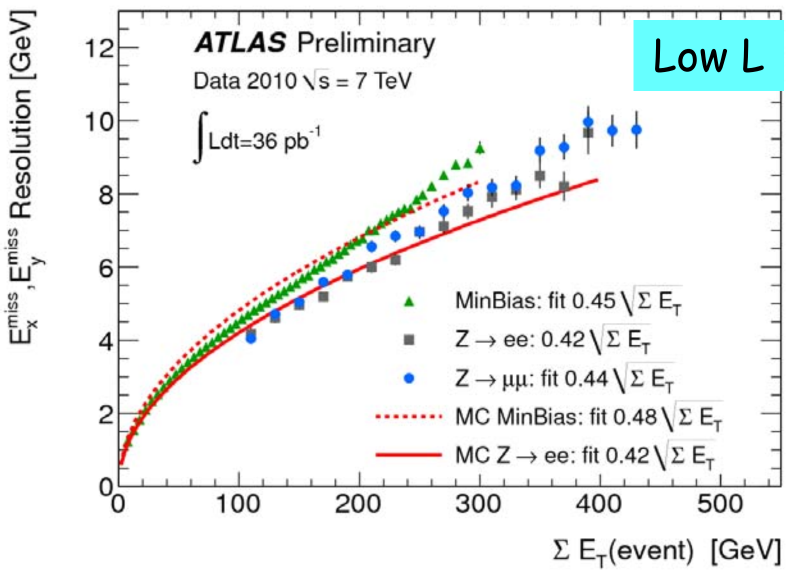
Leakage current

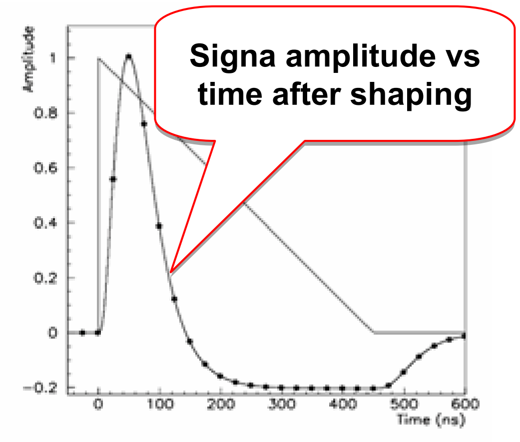


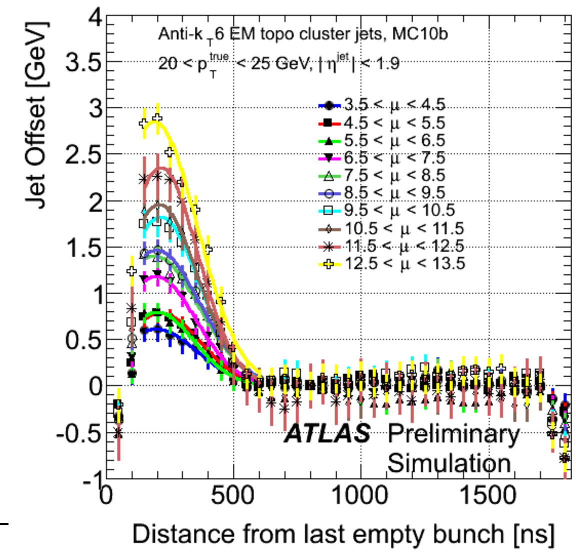
Depletion voltage

Impact of pile-up on Jets and MET

- Do not expect a significant impact on tracking, nor muons, nor even electrons and photons (except isolation)
- But sizable impact on jets (+E_T^{miss})
- Bipolar pulse shaping designed so that ‹ET› ~ 0 for 25 ns bunch-spacing and uniform intensity per BX
- Abort gap → positive bias f(BCID)





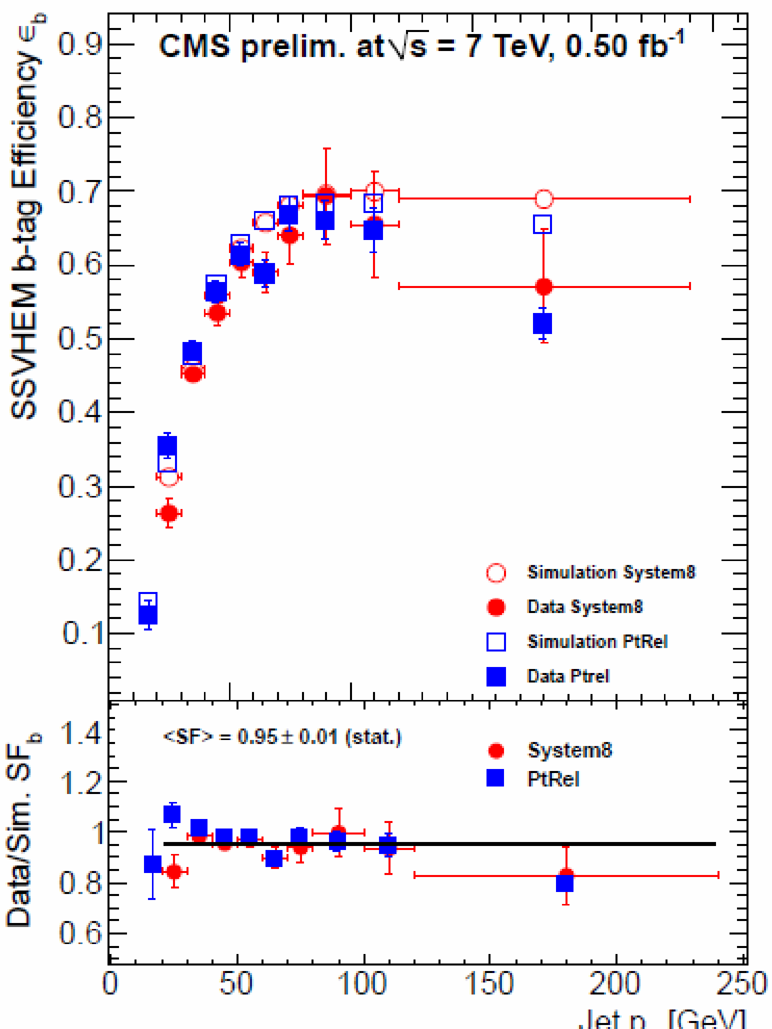


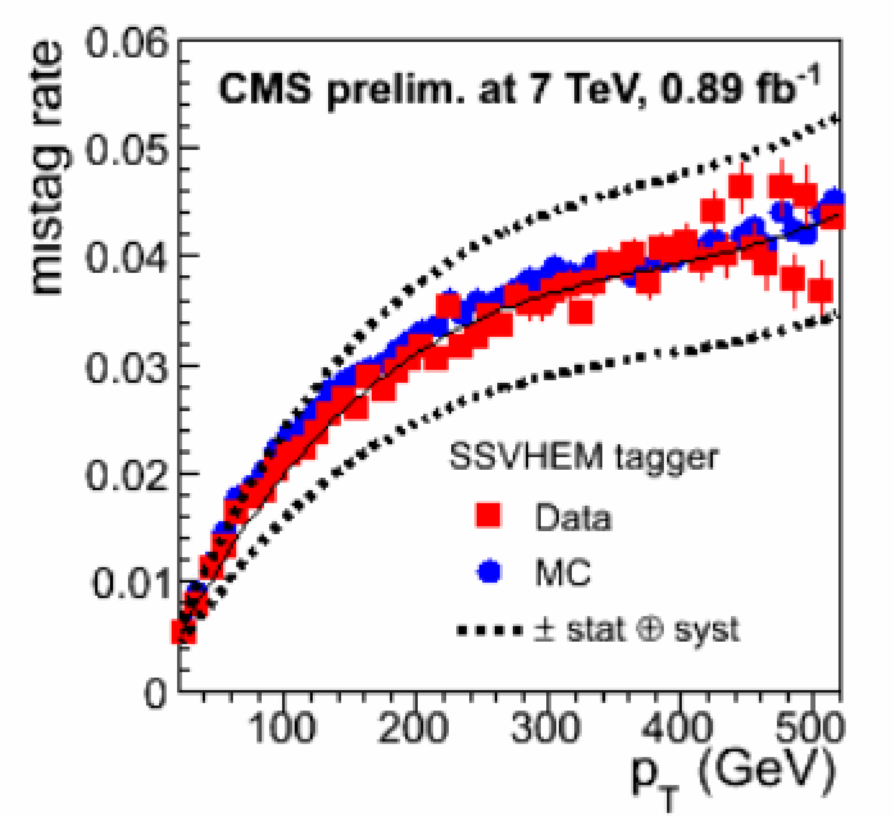
- Optimal performance will require correction per cell type in η-bins and as a function of luminosity to set average measured E_T to ~ 0

- At the moment, introduce increased jet energy scale uncertainty for low-p_T jets (at maximum 7% for jets in forward calo)

B-tagging in CMS

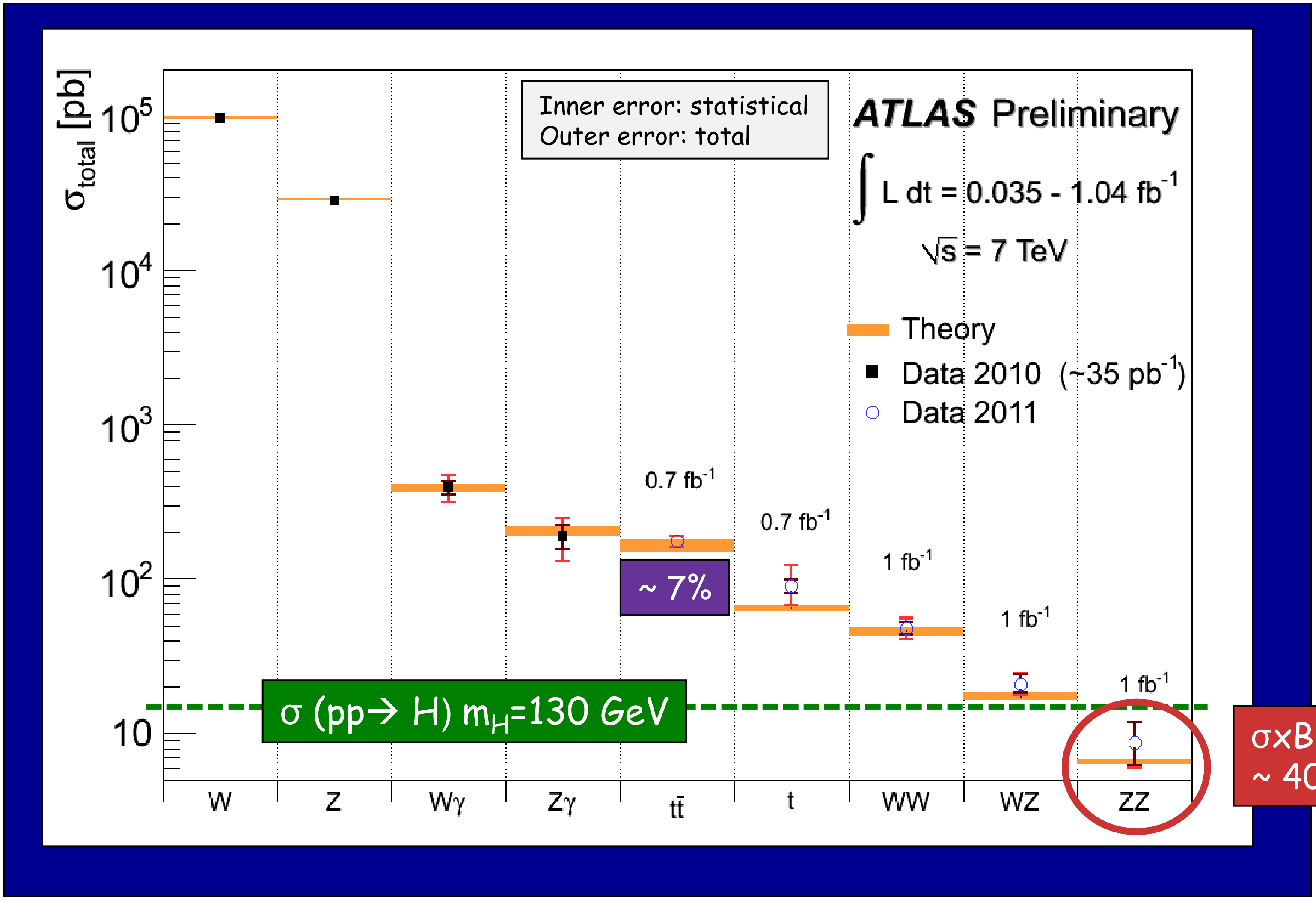
Several methods,depending on final state.
Exemple of SSVHEM
"Simple secondary Vertex,High Efficiency Medium"
(comparable to SV0 in ATLAS)





Efficiency measured in data with μ-tagged jets

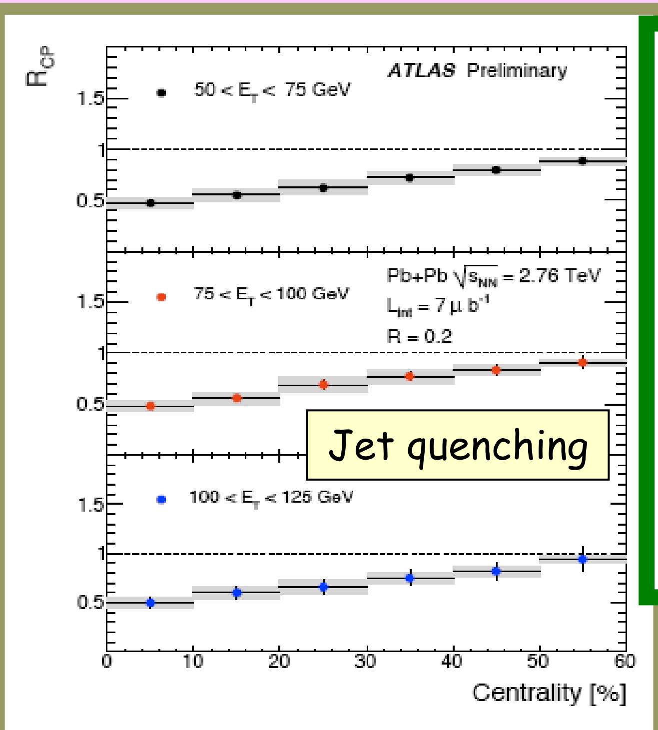
Summary of main electroweak and top cross-section measurements

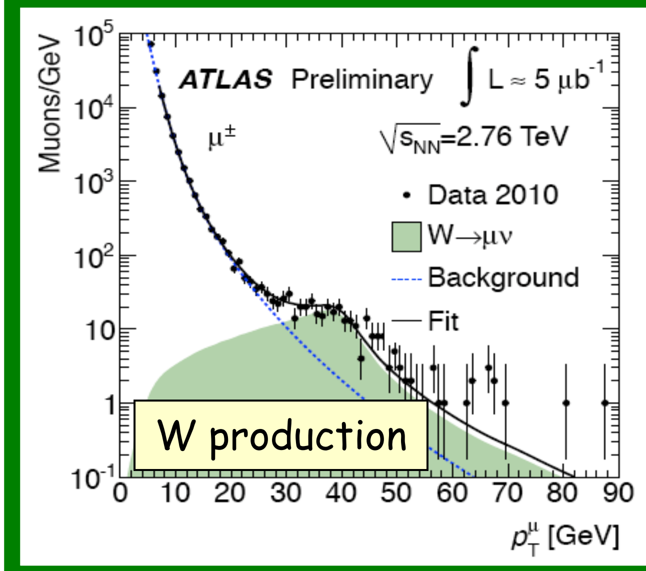


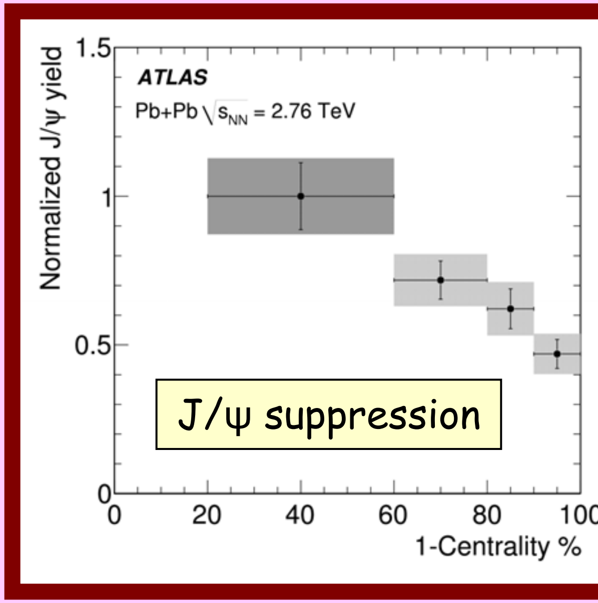
σxBR(ZZ→ 4l) ~ 40 fb

Good agreement with SM expectations (within present uncertainties)

Measuring cross-sections down to few tens of fb (including leptonic branching ratios)

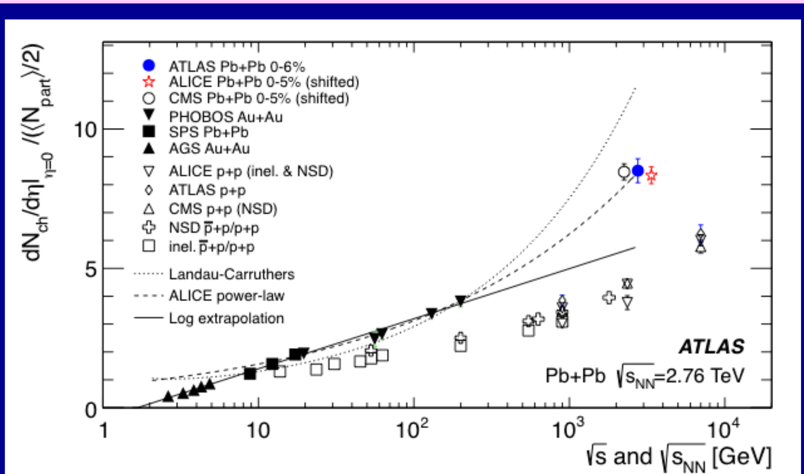






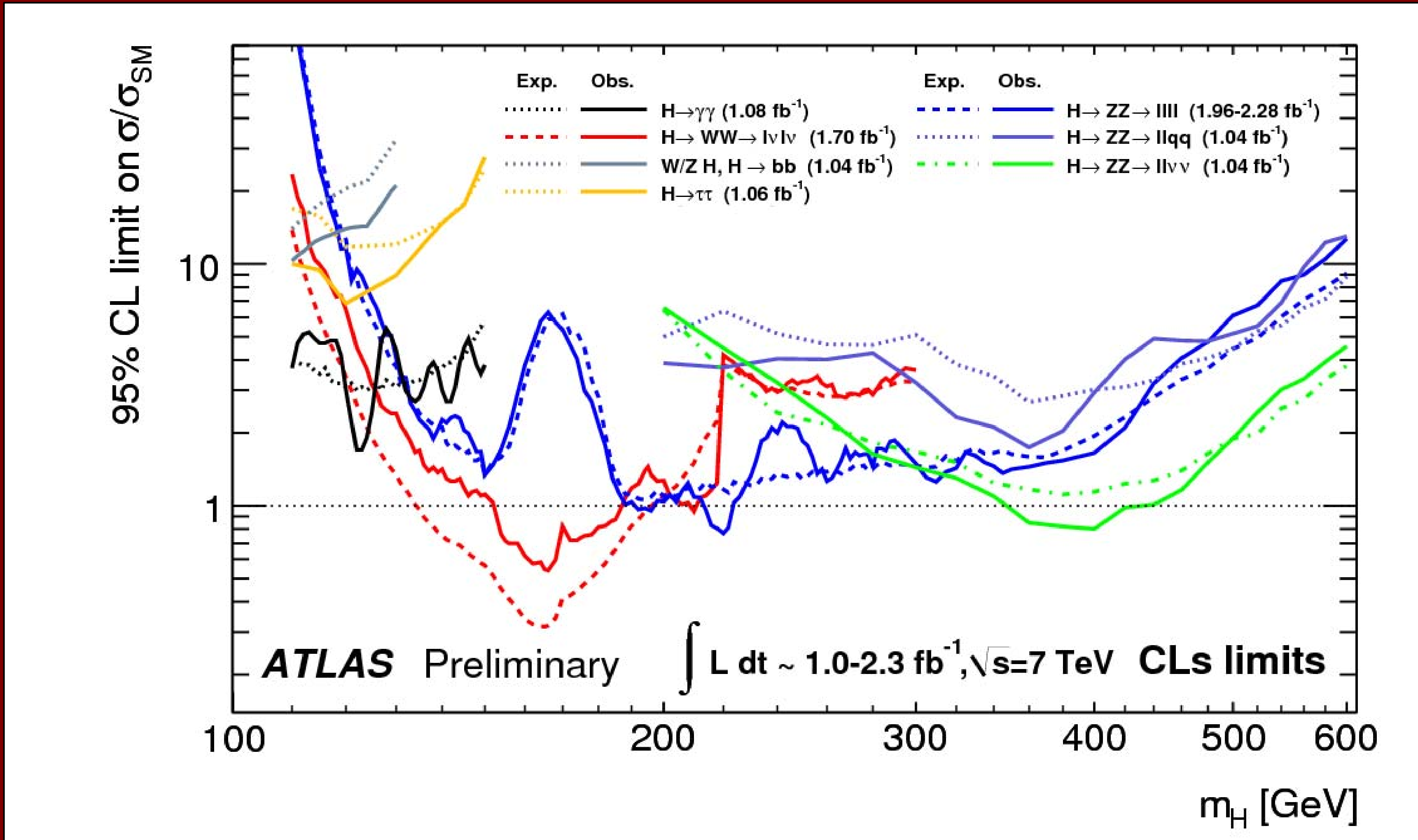
Heavy Ions

Recorded ~ 9 μb^{-1} in 2010



- Measurements of direct jet quenching → ratio of jet rates in central and peripheral collisions (~ 0.5) is ~ independent of E_T (jet)
- Observation of J/ψ suppression
- Observation that W and Z are not suppressed
- Studies of elliptic flow and charged particle multiplicities

→ looking forward to the second HI run in Nov-Dec



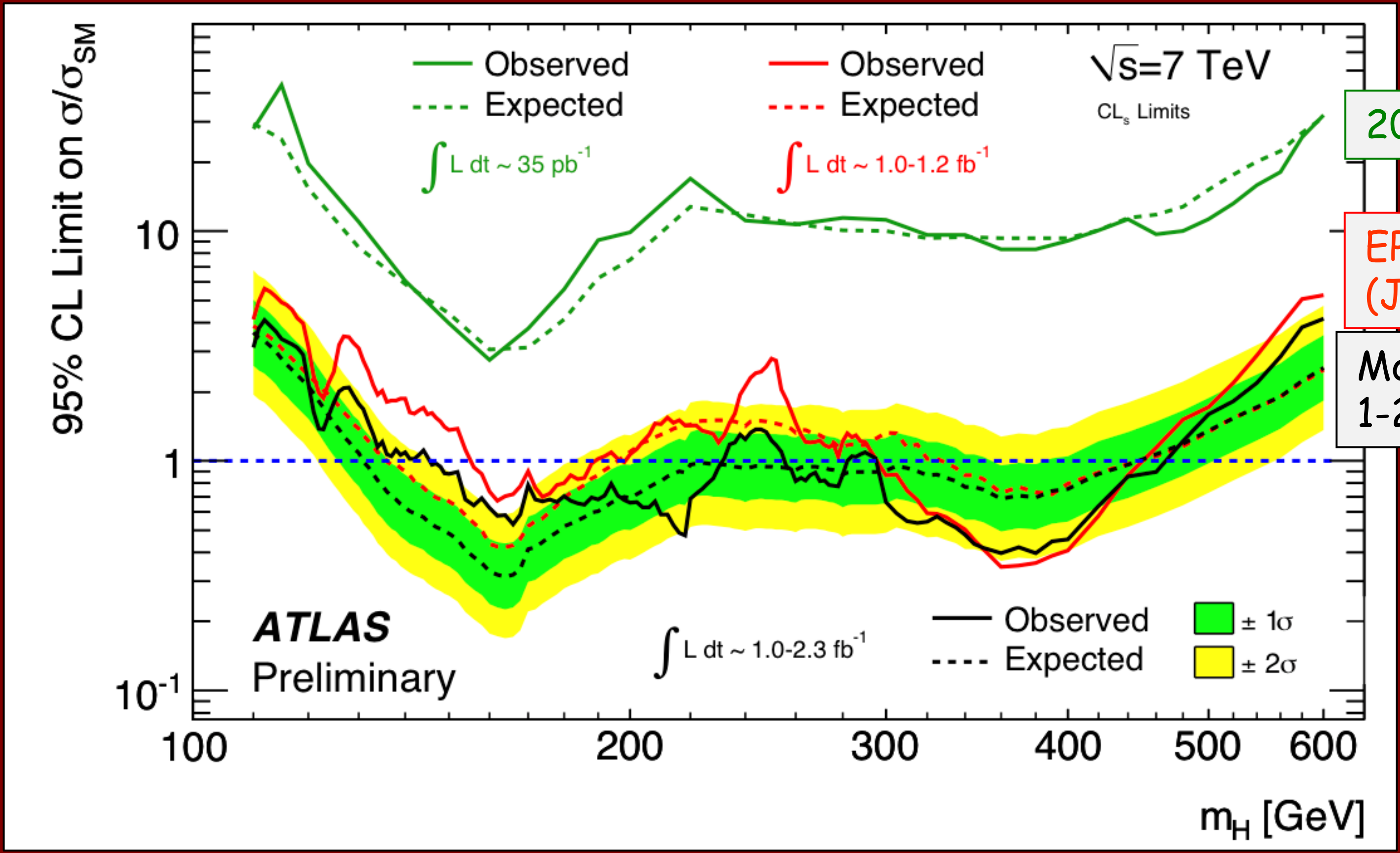
$H \rightarrow \gamma\gamma$: most sensitive channel $m_H \leq 120$ GeV

$H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$: most sensitive channel $130 \leq m_H < 180$ GeV

$H \rightarrow ZZ^{(*)} \rightarrow 4l$: most sensitive channel $180 \leq m_H \leq 300$ GeV and most convincing channel down to ~ 130 GeV

$H \rightarrow ZZ \rightarrow ll\nu\nu$: most sensitive channel $300 < m_H \leq 600$ GeV

Improvements with time



2010 data (35 pb^{-1})

EPS results (July, 1-1.2 fb^{-1})

Most recent results: 1-2.3 fb^{-1}

Prospects for ATLAS+CMS combined:
with ~5 fb^{-1} per experiment in 2011 and assuming ~10 fb^{-1} per experiment by end 2012:

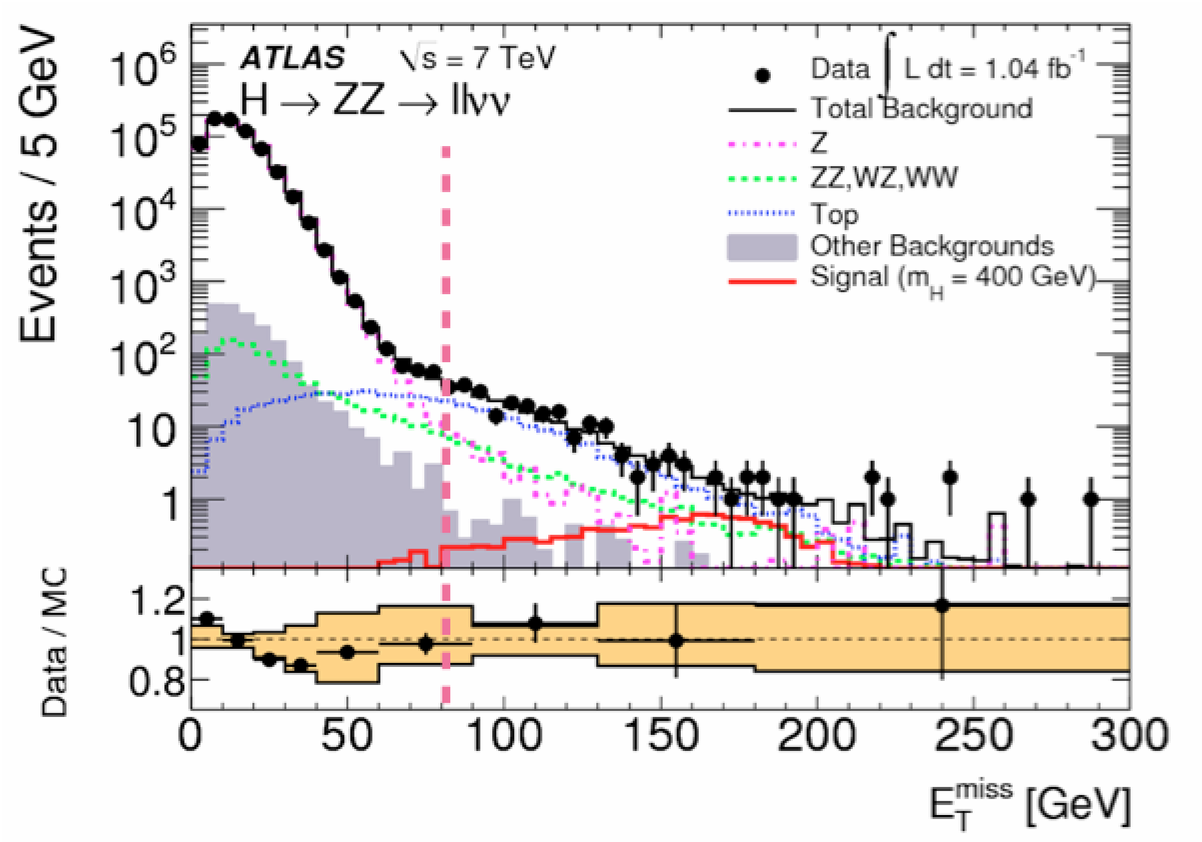
- First half 2012: sensitivity to exclude full mass region up to m_H ~ 600 GeV (≥ 95% CL)
- End 2012: may achieve 5σ discovery over the same range

Summary of present Higgs searches in ATLAS

Channel	m_H range (GeV)	Int. lumi fb^{-1}	Main backgrounds	Number of signal events after cuts	S/B after cuts	Excluded σ/σ_{SM} and m_H range
$H \rightarrow \gamma\gamma$	110-150	1.08	$\gamma\gamma$, γj, jj	~ 15	~ 0.02	~ 4
$H \rightarrow \tau\tau \rightarrow ll+\nu$	110-140	1.06	$Z \rightarrow \tau\tau$, top	~ 0.8	~ 0.02	30-60
$H \rightarrow \tau\tau \rightarrow l\tau_{had}$	100-150	1.06	$Z \rightarrow \tau\tau$	~ 10	~ 5 10^{-3}	6-25
$W/ZH \rightarrow bbl(l)$	110-130	1.04	W/Z+jets, top	~6	~ 5 10^{-3}	10-20
$H \rightarrow WW \rightarrow l\nu l\nu$	110-300	1.7	WW, top, Z+jet	~ 50 (150 GeV)	~ 0.6	0.3-10 154-186 GeV
$H \rightarrow ZZ^* \rightarrow 4l$	110-600	up to 2.3	ZZ*, top, Zbb	~ 1 (130 GeV)	~ 1	1-10 190-200 GeV
$H \rightarrow ZZ \rightarrow ll\ \nu\nu$	200-600	1.04	ZZ, top, Z+jets	~ 10 (400 GeV)	~ 0.3	1-5 340-450 GeV
$H \rightarrow ZZ \rightarrow ll\ qq$	200-600	1.04	Z+jets, top	~ 5	~0.05	2-13
$H \rightarrow WW \rightarrow l\nu qq$	240-600	1.04	W+jets,top,jets	~ 60	10^{-3}	~ 3-20

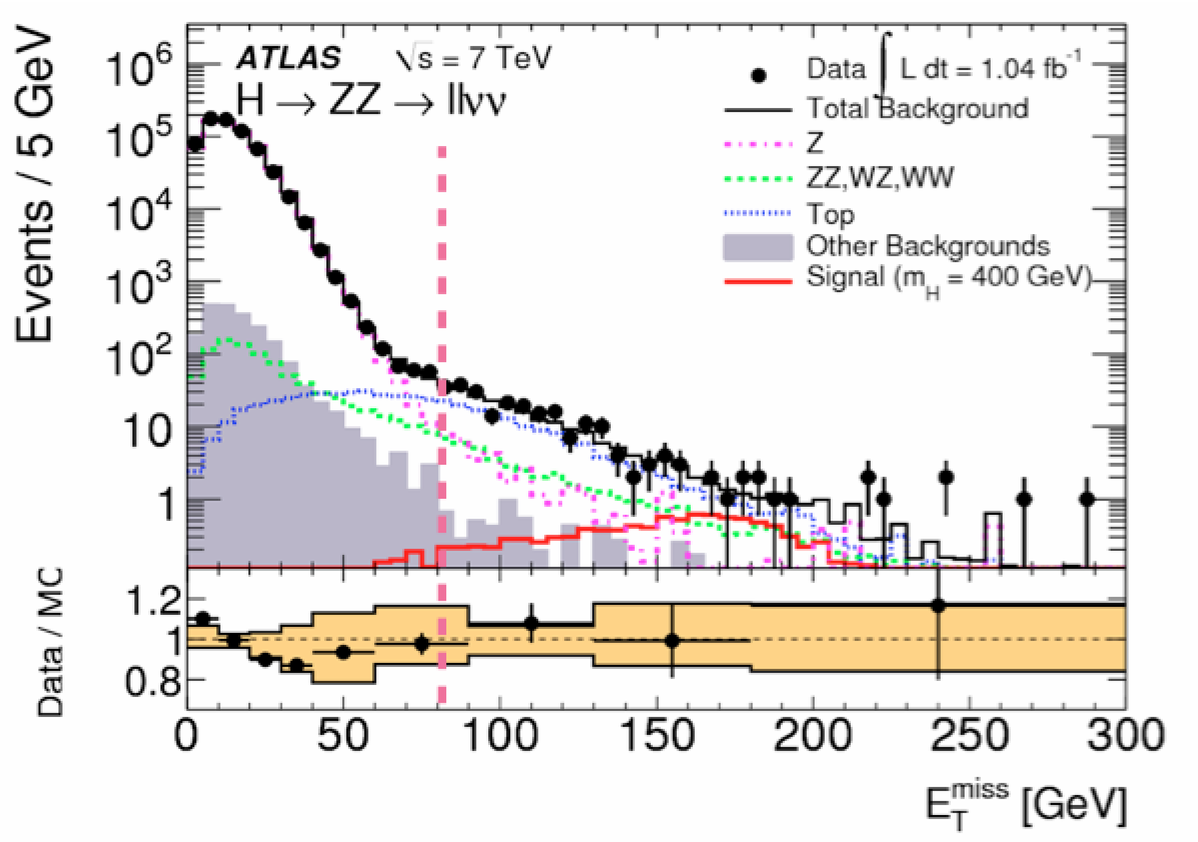
- Based so far on (conservative) cut-based analyses
- Large and sometimes not well-known backgrounds estimated mostly with data-driven techniques using signal-free control regions

ET miss in Z→ll υυ



Understanding of ETmiss scale/resolution/cleanliness essential

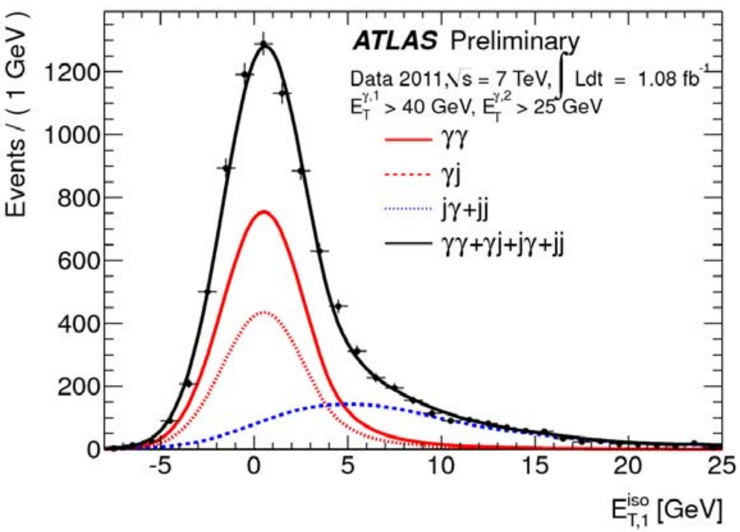
ET miss in Z→ll υυ

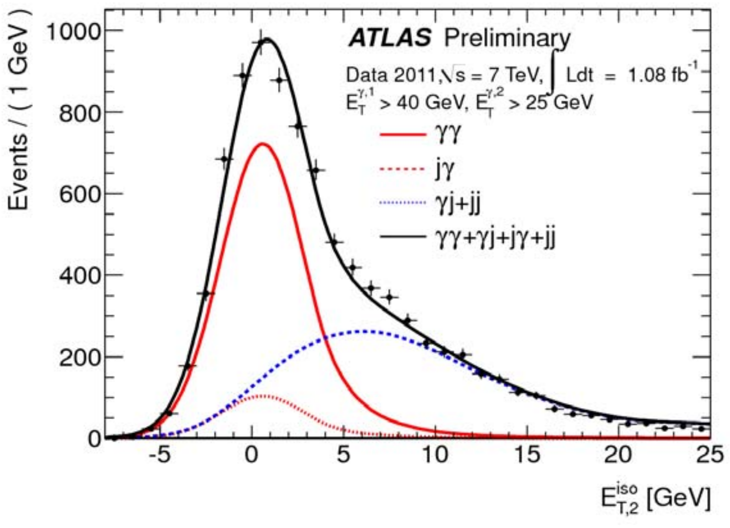


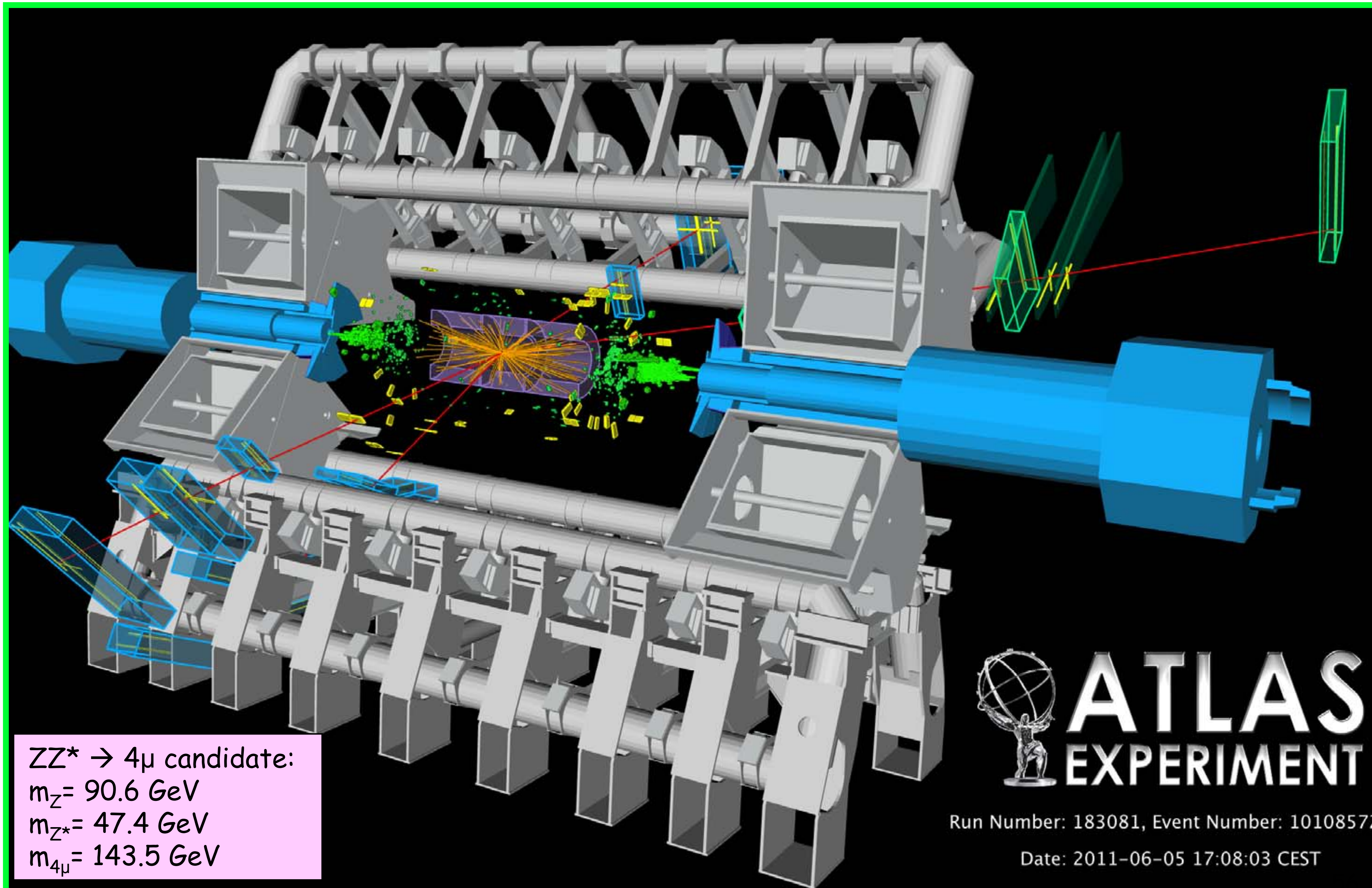
Understanding of ETmiss scale/resolution/cleanliness essential

Isolation in H→γγ

Subtraction of "ambient" ET level
Cut at 5 GeV ET





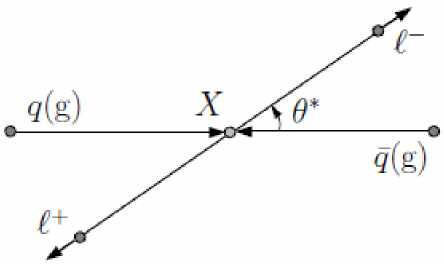


$ZZ^* \rightarrow 4\mu$ candidate:
m_Z= 90.6 GeV
m_{Z^*}= 47.4 GeV
$m_{4\mu}$= 143.5 GeV

SM precision measurement: $\sin^2(\Theta_W)$ from Drell-Yan asymmetry in CMS

Difficult measurement:

- Use Boost direction of produced Zs as direction of incoming quark (to sign $\cos(\theta^*)$)

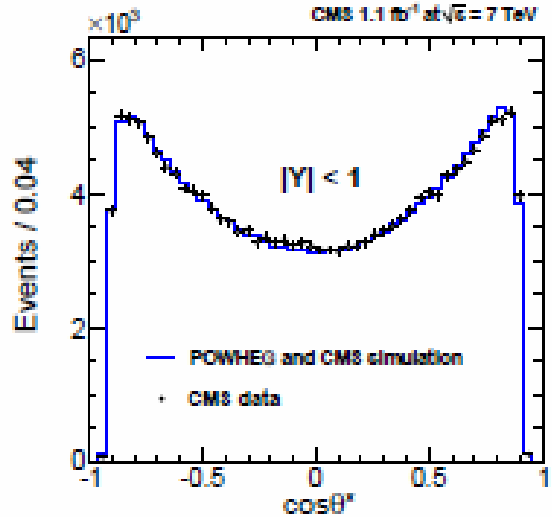


- High dilution factor for small values of $|y|$ where $\cos(\theta^*)$ acceptance is good
- Benefit from high statistics
  (300 k evts $Z/\gamma^* \to \mu^+\mu^-$ in $1.07 fb^{-1}$)

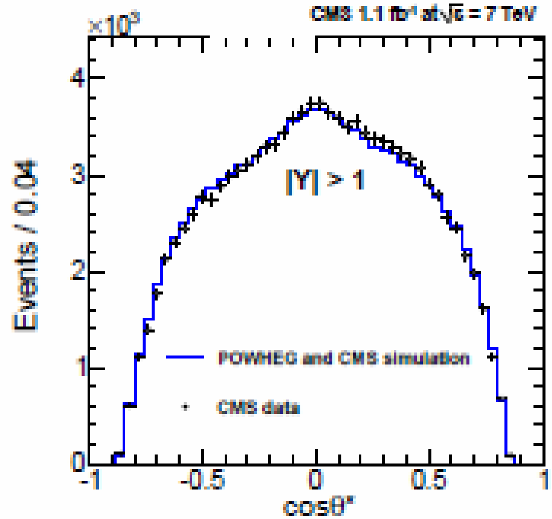
$$\boxed{\sin^2(\Theta_W) = 0.2287 \pm 0.002 \pm 0.0025}$$

Precision comparable to Neutrino expt, DIS/Hera
(D0 has ~3 times smaller errors with $5 fb^{-1}$,
and LEP ~10 times smaller)

- Limiting systematics : <u>tracker alignment</u>, PDF



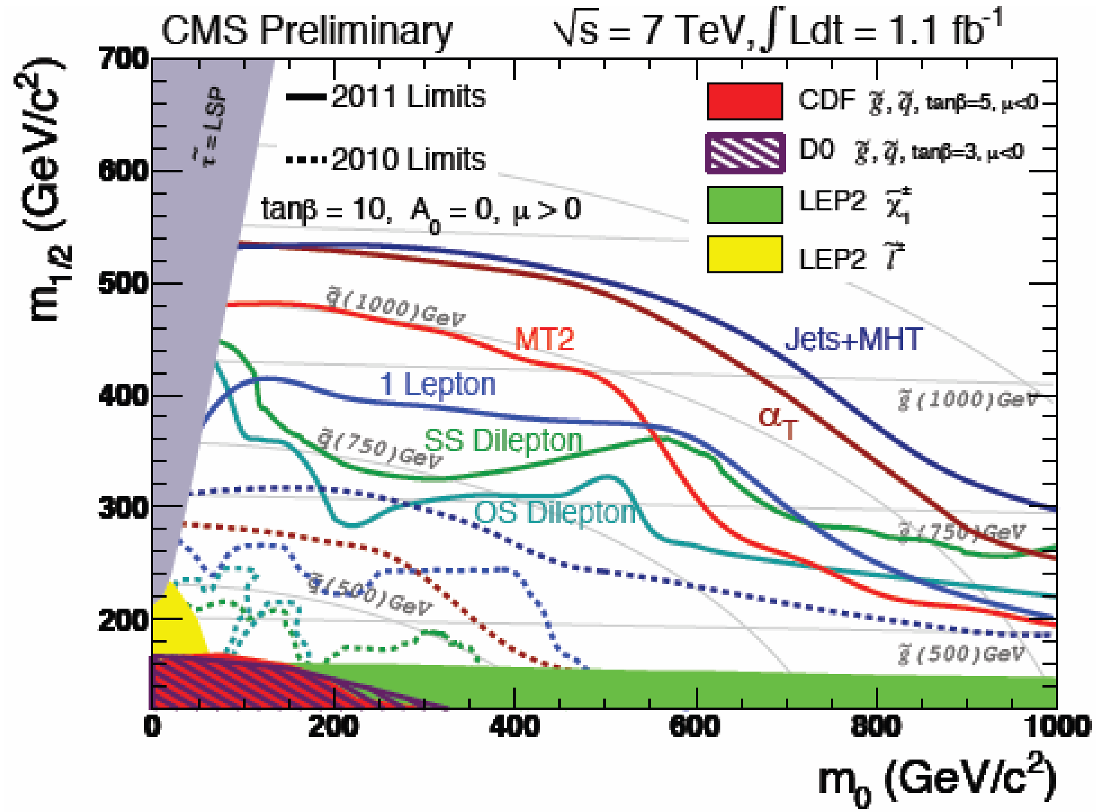
High dilution



Low acceptance

CMS : SUSY /CMSSM

- Allows to compare limits from different final states(0,1,2 leptons)
- Best limit from Jets + MHT (MHT=ETmiss calculated from jets with PT>30GeV)
- Several "benchmark" points already excluded (LM4,LM6)

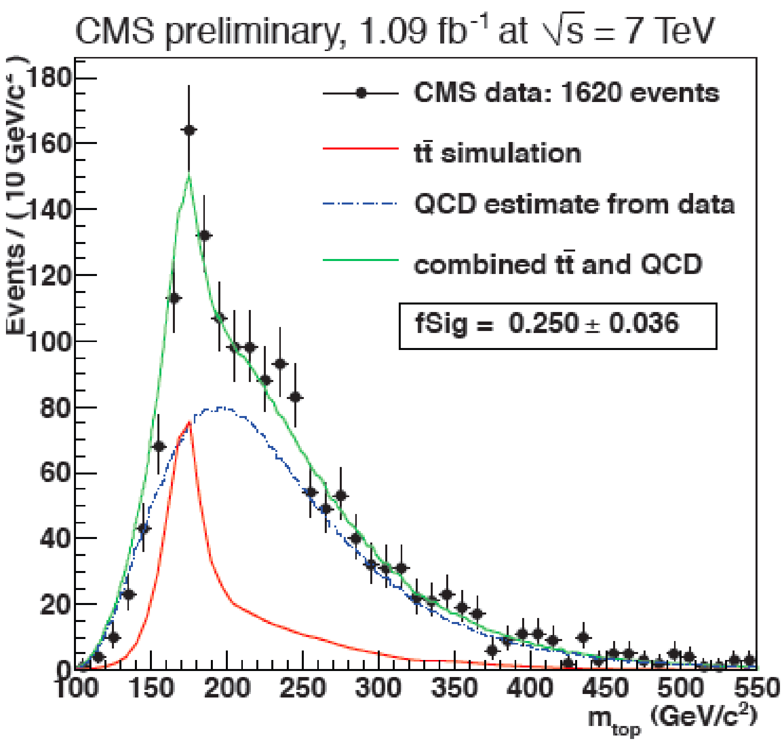


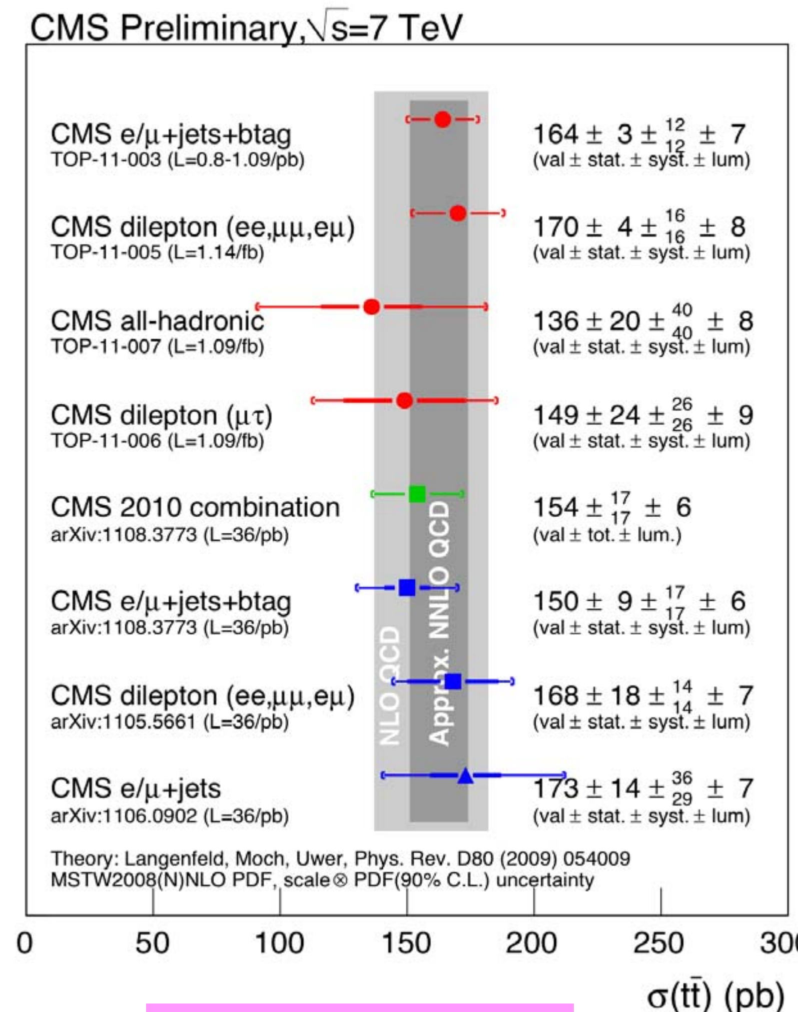
MT2:

α_T: variable used to spot mismeasured jets

Very substantial gain with increased luminosity

CMS: t tbar cross-section and mass difference





Comparing “hadronic top mass” in μ^+jets and μ^- jets events

Δm (t-tbar)= -1.20±1.21(stat)±0.47(syst)GeV

σ = 164±3±12±7 pb