Higgs Searches

V Workshop ATLAS-Italia

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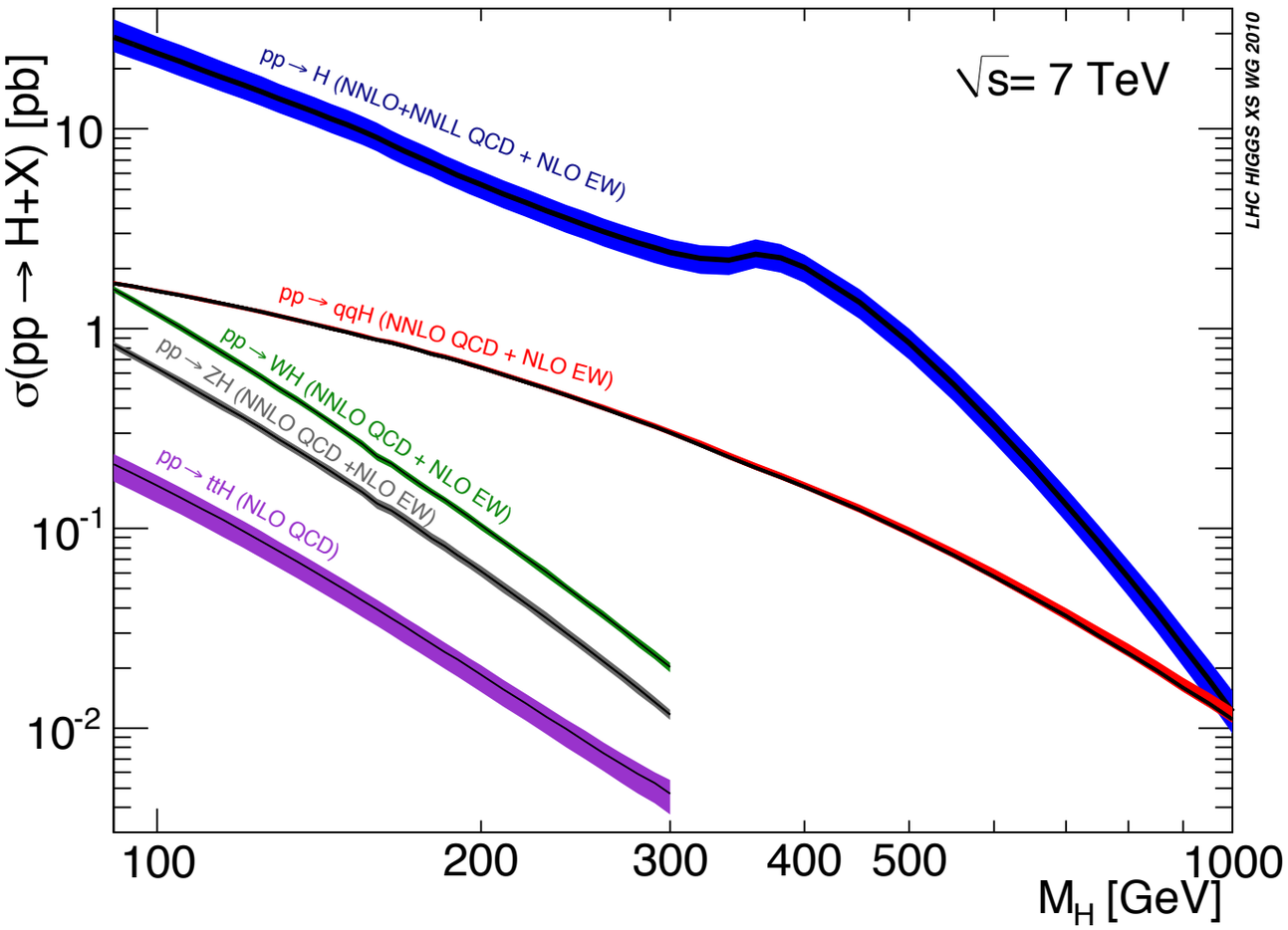
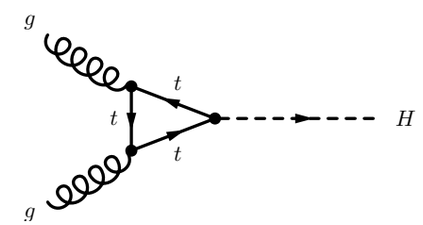
INFN Roma

Standard Model Higgs @ LHC

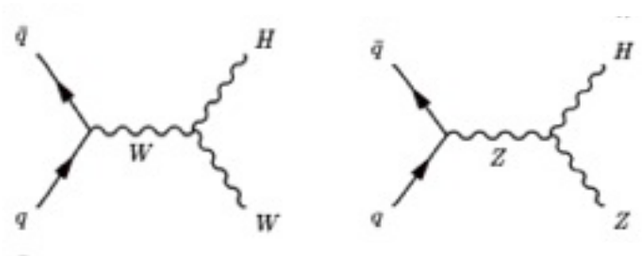


- Common effort (ATLAS, CMS, Theorists) for cross sections determinations (Yellow Report CERN-2011-002)

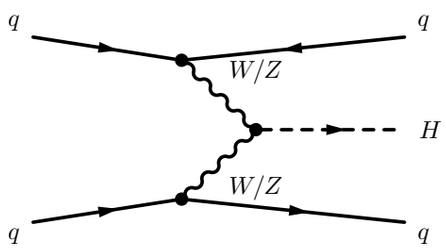
- Backgrounds are in general determined from data
→ use N(N)LO signal cross sections for exclusion



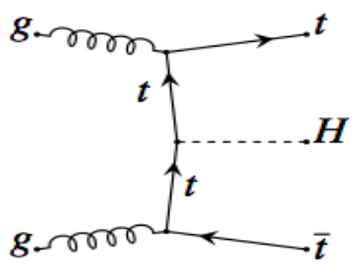
Gluon fusion: known at NNLO with large uncertainty ~15-20% on gluon processes



Associated production with W / Z:
Known at NNLO uncertainty ~5%



Vector Boson Fusion:
Known at NNLO QCD+NLO EW, uncertainty ~ 5%



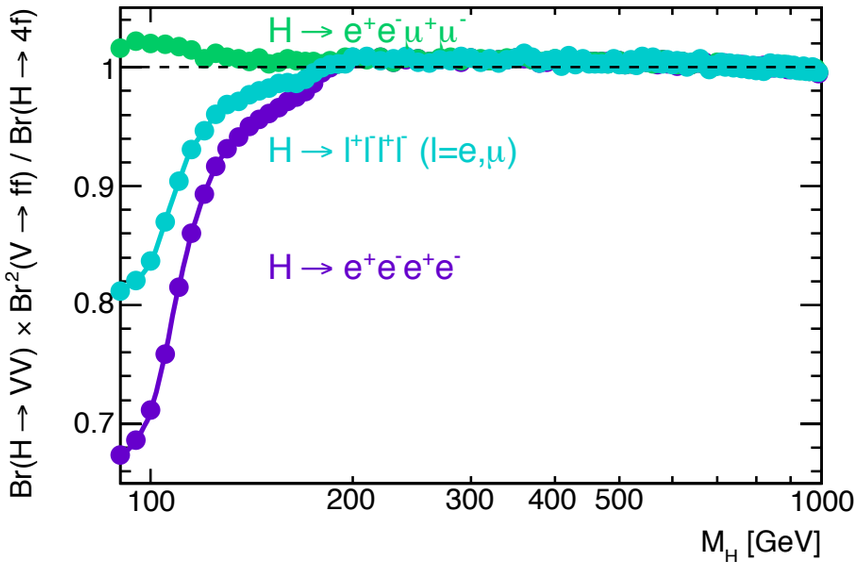
Associated production with ttbar:
Known at NLO uncertainty ~15%

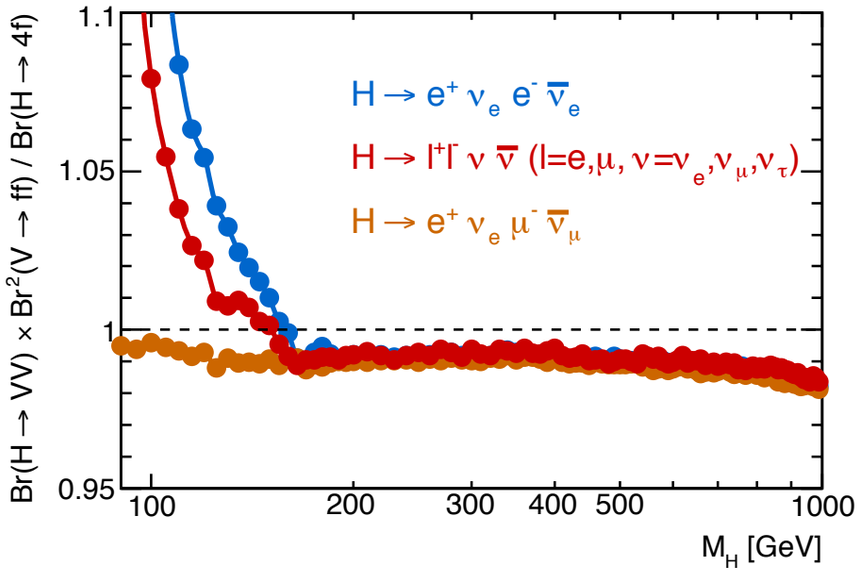
Cross Sections: Italian groups involved

Pavia: D. Rebuzzi

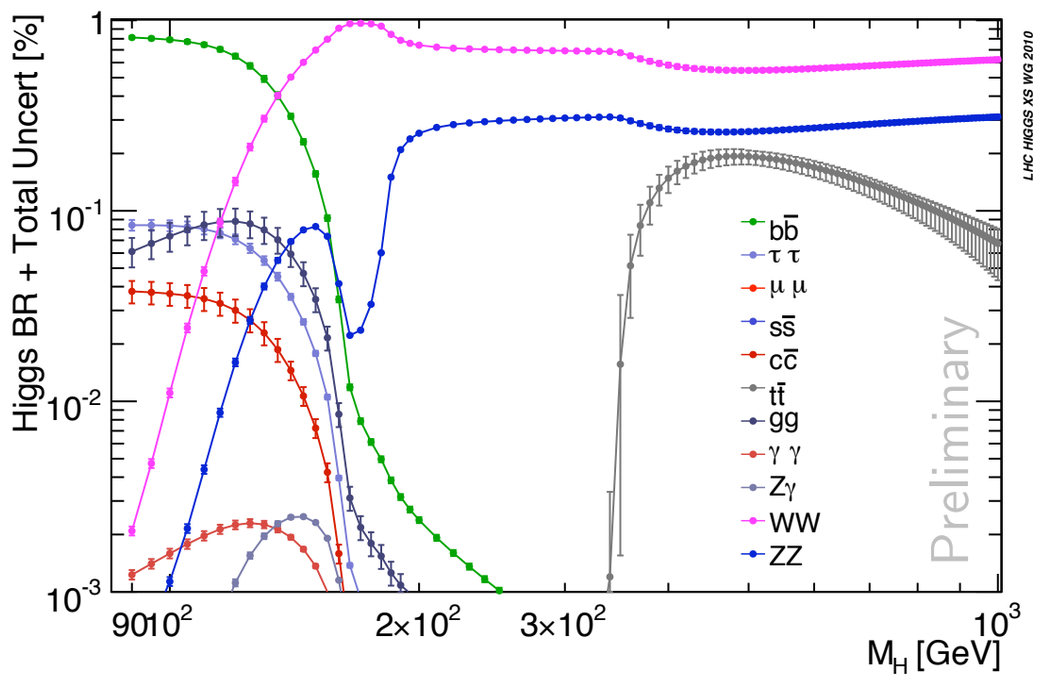
- Participation in the Yellow Report preparation - contact for ATLAS on VBF and Higgs BR
- VBF NNLO and NLO EW cross sections, study of POWHEG differential distributions
- Higgs BR: calculation of the total parametric and theoretical uncertainties (with HDECAY and Prophecy4f) - EW - NLO corrections

$$BR(H \to VV) \times BR(V \to ff) \times BR(V \to ff) \times \text{stat factor} / BR(H \to 4f)$$



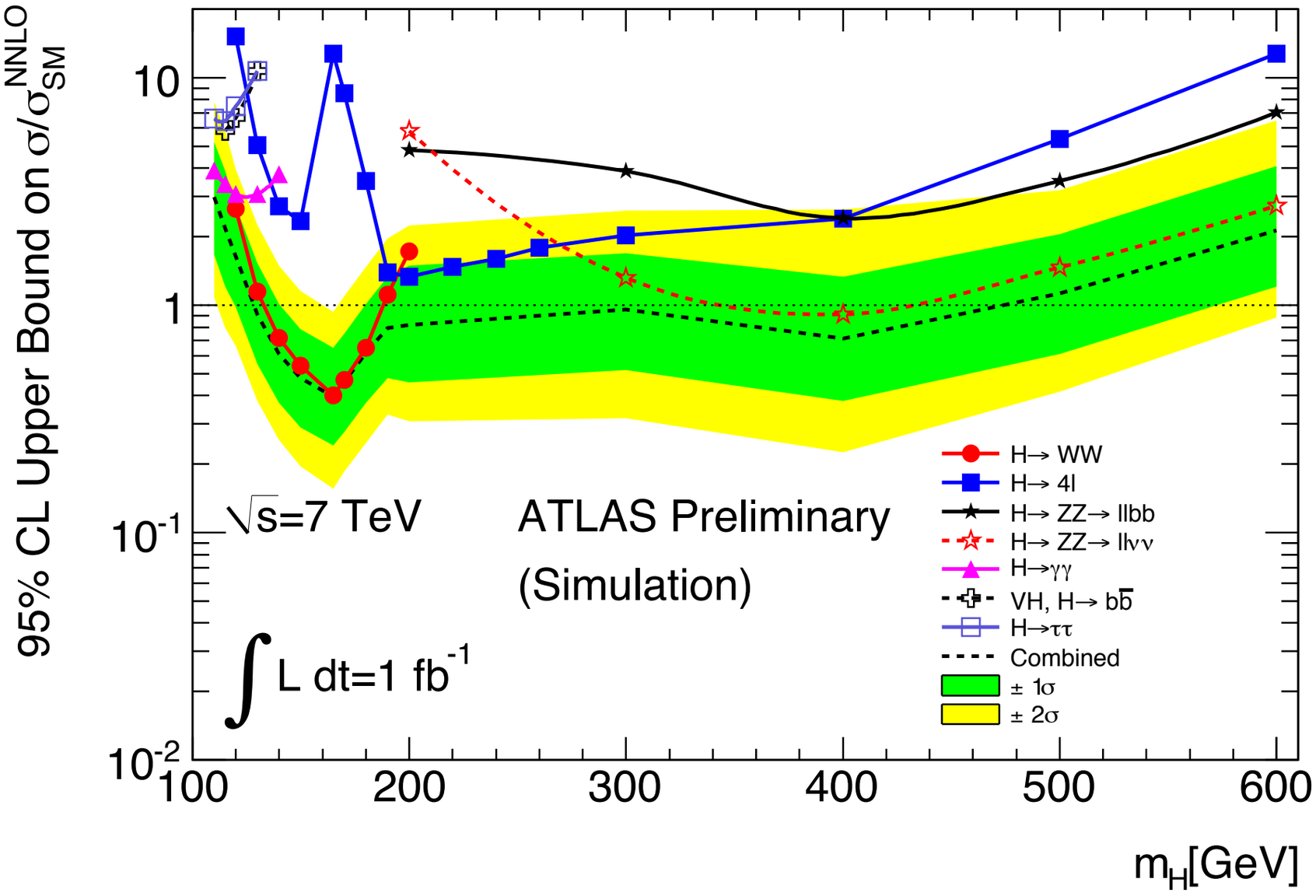


Interference not negligible
for H→llll , H→lνlν,
and H→qqqq
for M_H<200 GeV



Total Uncertainties on BRs for $M_H > 200$ GeV			
$H \to WW$	O(2%) for $M_H > 360$ GeV	$H \to ZZ$	O(2%) for $M_H > 350$ GeV
$H \to t\bar{t}$	O(40-50%) for $260 < M_H < 380$ GeV, O(200%) for $M_H \approx 2m_t$ (*)		
	below 10% for $M_H < 450$ GeV (**)		

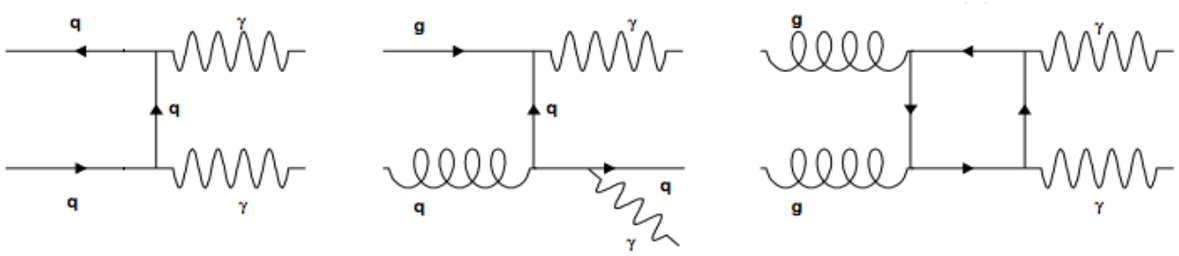
What do we expect



- Most sensitive channel for exclusion at high mass is H→ZZ (4l, llνν, llqq)
- At lower masses H→WW
- Low mass (<130 GeV) H→γγ
- H→ττ: relevant at low-mass, inclusive or dedicated VBF selection
- Associated production VH H→bb at low mass

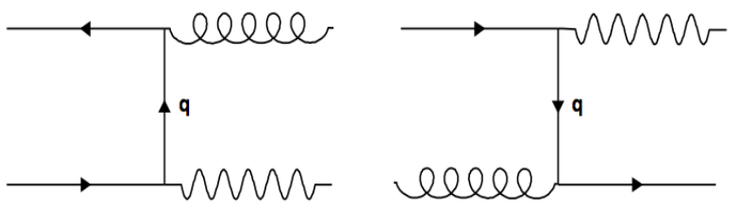
H→γγ

Irreducible backgrounds



Δσ/σ ~ 30%

Reducible backgrounds



Δσ/σ ~ 50% (γj) ~100% (jj)

A complete NNLO calculation is for the moment out of reach
→ determine backgrounds from data

Drell-Yan e+e-, electrons faking photons

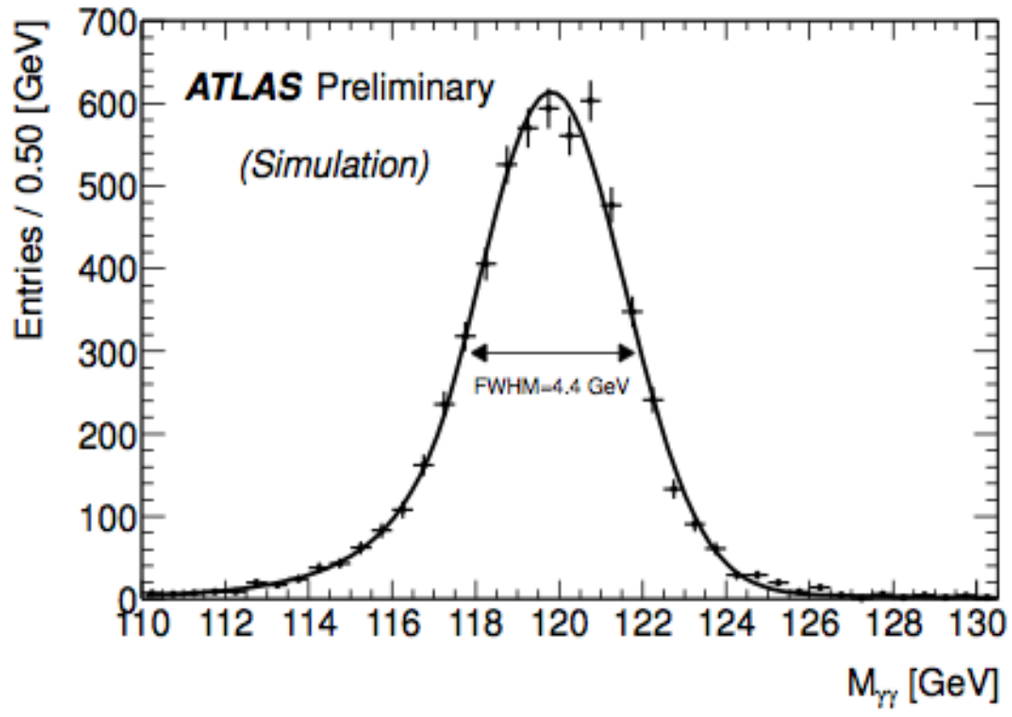
Δσ/σ ~ 10%

Event selection:

- 2 tight photons with pT> 40, 25 GeV
- $E_T^{Isolation}$ < 3 GeV
-Mass resolution quite dependent on PV choice

Right now max ΣP^2_T is used

→ exploiting photon pointing in vertex identification should improve mass resolution by ~10%



H→γγ background estimation

Data-driven estimate of the background composition

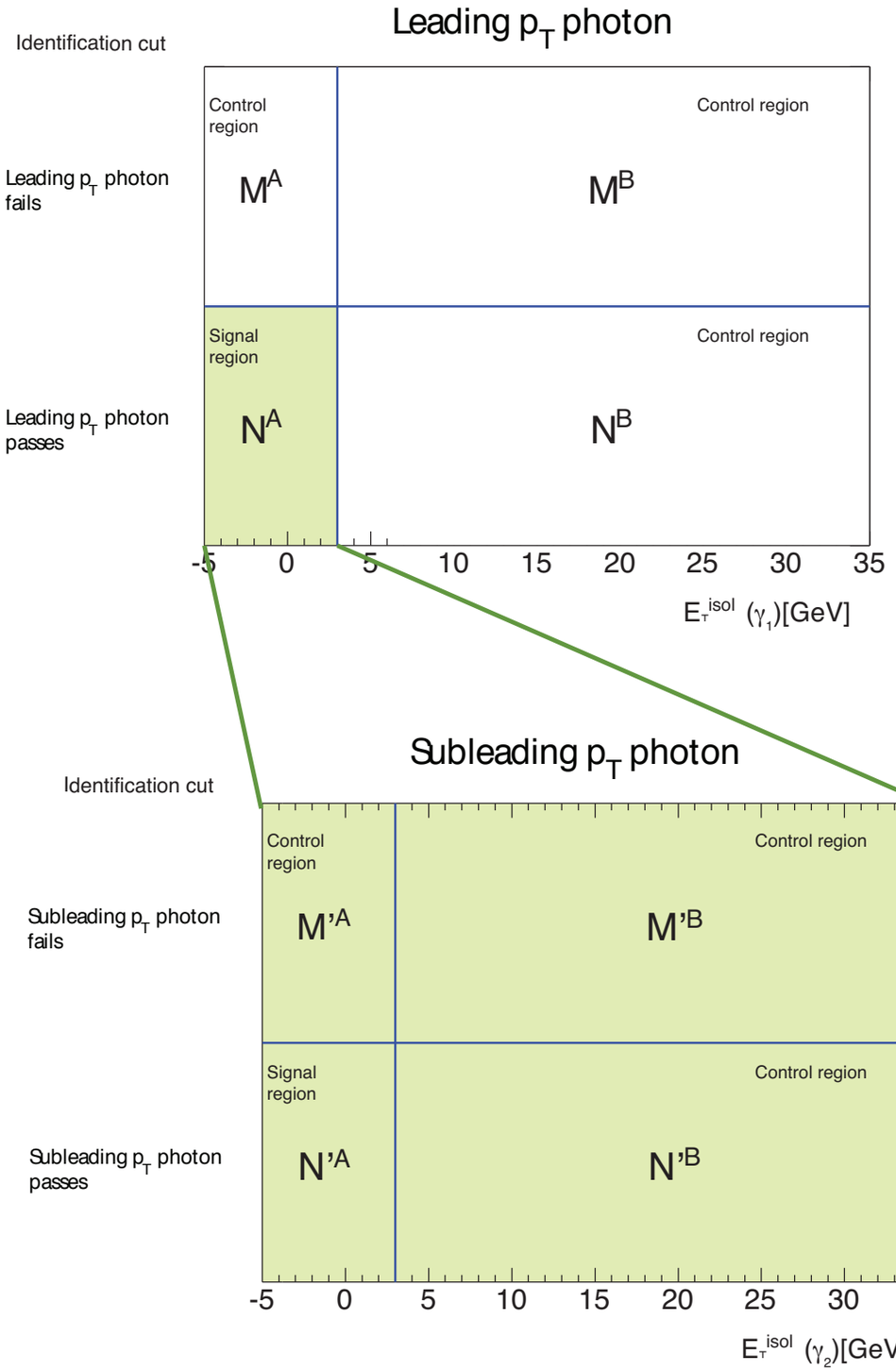
2x2D sideband method: cluster quality vs isolation

Applied sequentially to leading and subleading γ

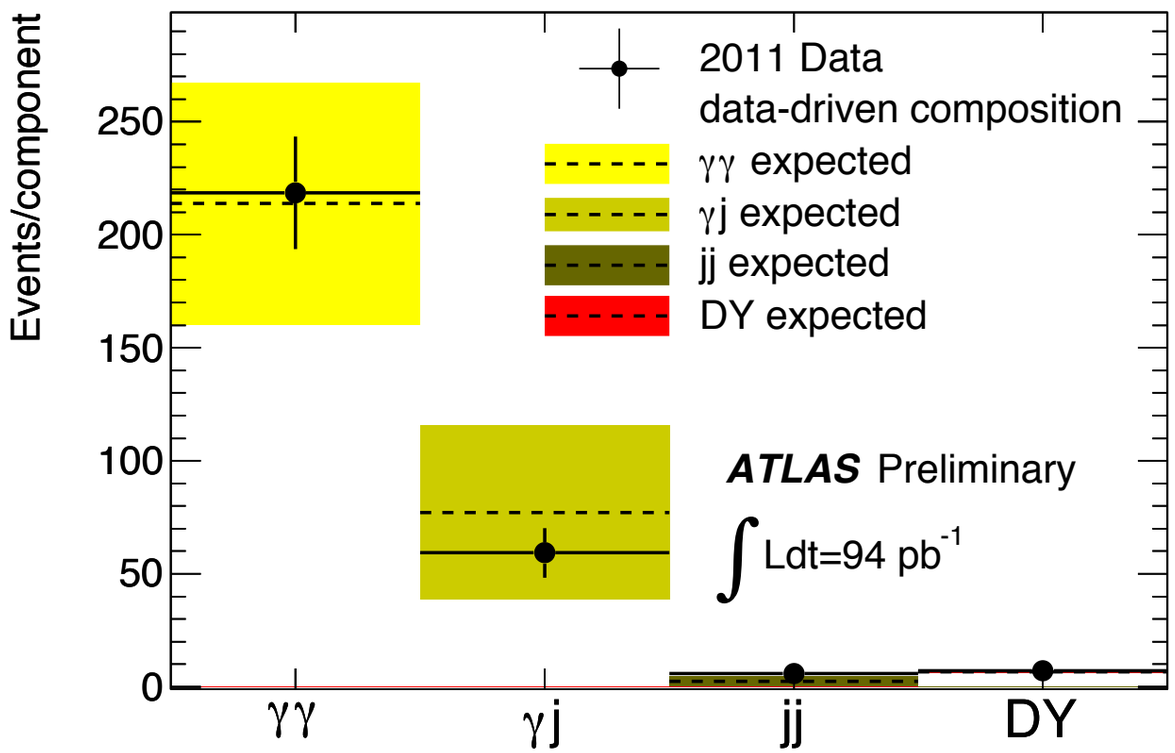
- step 1: γ-jet signal region, jet-jet control regio
- step 2: γ-γ signal region, γ-jet control region

Cross-checked with other methods:

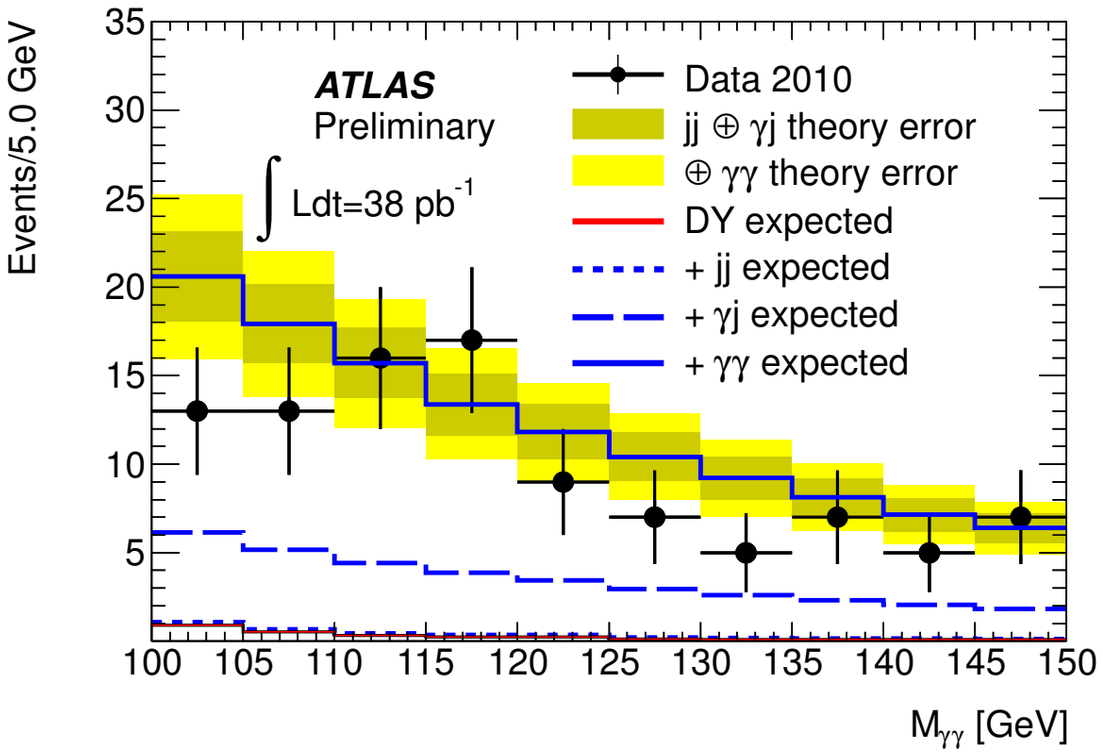
- background templates on reversed quality regions
- fake rate estimate from background enriched sample

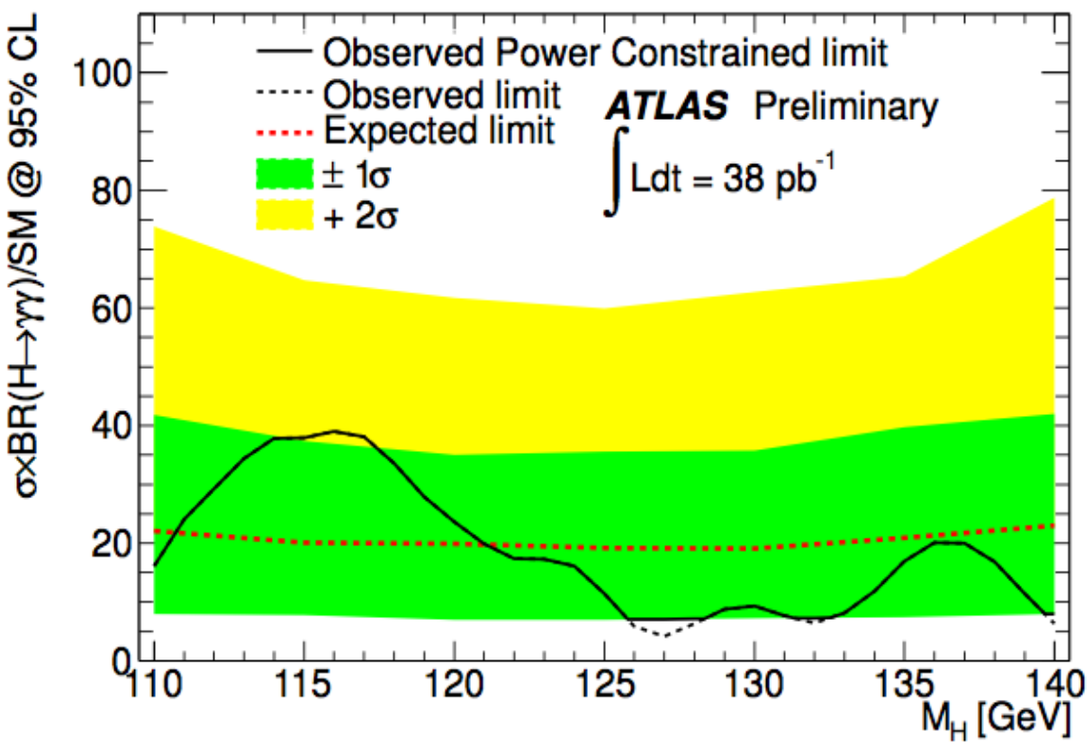


Drell Yan checked with Z→ee events



H→γγ , 2010 results and the recent update

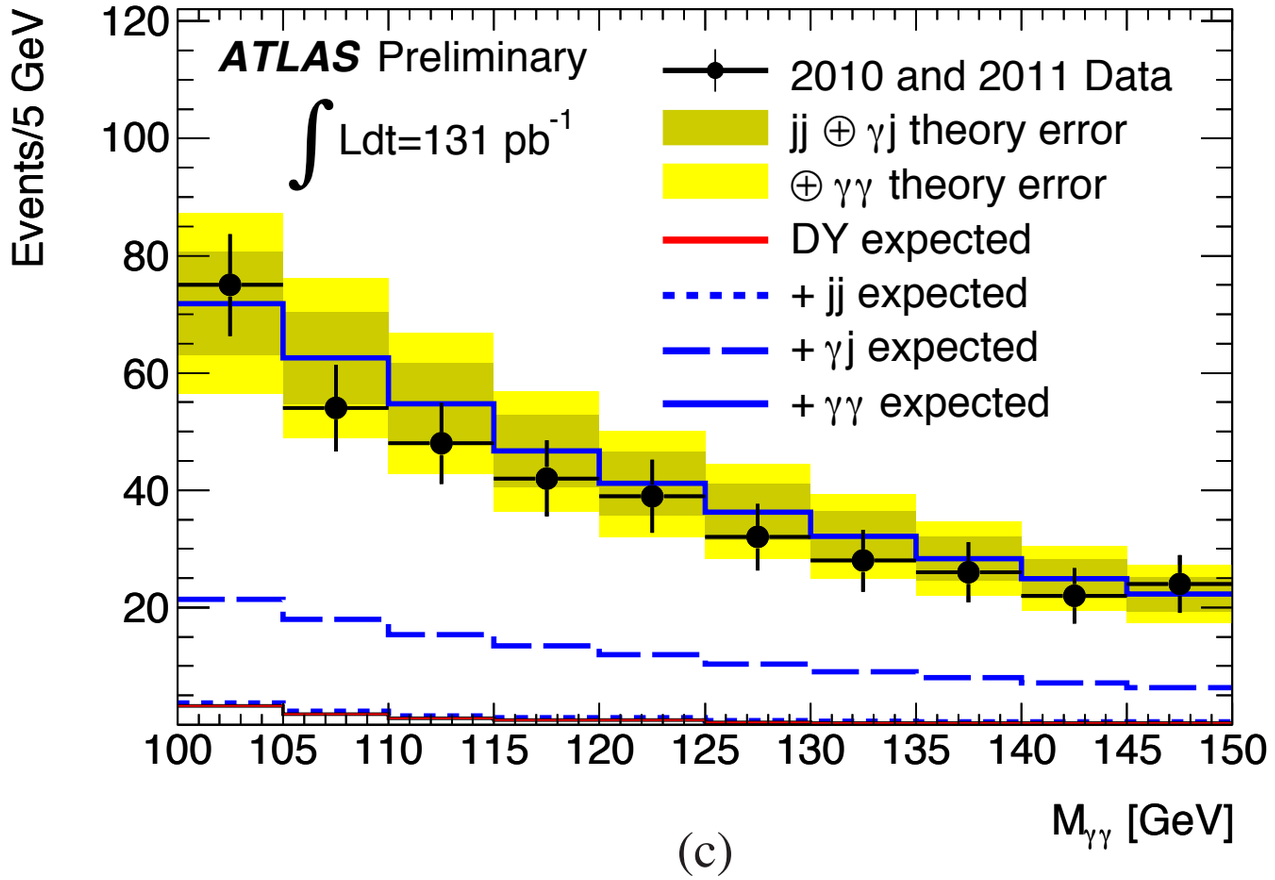




Main systematic effects on expected signal are:

γ efficiency and resolution (15% and 13%)

signal cross section (15%)



(c)

H→γγ Italian groups involved

Milano: L. Carminati, C. Costa, M. Fanti, I. Koletsou, L. Mandelli, F. Tartarelli, R. Turra

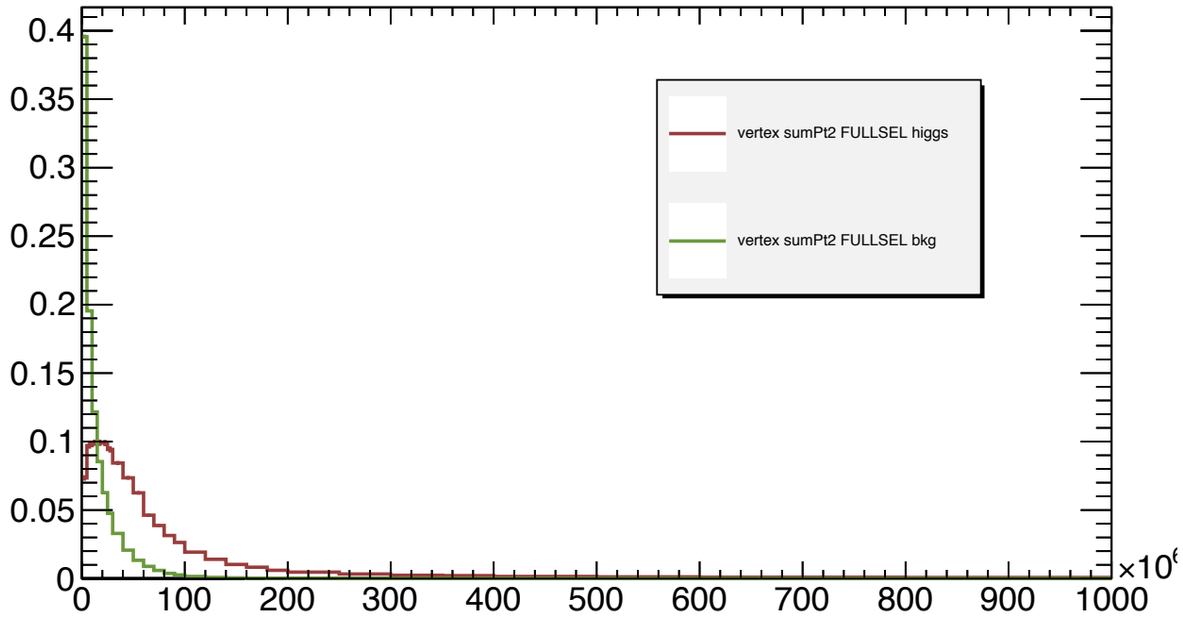
Strong involvment in prompt-photon and di-photon papers (editors L. Carminati, M. Fanti)

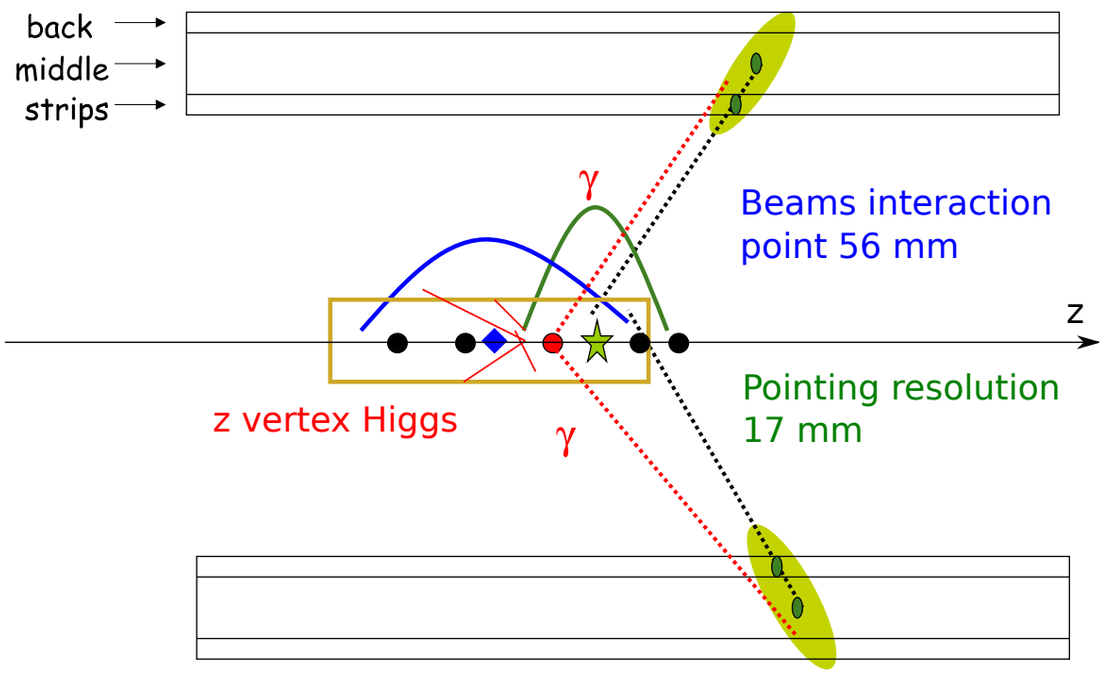
Now also focusing on H→γγ

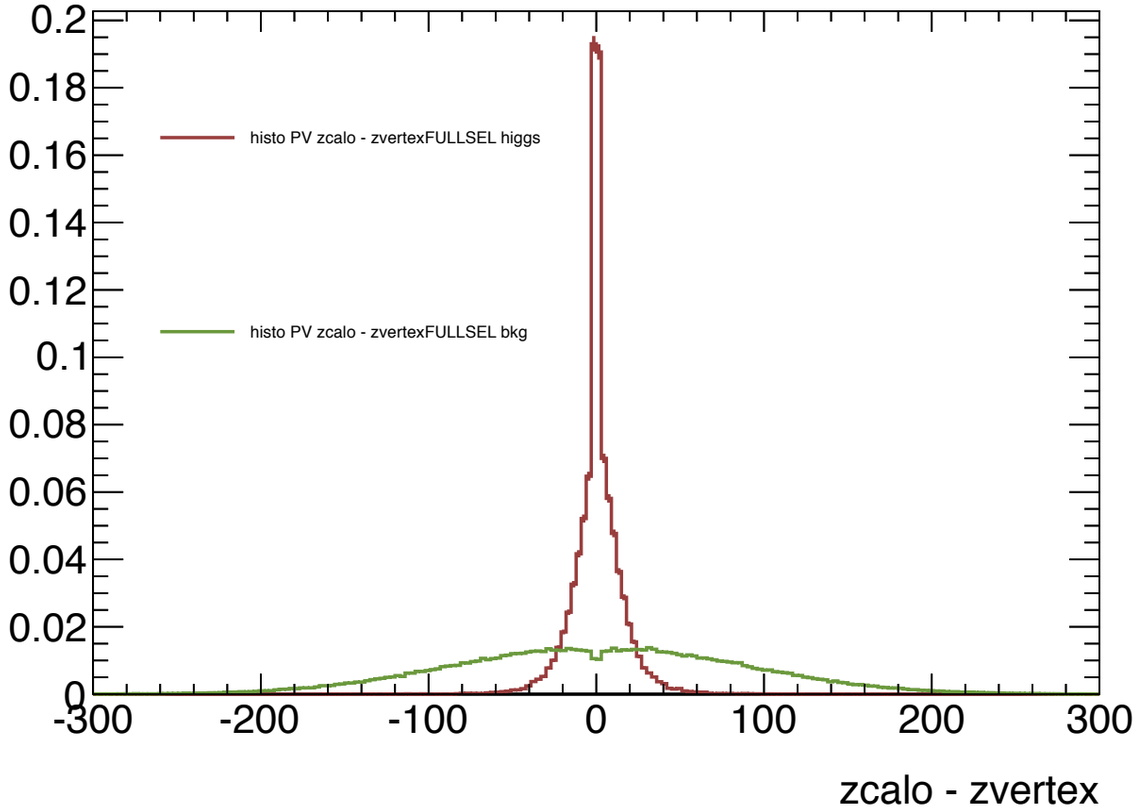
- photon calibration optimization
- vertex ID with photon direction reconstruction

Get photon direction from middle and strip layer

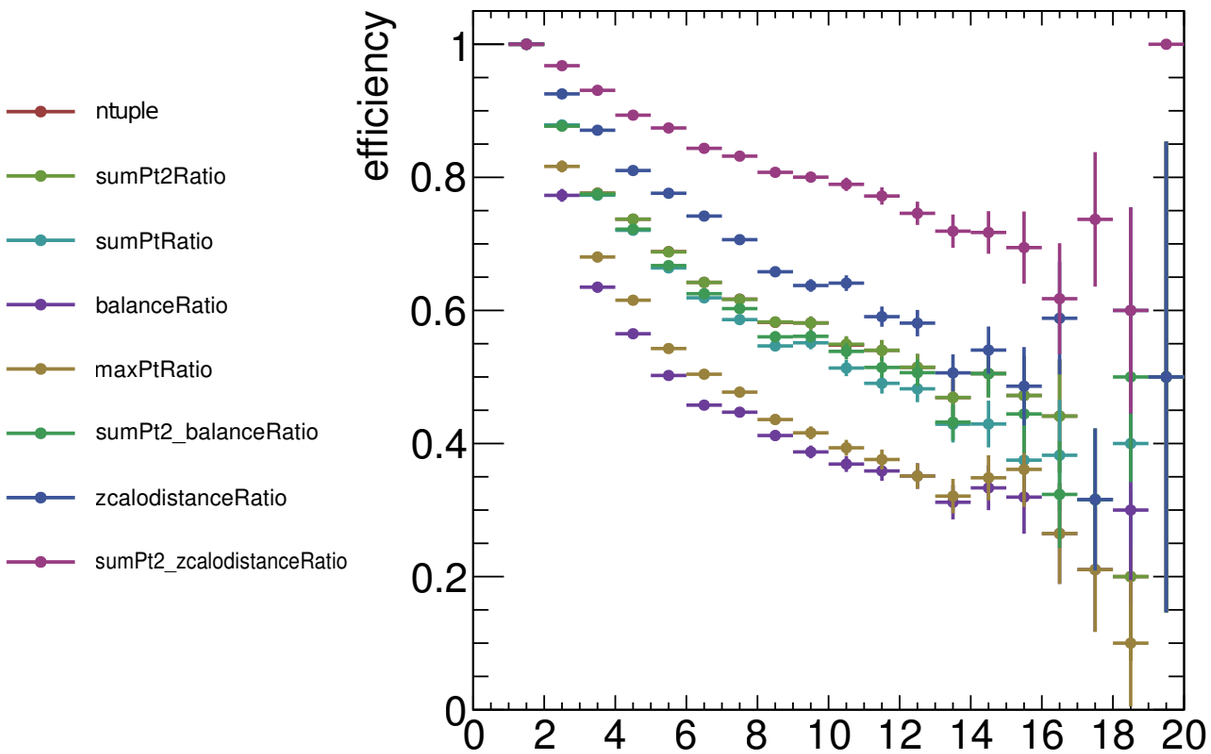
Identify the primary vertex with a likelihood ratio combining various variables, including Z-Zcalo

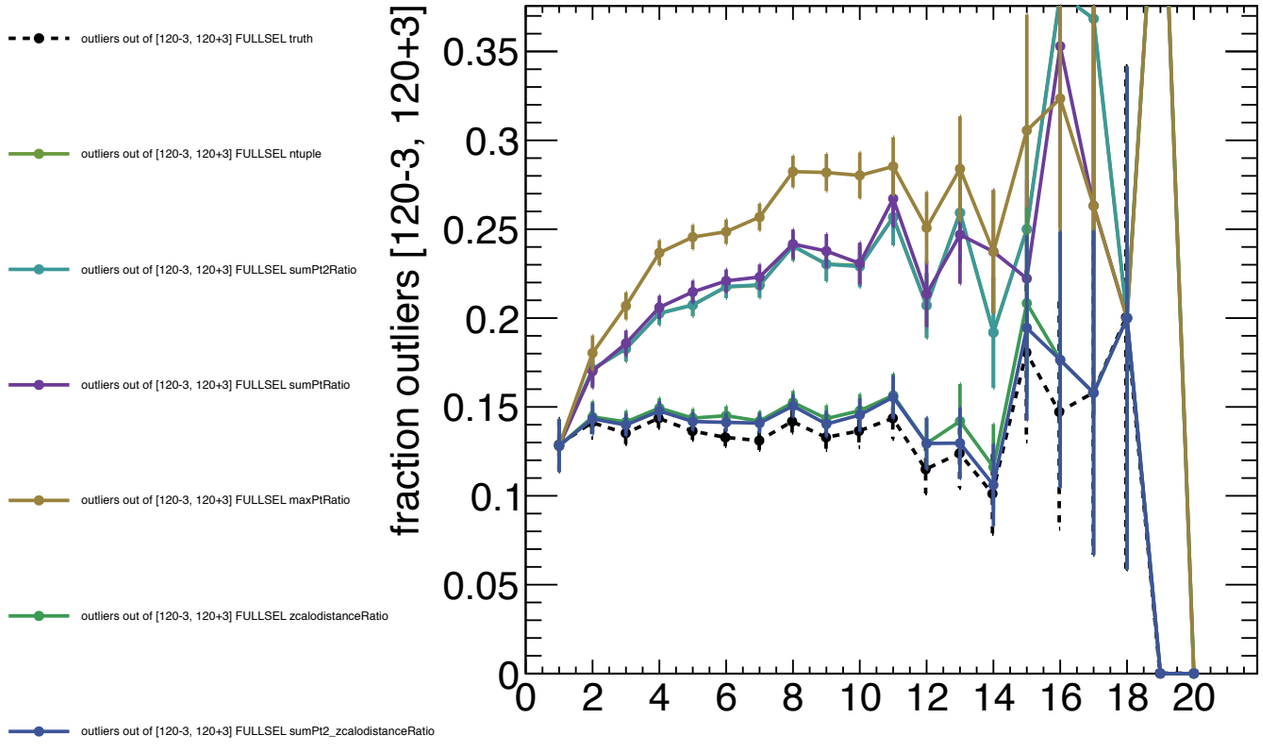


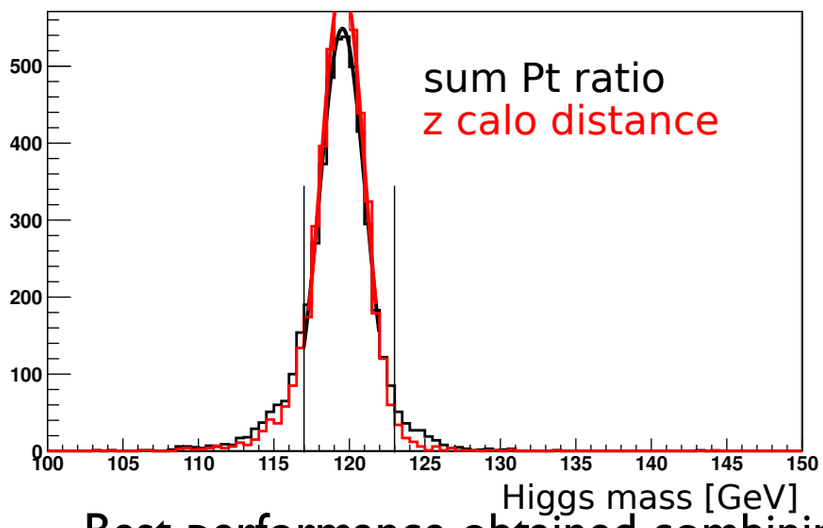




H→γγ mass resolution

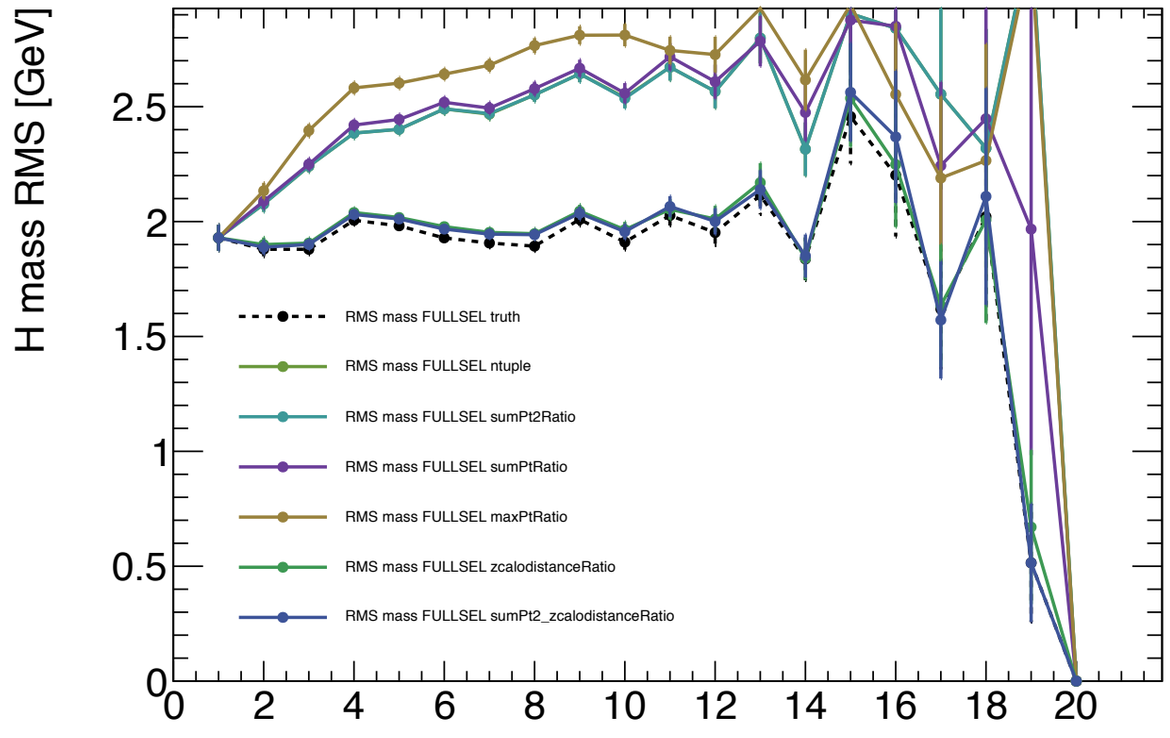






- Best performance obtained combining ΣP^2_T and Z-Zcalo
- Very close to the best possible performance

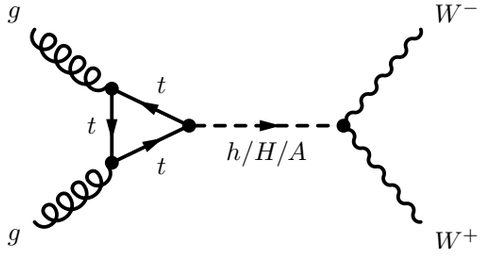
Thanks to Ruggero Turra for the plots

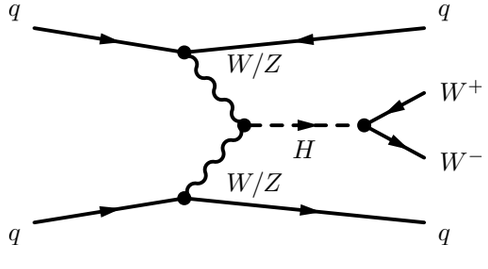


H→WW→lνlν

Exclusive analyses 0- 1- 2-jets

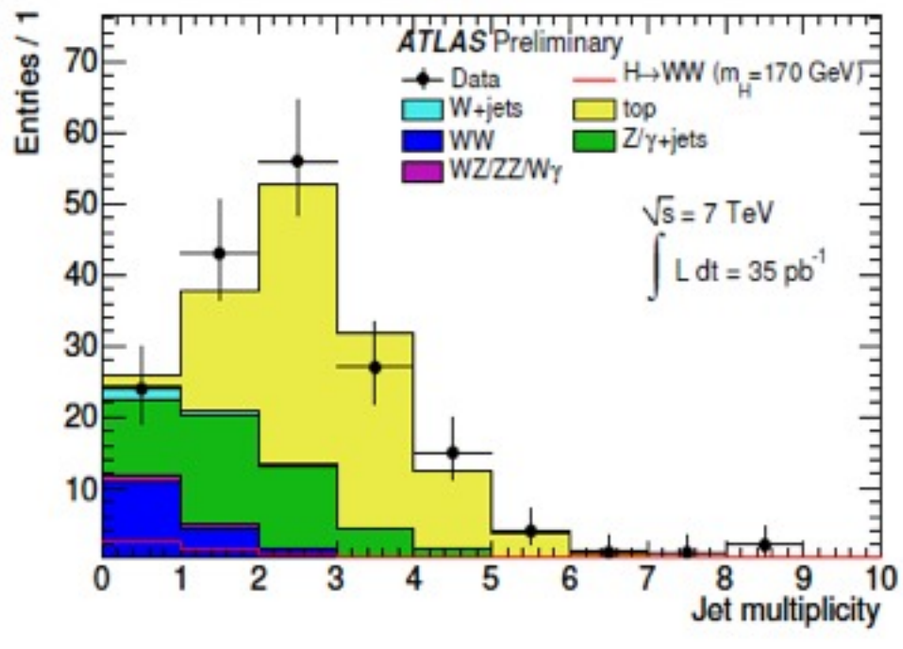
- 0- and 1-jet bins are dominated by ggF
- 2-jets bin dominated by VBF





Uncertainty on signal events varies:

0-jet 10% , 1-jet 6%, 2-jets 35%

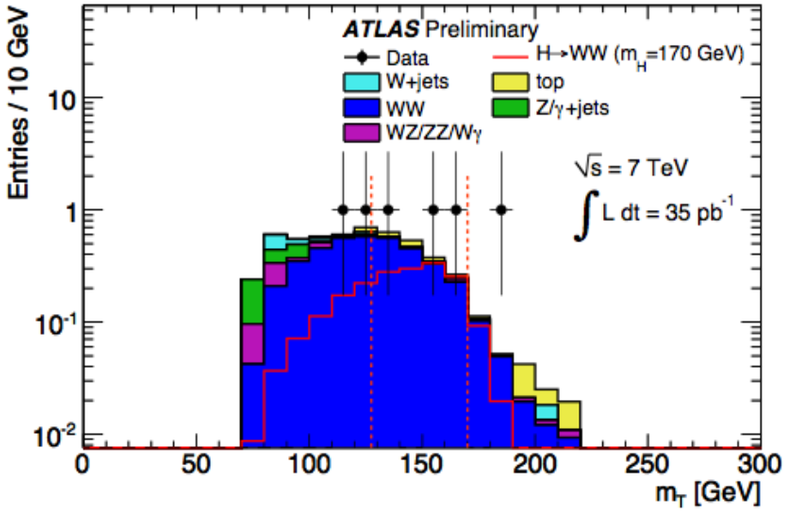


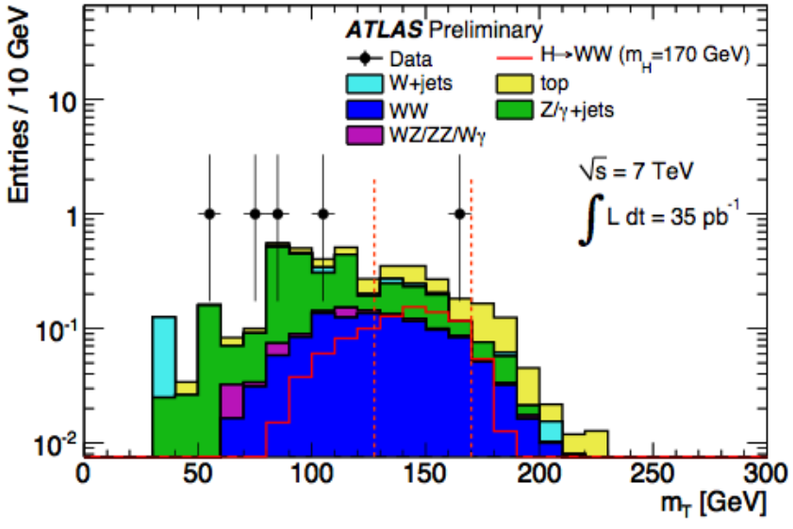
Common preselection

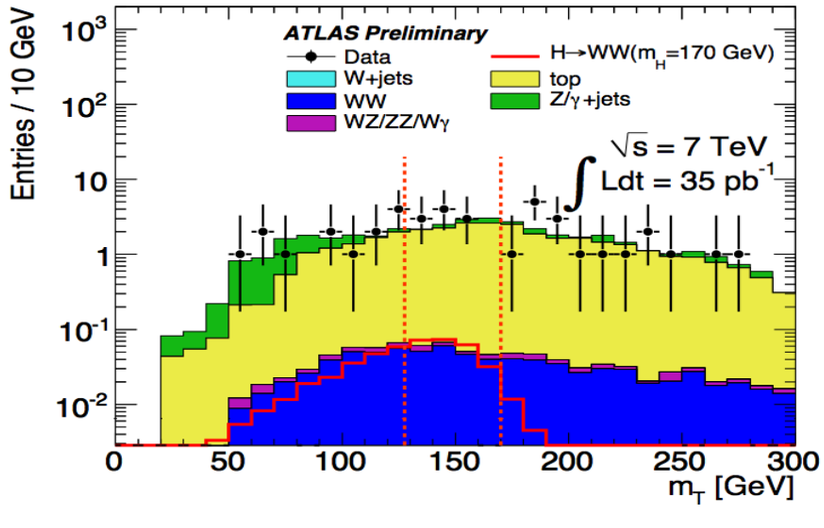
- 2 opposite sign leptons p_T>20, 15 GeV
- M_{ll}>15 GeV $|M_{ll}-M_Z|$>10 GeV (ee,μμ)
- MET>30 GeV
- Δφ(ll)<1.3 (1.8) M_H<170 GeV (>170 GeV)

Sensitivity optimized in each Njet bin and for each Higgs mass

$$m_{\mathrm{T}} = \sqrt{(E_{\mathrm{T}}^{\ell\ell} + E_{\mathrm{T}}^{\mathrm{miss}})^2 - (\mathbf{P}_{\mathrm{T}}^{\ell\ell} + \mathbf{P}_{\mathrm{T}}^{\mathrm{miss}})^2}$$







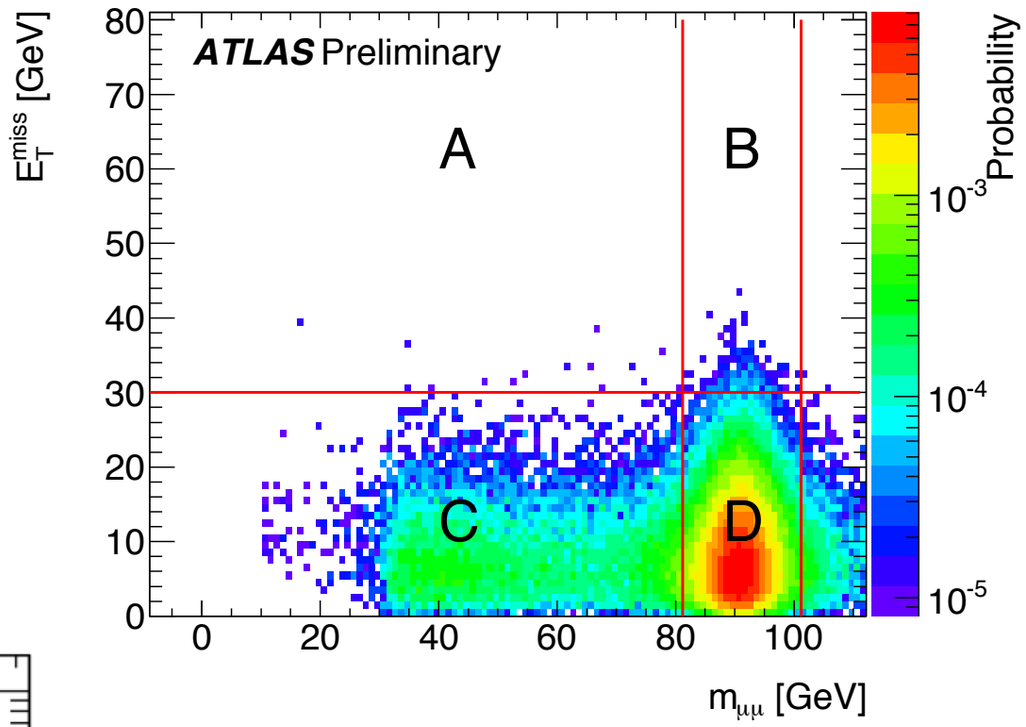
H→WW→lνlν

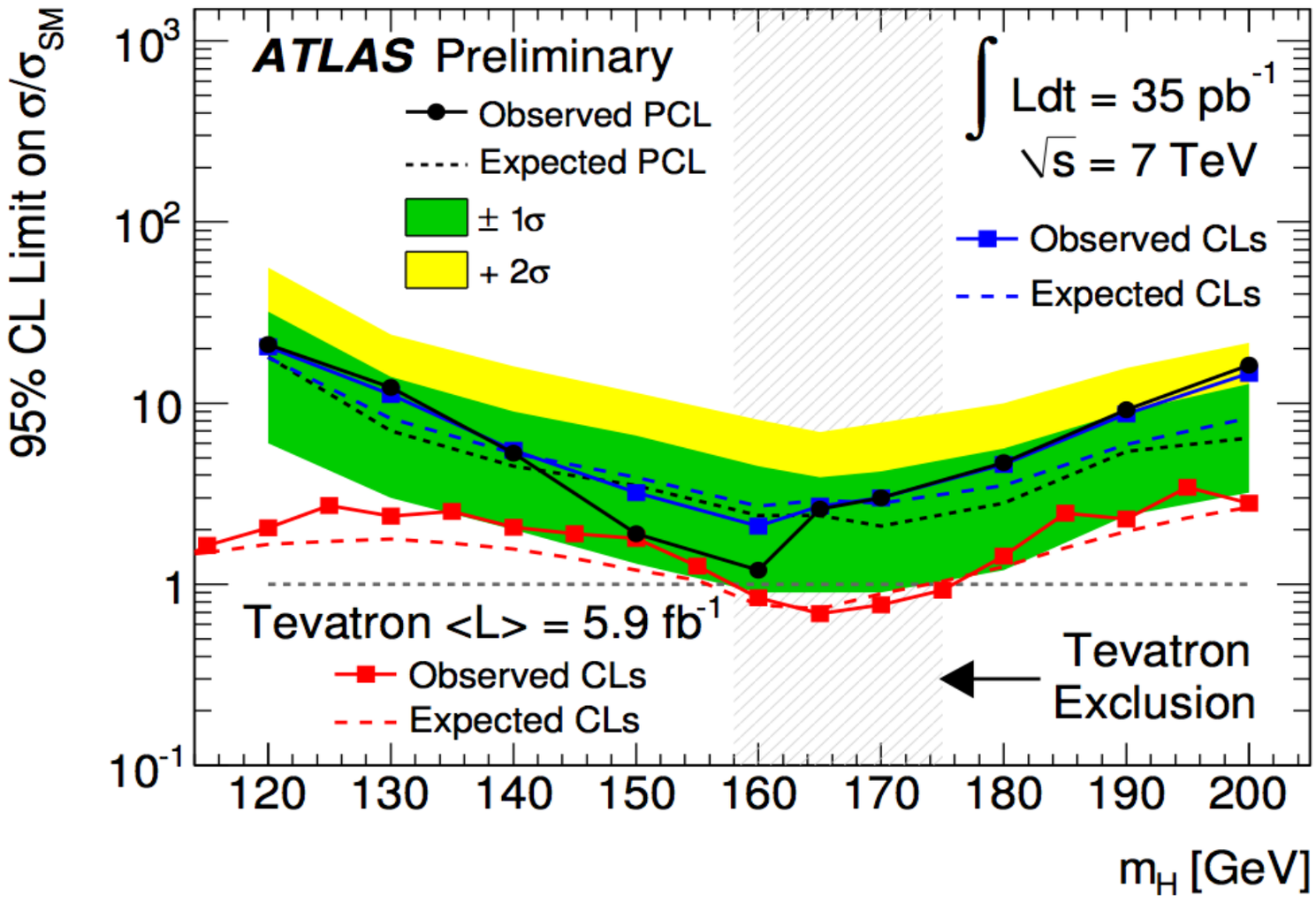
All relevant backgrounds are determined from data

- WW: shape from sidebands (M_{ll}>80 GeV)
- Z+jets: ABCD method in MET, Mll plane

$$A_{\mathrm{MC}}^{\mathrm{corr}} = A_{\mathrm{MC}} \frac{B_{\mathrm{data}}}{D_{\mathrm{data}}} \frac{D_{\mathrm{MC}}}{B_{\mathrm{MC}}}$$

- top: control sample from b-tagged jets
- W+jets: loose ID on the second lepton to build control region





Exclusion reaches ~1.2 times the SM cross section for MH=160 GeV

Main systematics are:

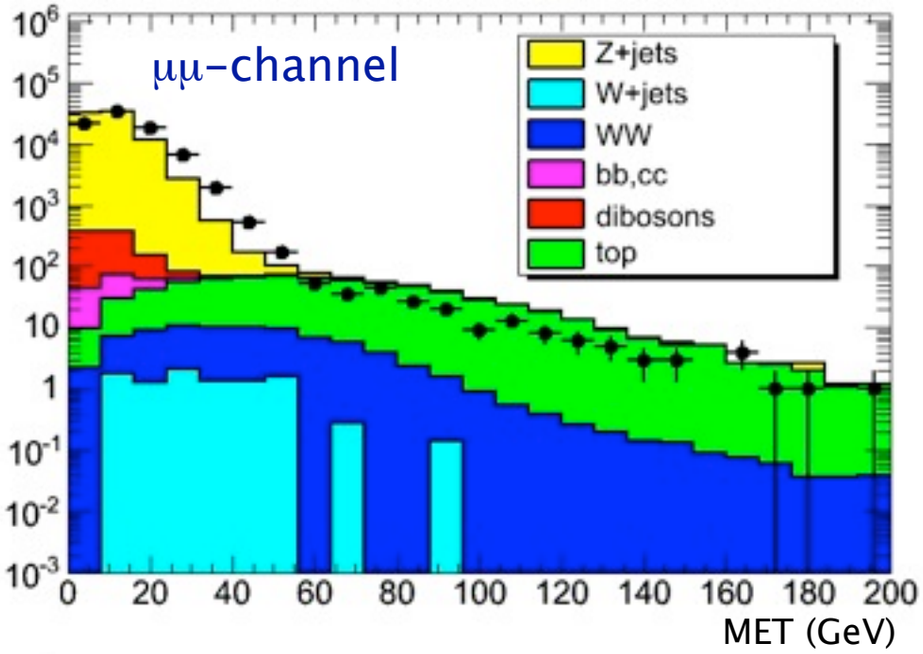
- e efficiency and resolution
- JES and Jet resolution
- btagging efficiency and mistag rates
- MET resolution

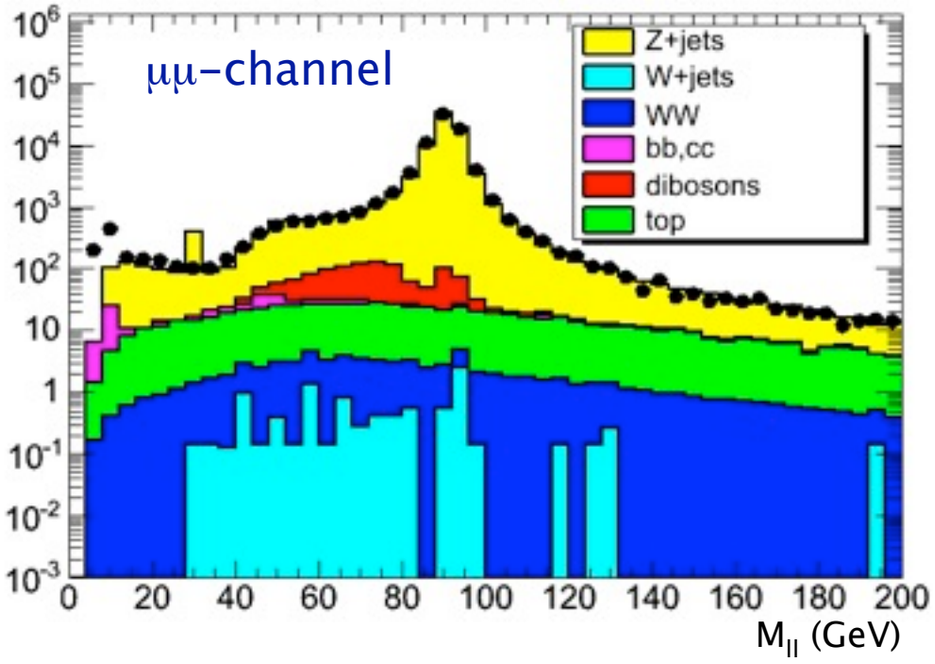
H→WW→lνlν Italian groups

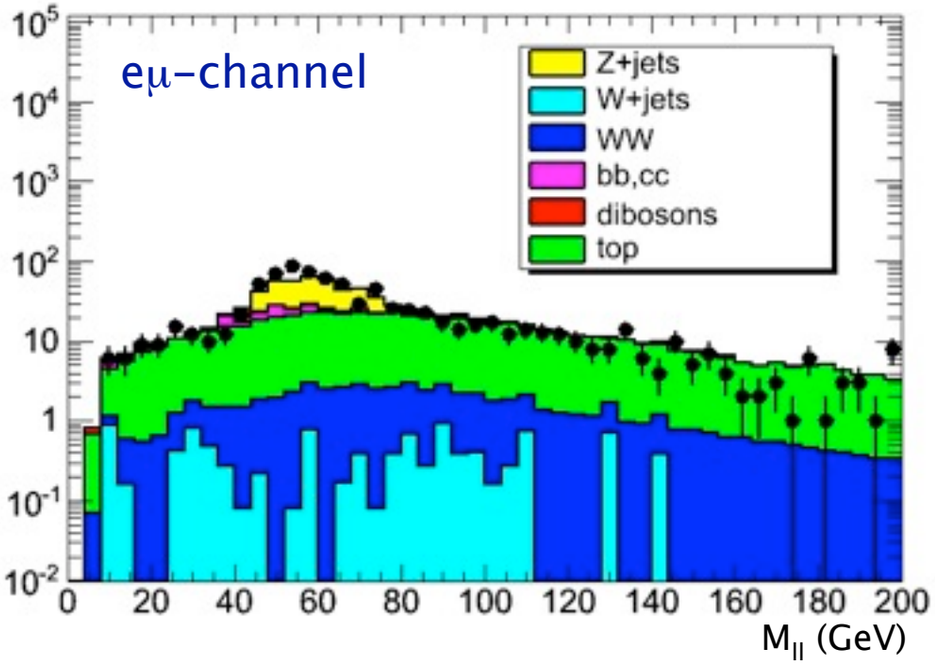
Roma 3: T. Baroncelli, M. Biglietti, F. Ceradini, B. Di Micco, A. Farilla, M. Iodice, D. Orestano, F. Petrucci

- Work just started on this channel - many technical aspects now fully under control
- Implementation of the standard selection well under way
- Processed 205 pb-1 of 2011 data, some plots after standard cleaning + 2 OS leptons

- M_{ll}>15 GeV (only same flavour)
- ETMiss>40 GeV (>25GeV eμ channel)
- Z Veto (only same flavour)
- Njets=0
- Pt leading >25 GeV,
- Pt subleading > 20 GeV



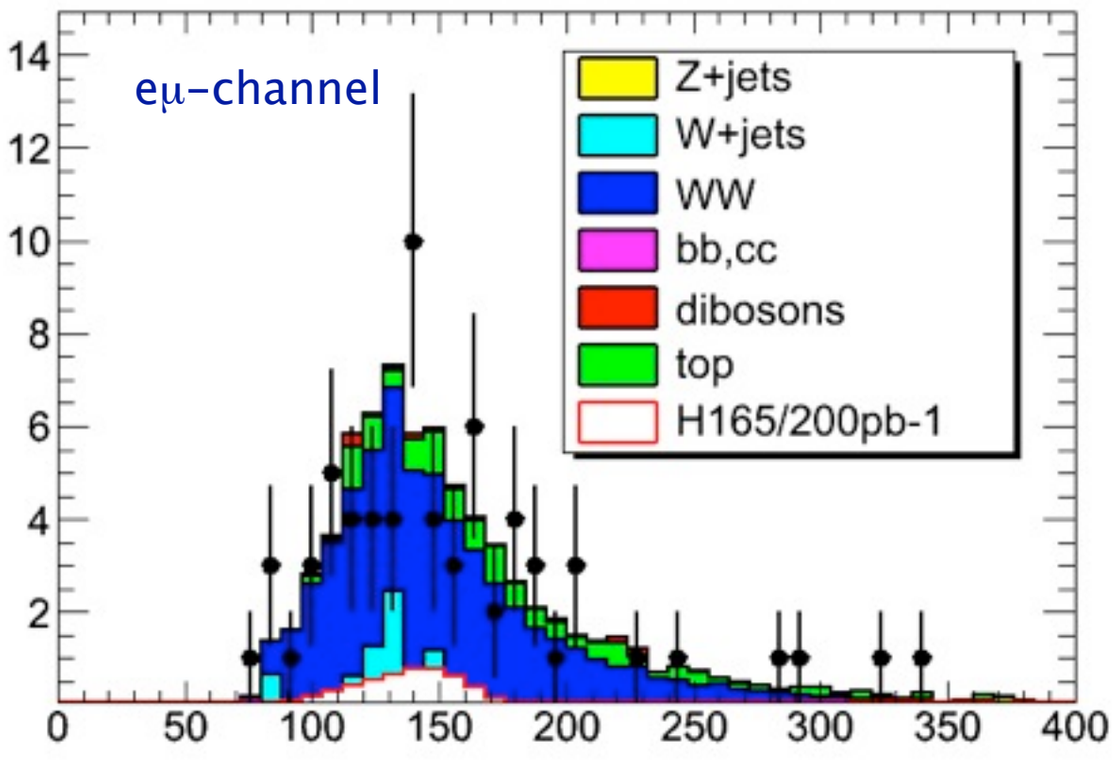


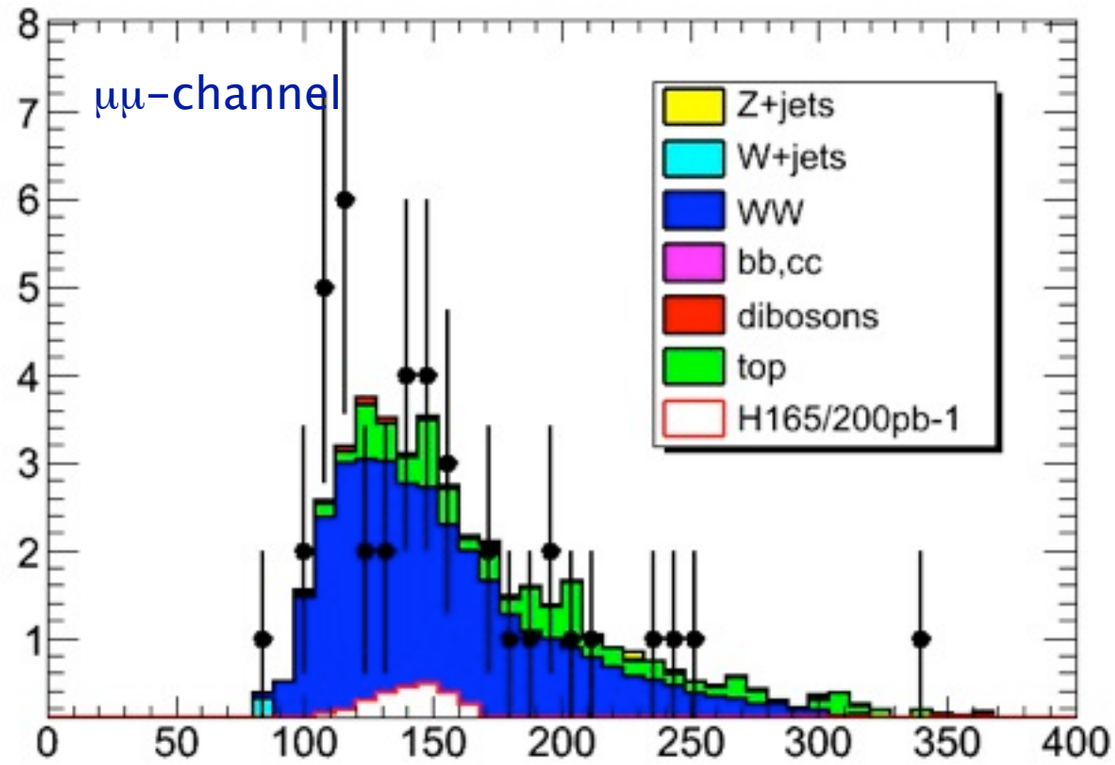


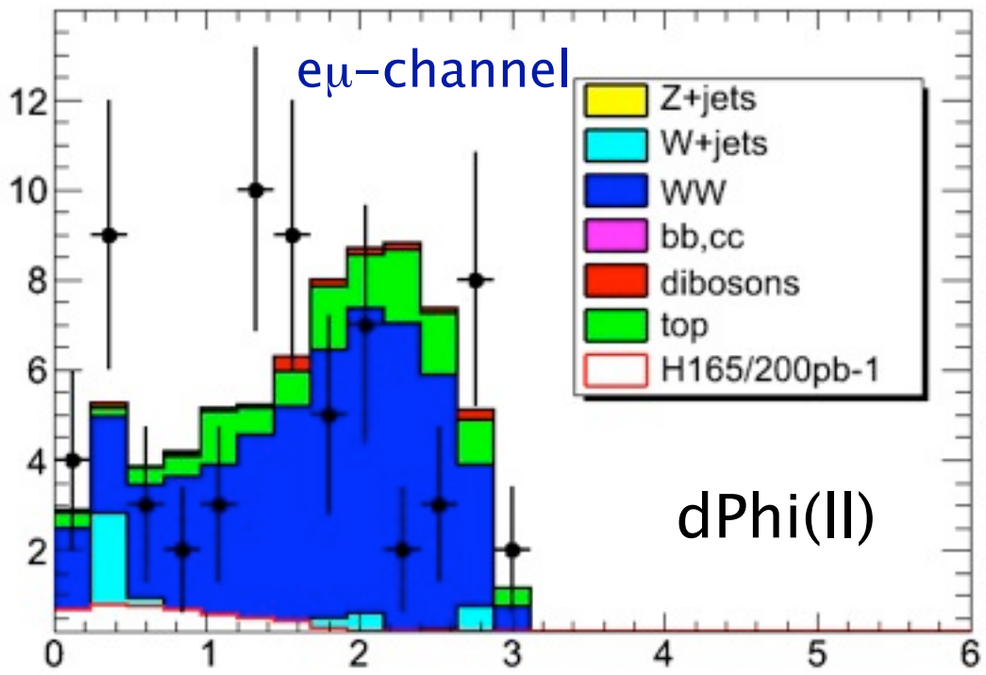
H→WW→lνlν Italian groups

Roma 3: T. Baroncelli, M. Biglietti, F. Ceradini, B. Di Micco, A. Farilla, M. Iodice, D. Orestano, F. Petrucci

After the full selection: Njets = 0, lepton pT > 25,20 GeV, MET > 40 GeV (25 GeV for eμ channel)







data yields and BKG composition from MC

	data	WW	top	diboson	W+Jet
μμ	41	0.78	0.19	0.02	0.01
ee	18	0.68	0.18	0.01	0.12
eμ	67	0.76	0.16	0.02	0.06

$H \rightarrow ZZ^{(*)} \rightarrow 4l$

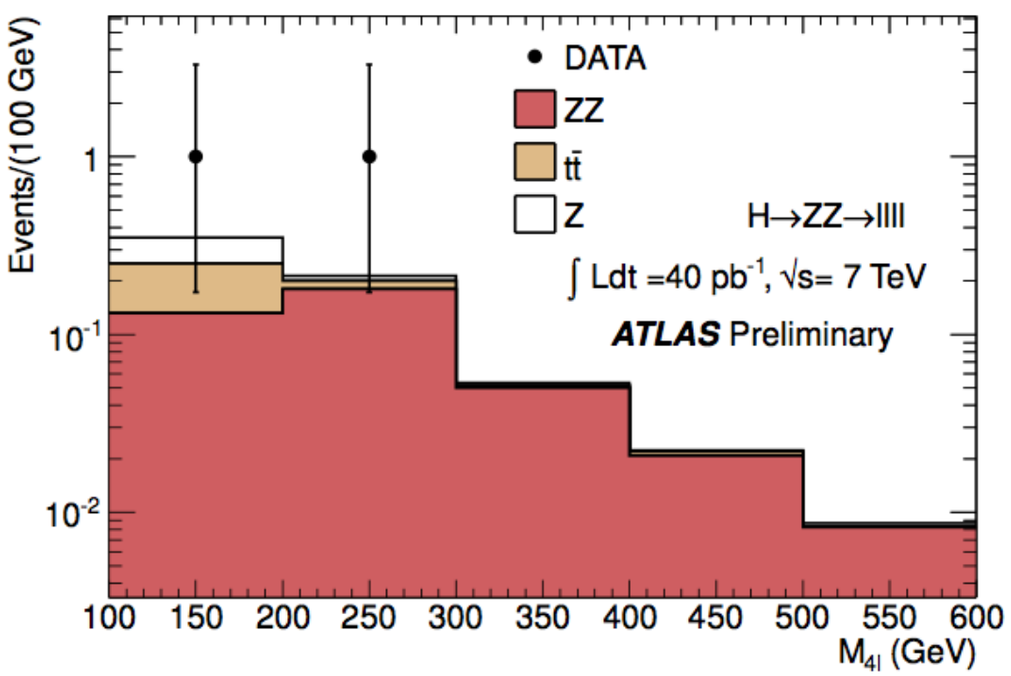
Small BR, but very clean channel
Less affected than other channels by pileup

Event selection

Two pairs of opposite sign leptons (e,μ)
pT > 7 (15) GeV for μ (e) , at least 2 leptons with pT>20 GeV
Track and calo isolation
IP significance
Z_1, Z_2 and 4-lepton mass window

ZZ is the main background: checked
using Z→ll (~25% error)

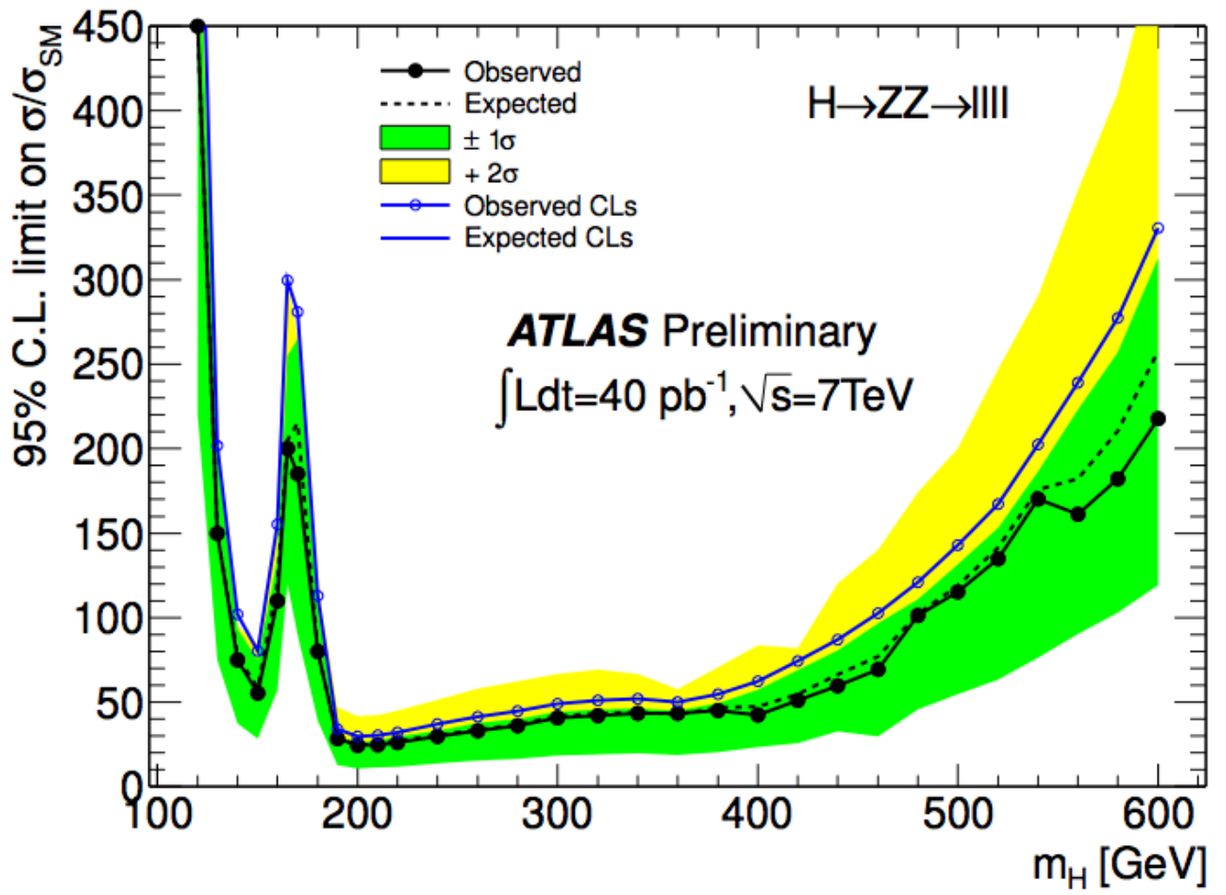
$$N_{ZZ} = \sigma_{ZZ}\varepsilon_{ZZ}^{exp} L \times \left[\frac{N_Z^{Data}}{\sigma_Z \varepsilon_Z^{exp} L}\right] = N_{ZZ}^{MC} \times R$$



Events after full selection

Signal M_H=200 GeV	Background	Data
0.095±0.017	0.41	0

Channel not yet very sensitive in 2010
~25 times the SM excluded at 200 GeV
But: will be crucial in 2011-2012

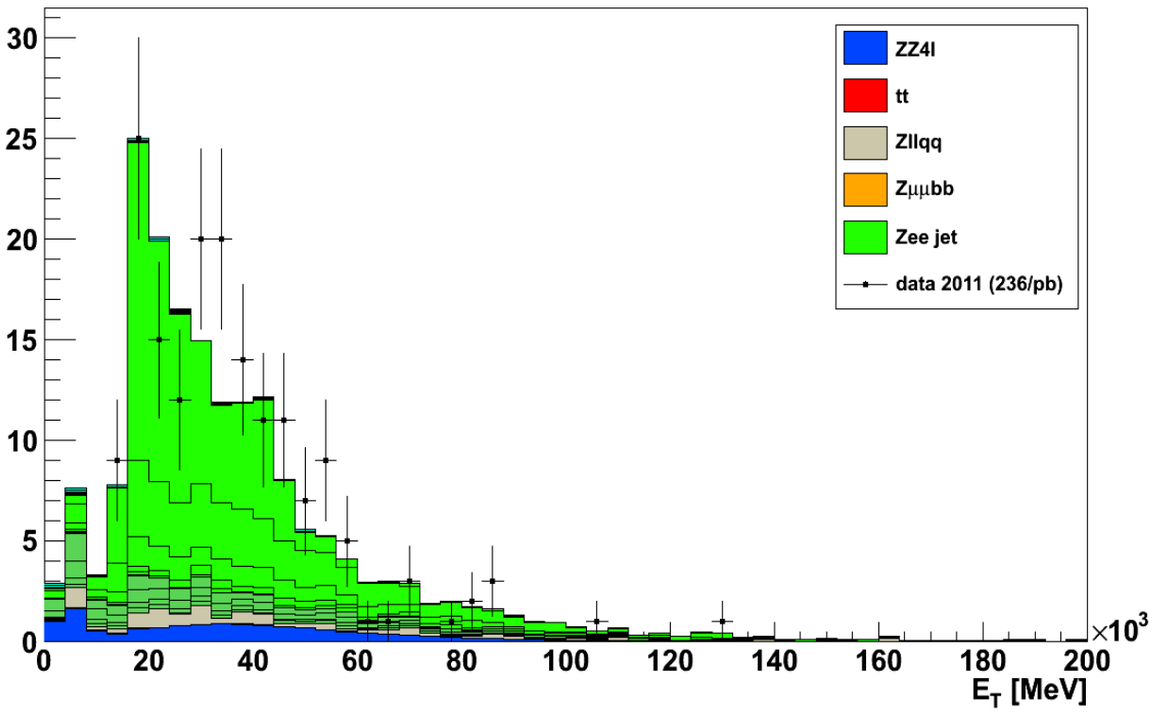


$H \rightarrow ZZ^{(*)} \rightarrow 4l$ Italian groups involved

Roma 2: A. Di Ciaccio, A. Di Simone, I. Migliaccio, C. Papaleo

- A. Di Simone responsible of the DPD group production
- right now working on acceptance challenge, data-MC comparisons w/ 2011 data

Example: data-MC comparison of electron E_T



Roma 1 plans to re-enter in this analysis (just started with llqq, llνν)

- provide a full and complete analysis
- optimization of signal efficiency over the whole mass range (optimize cuts + multivariate analysis)
- backgrounds extraction

Napoli expressed interest in the $H \rightarrow ZZ$ channel

2e2μ STACO	BNL	MPI	Roma2	CPPM	SMU
Total Events	29991	29991	29991	29991	29991
4 leptons (2e, 2μ)	5478	5473	-----	-----	5480
SFOS Pairs	5392		-----	-----	5396
ee && μμ >15 GeV	5308		5410	-----	5311
Kinematics	5245	5327	5342	5489	5228
Z1	4730	4803	-----	5426	4705
Z2	4116	4116	4251	4953	4087
Quadruplet After min[ΔR]	4096	4096	4233	4225	-----
Track Isolation	3723	3913	3762	3753	3917
Calo. Isolation	3601	3838	3724	3715	3818
Impact Parameter	3423	3594	3291	3512	3600

Bin	Cut	N eventi
0	Total events	8705573
1	GRL	7450475
2	Vertex	7005561
3	Trigger	2432972
4	Preselection	14
5	Refine presel.	10
6	//	10
7	Check b. masses + OC	2
8	Min[ΔR]	2
9	Track Isolation	1
10	Calo Isolation	***1***
11	Impact Parameter	0

$H \rightarrow ZZ \rightarrow llqq$

- Lower Z+jets background at high mass → these channels can be exploited

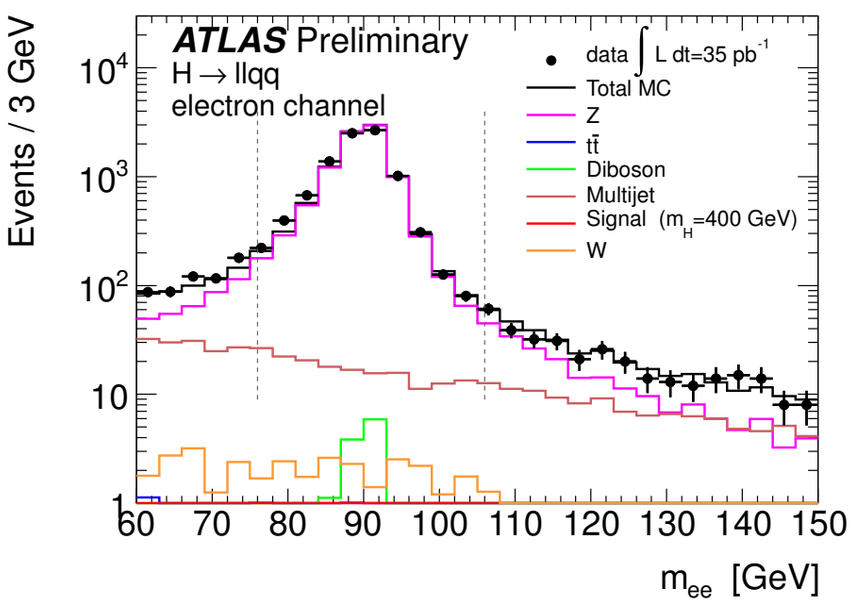
Common preselection with llνν:
- 2 leptons with pT>20 GeV
- $76 < M_{ll} < 106$ GeV

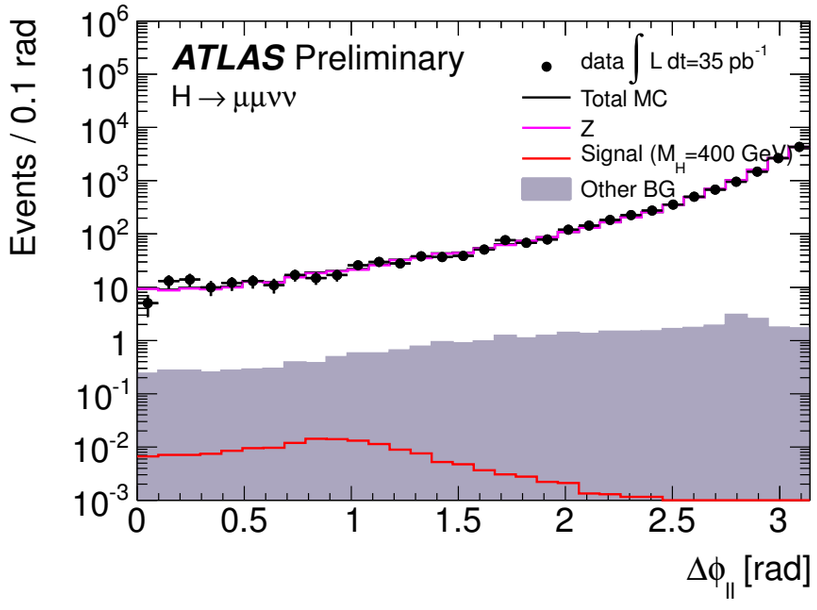
Event Selection:
- ETmiss < 50 GeV
- at least 2 jets, two highest pT with $70<m_{jj}<105$ GeV

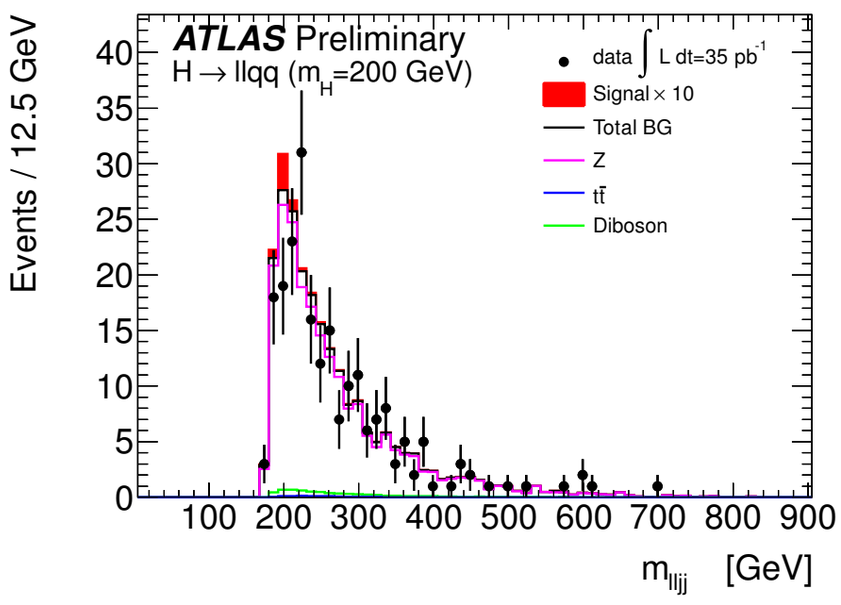
Z boost for $M_H>360$ GeV
- $\Delta\varphi_{ll}$ and $\Delta\varphi_{jj} < \pi/2$
- p_T(jet) > 50 GeV

Backgrounds:
- Z+jets: MC normalization cross-checked on m_{jj} sidebands
- QCD eeqq channel: template from control sample with loosened lepton-id, determined for exclusive and di-jet sample (compatible within stat)
- QCD μμqq channel: estimated negligible (cross checked with same-sign events)
- tt: from MC, shape and normalization checked on M_{ll} sidebands, reversing E_{Tmiss} cut
- ZZ,WZ: from MC

m_{lljj} is the discriminating variable







H→ZZ→llνν

Common preselection with llqq:

- 2 leptons with pT>20 GeV
- 76 < M_{ll} < 106 GeV

Event Selection:

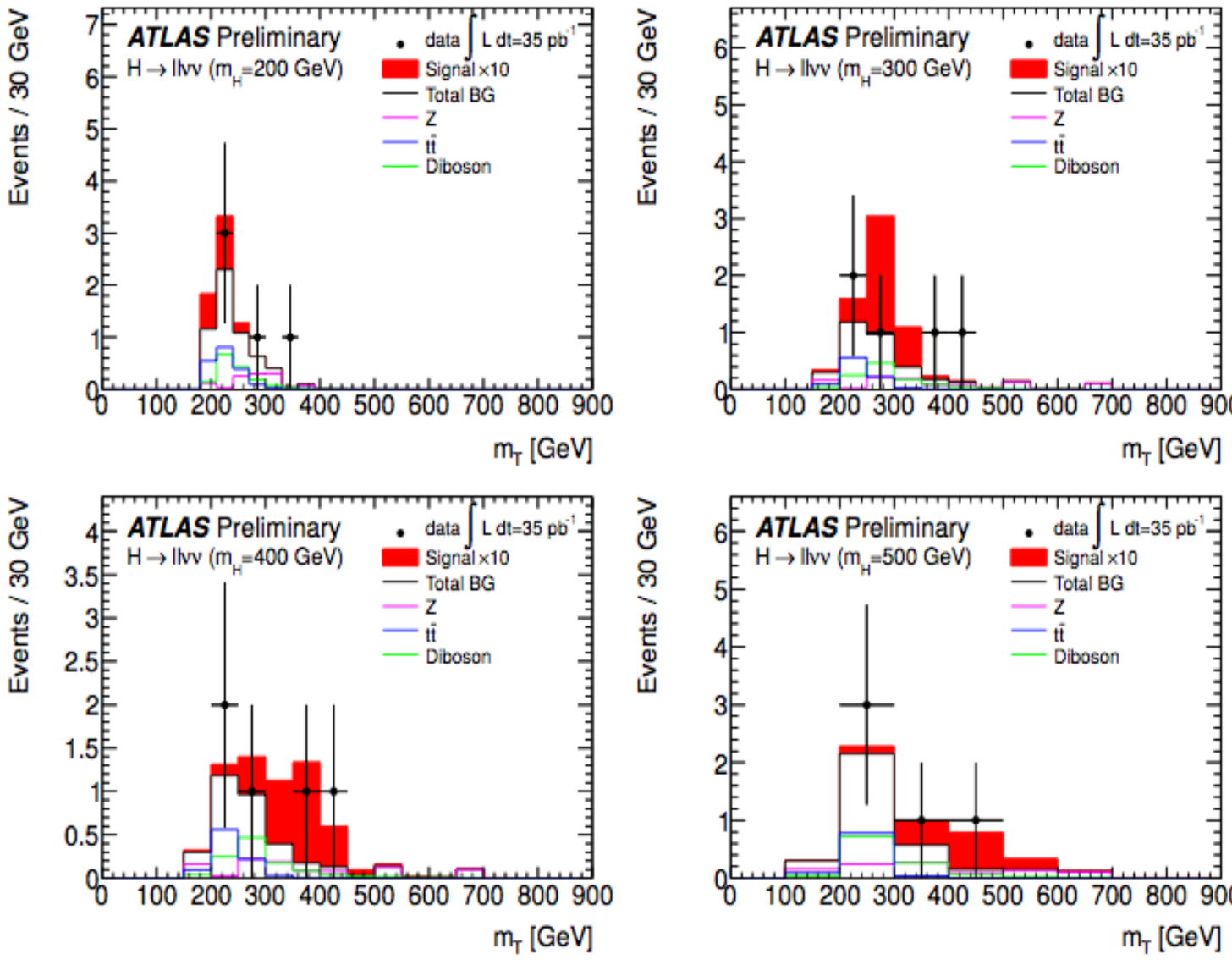
- ETmiss > 66 or 82 GeV for M_H < 280 GeV or M_H>280 GeV
- reject the event if one or more b-tagged jet (use SV0, 50% eff)
- H-mass dependent $\Delta\varphi_{ll}$ cut

Backgrounds:

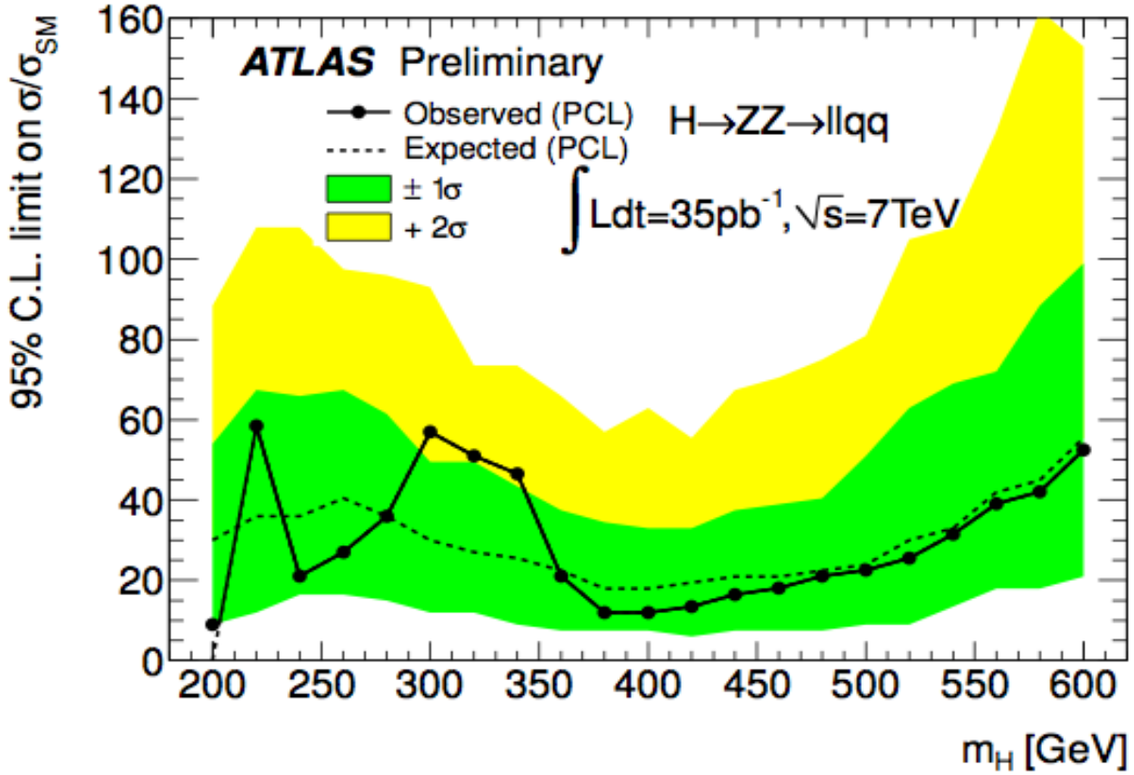
- tt: check shape and normalization on control sample with loosened MET cut and at least one b-tagged jet
- W: negligible for the muon channel, checked vetoing b-tagged jets
- QCD: as for llqq
- Z+jets: small, compare ETmiss in data and MC

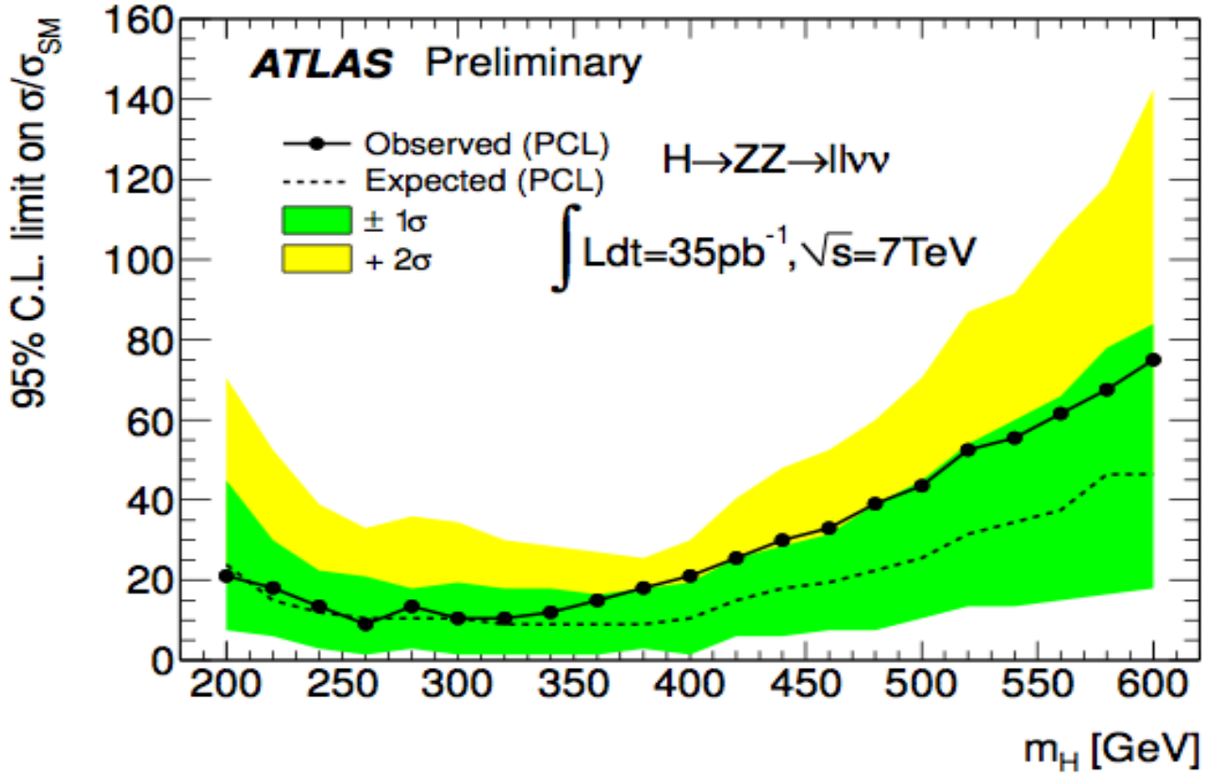
m_T is the discriminating variable

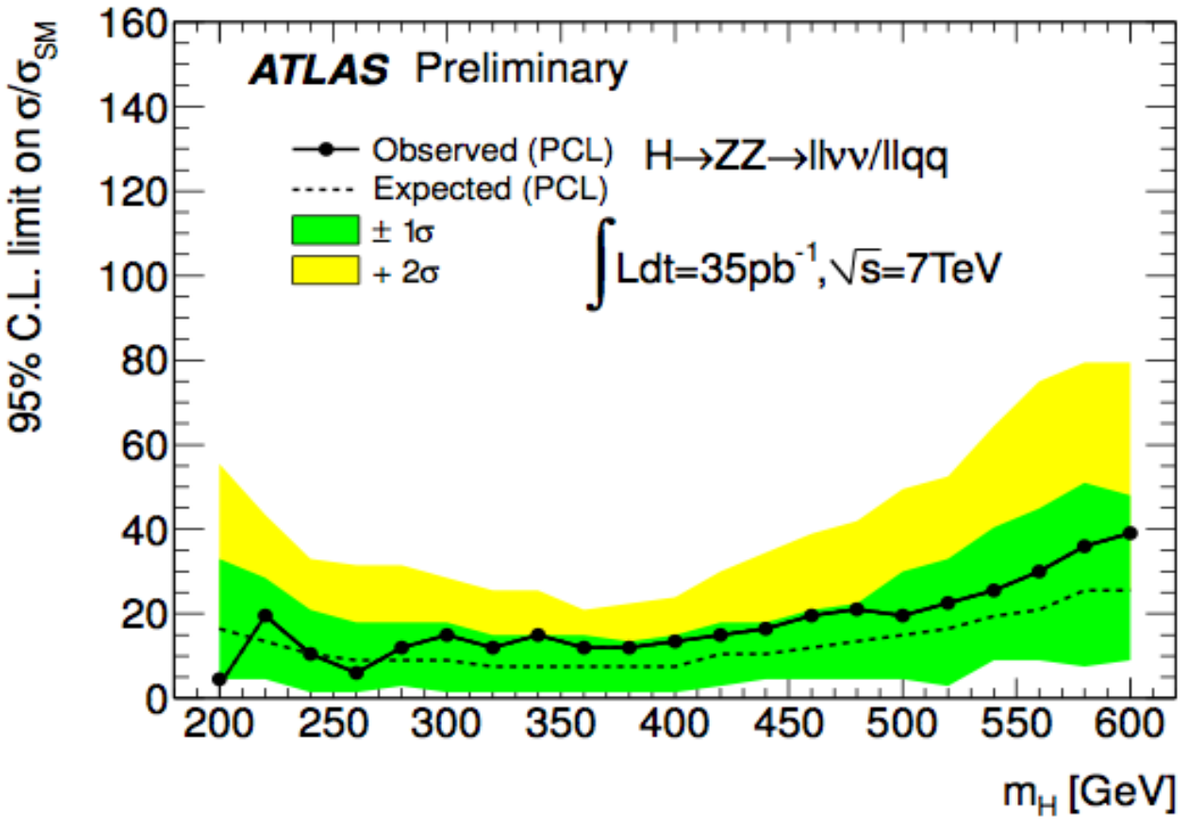
$$m_T^2 \equiv \left[\sqrt{m_Z^2 + |\vec{p}_T^{\,\ell\ell}|^2} + \sqrt{m_Z^2 + |\vec{p}_T^{\,\mathrm{miss}}|^2}\right]^2 - \left[\vec{p}_T^{\,\ell\ell} + \vec{p}_T^{\,\mathrm{miss}}\right]^2$$



H→ZZ→llqq,llνν limits







Main systematics:

- MET resolution
- b-tagging efficiency and mistag
- signal and backgrounds cross section
- Jet resolution and scale

H→ZZ→llqq,llνν Italian groups involved

Roma 1: G. Artoni, C. Bini, S. Borroni, S. Giagu, V. Ippolito, F. Lo Sterzo, M. Rescigno, S. Rosati, E. Solfaroli

Aim at providing a full and complete analysis on both channels:

- Right now in the "acceptance challenge" phase on 2011 MC (MC10a→MC10b) and data within the HSG2 group
- Provide full analysis for EPS (very tight timescale)
- Optimize the selection: cut-based selection, multivariate techniques

Pavia: D. Rebuzzi

- Develop a dedicated VBF selection on llqq: try and isolate a cleaner signature

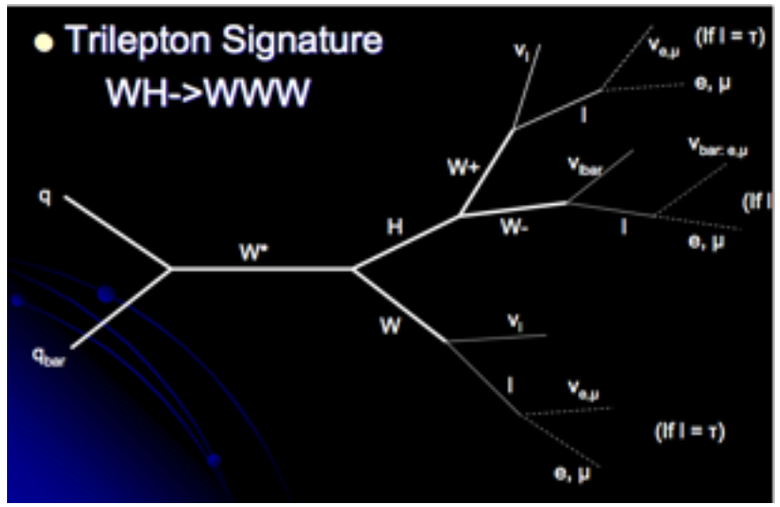
Napoli: F. Conventi et al.

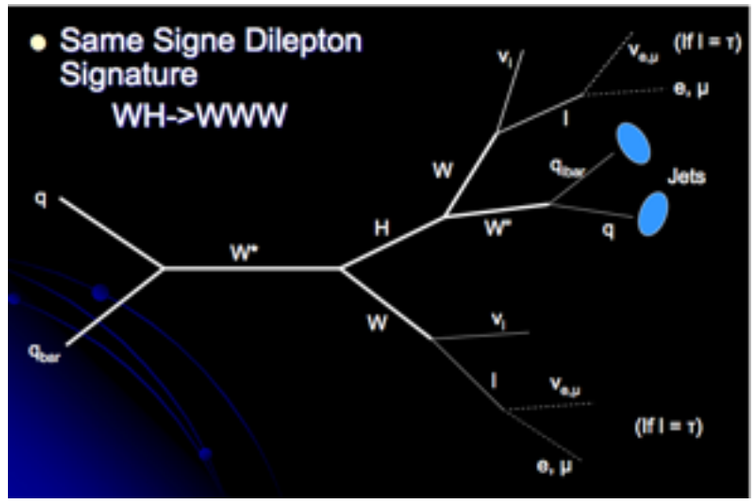
- Expressed interest in H→ZZ

Associated production WH

Roma 1: M. Rescigno, G. Zurzolo
Napoli: A. Sanchez Parigi: S. De Cecco

Significant for low Higgs masses
- tri-lepton + MET
- same sign di-lepton + jets + MET
Studied at Tevatron and for CSC notes
Signal samples produced, optimizations ongoing, aim at full analysis in autumn



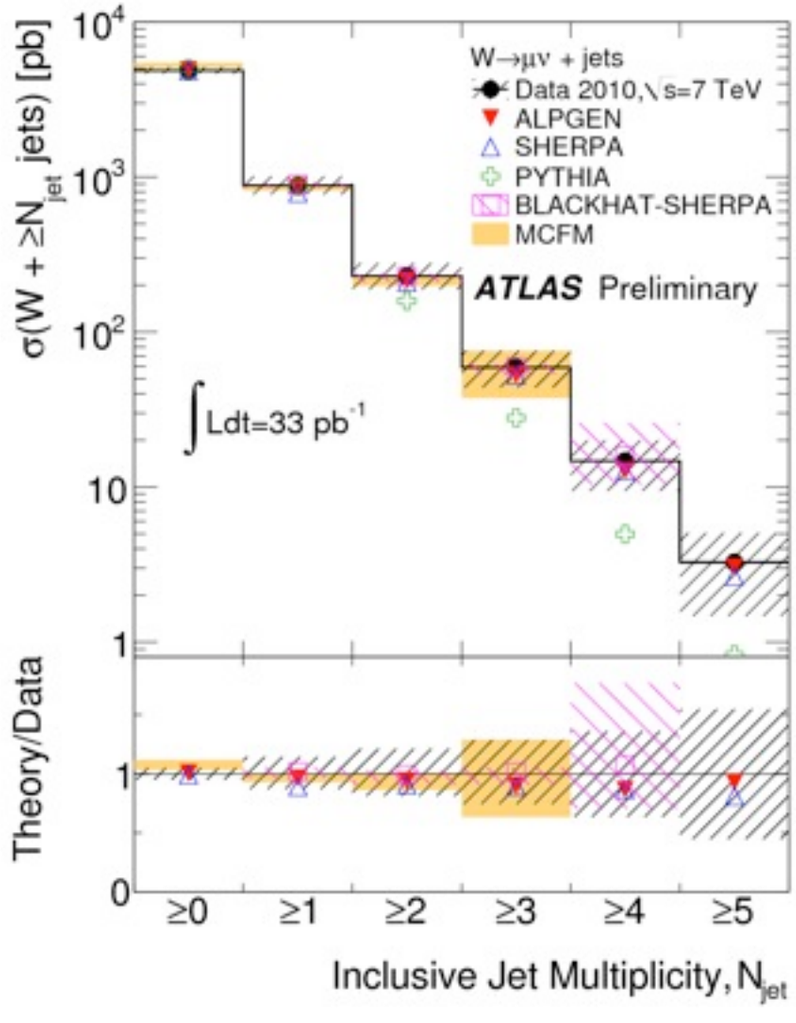


Most offending backgrounds:

- SS leptons:
W+ >=3 Jets (100 pb)

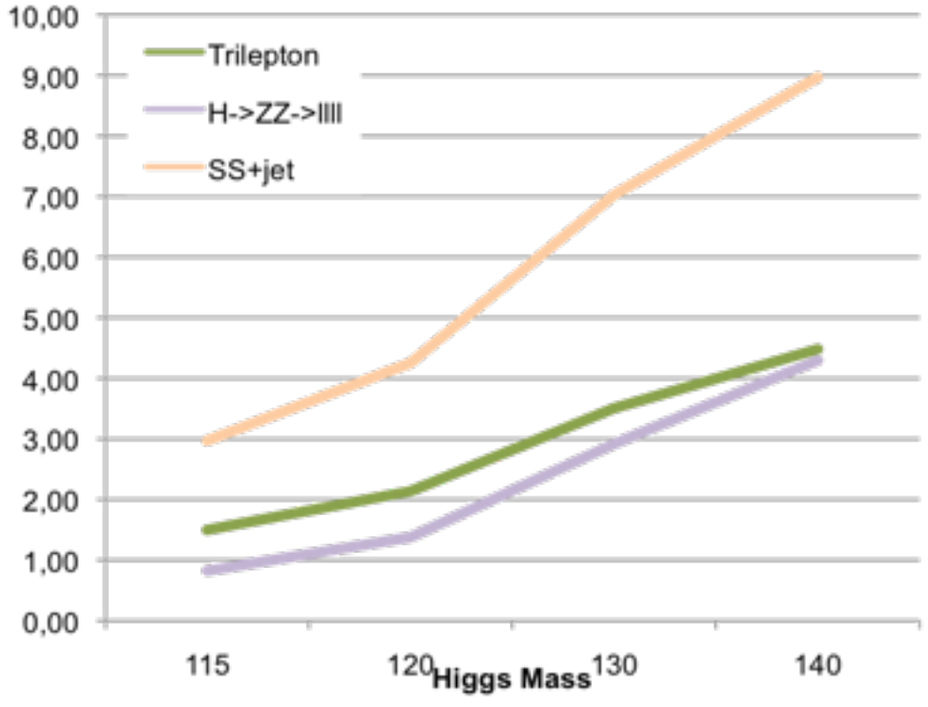
- Tri-leptons
ttbar → dilepton + jet (6 pb)
WZ →tri-lepton (0.3 pb)

Precise background evaluation ongoing



Yield is larger than H→4l

1 fb-1 at 7 TeV



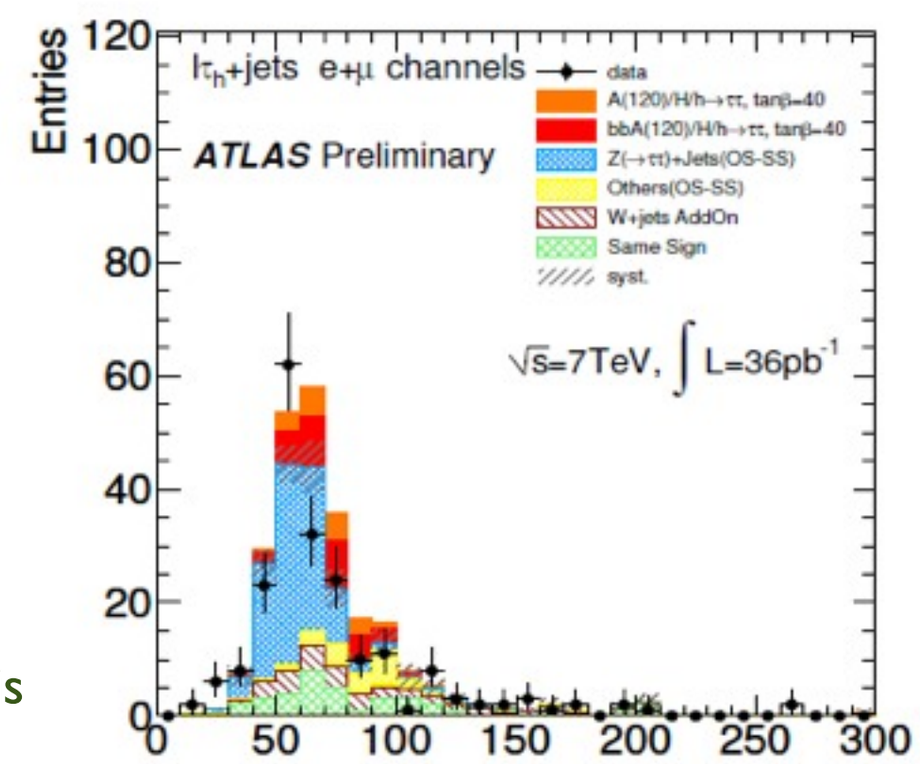
Channels with taus

MSSM A/H→ττ
(see talk by Sofia Consonni)

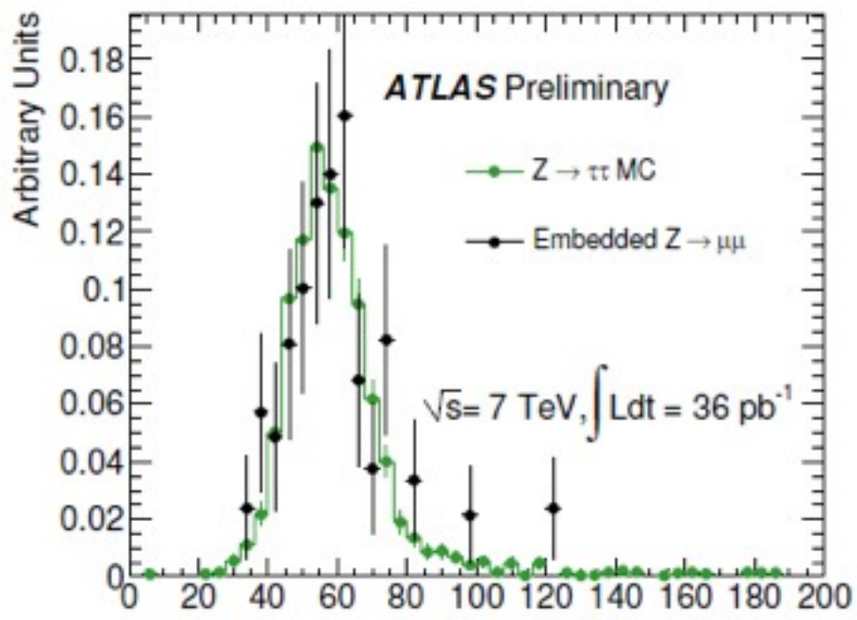
Event selection:
- 1 lep (e,μ) 1 had-τ, OS
- MET > 20 GeV
- M_T<30 GeV

$$M_{\mathrm{T}} = \sqrt{2 p_{\mathrm{T}}^{\mathrm{e}/\mu} E_{\mathrm{T}}^{\mathrm{miss}} (1 - \cos\Delta\phi)}$$

Milano plans to re-enter in this channel

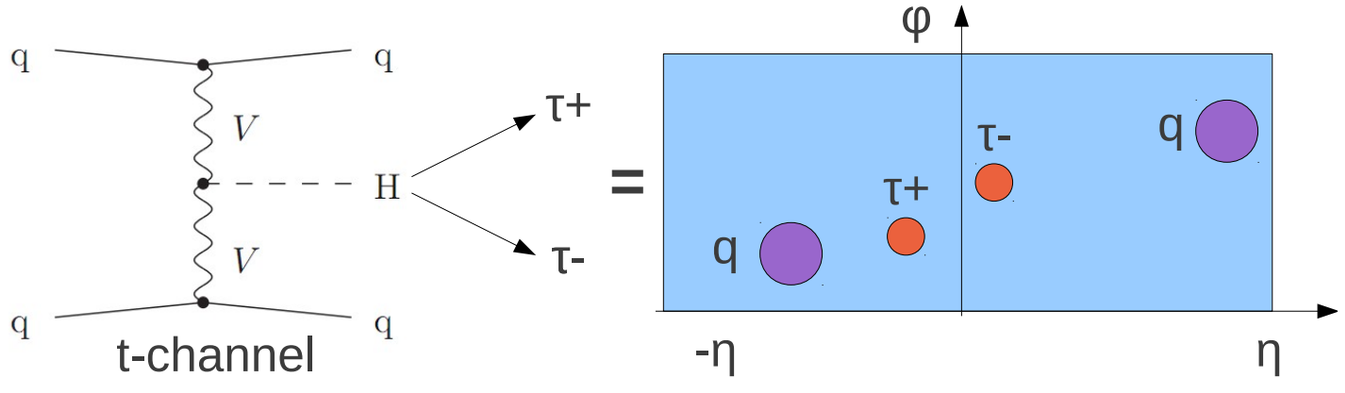


Z→ττ modeled embedding taus in Z→μμ data events



Pisa: V. Cavasinni, Z. Zenonos

VBF H→ττ
Forward jets, Central Jet Veto
Relevant for low masses



In conclusione

- I prossimi mesi saranno decisivi per le analisi Higgs: c'e' spazio per inserirsi in tutte le analisi, anche in quelle che sembrano piu' avviate
- Con alcune eccezioni, non c'e' stato un forte coinvolgimento dei gruppi italiani nelle analisi del 2010 - comprensibilmente viste le molte analisi in altri gruppi di fisica e performance
- Diversi gruppi hanno iniziato ad inserirsi, o stanno rientrando, nei gruppi di lavoro dell'Higgs working group, primi risultati attesi per l'EPS
- Disclaimer: non ho coperto in questo talk alcuni canali altrettanto importanti (e.g. $WW \rightarrow l\nu qq$ o MSSM $h/A \rightarrow \mu\mu$)