

ATLAS
EXPERIMENT

ATLAS Italia
Run 13197, lve 16719403
Time 2010-05-24, 17:38 CEST

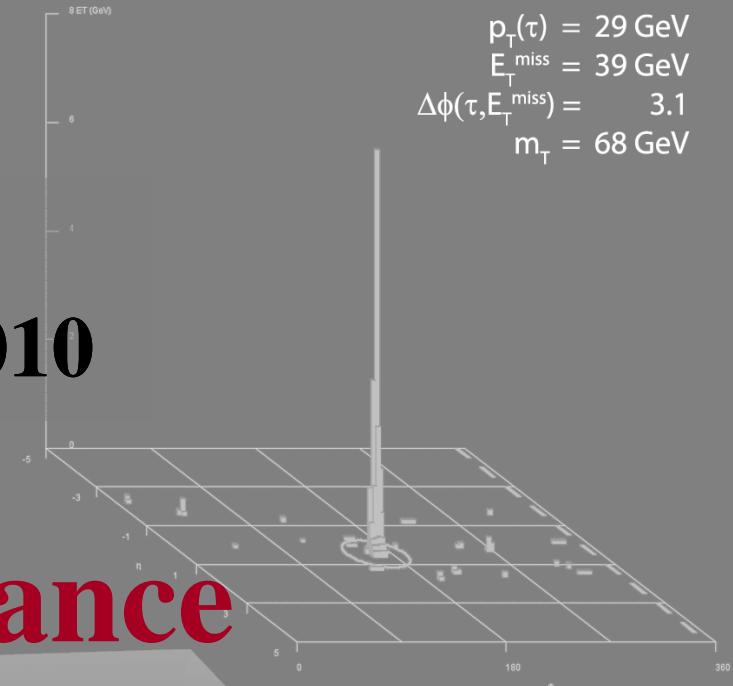
Pisa, 29 ottobre 2010

$W \rightarrow \tau\nu$ candidate in
7 TeV collisions

E_T^{miss} performance and status of W/Z decays to τ

Attilio Andreazza

INFN and Università di Milano
for the ATLAS Collaboration



$p_T(\tau) = 29 \text{ GeV}$
 $E_T^{\text{miss}} = 39 \text{ GeV}$
 $\Delta\phi(\tau, E_T^{\text{miss}}) = 3.1$
 $m_\tau = 68 \text{ GeV}$



Layout

- Stato corrente della ricostruzione di E_T^{miss}
 - Milano + Frascati
 - **MET_RefFinal scelta consigliata per il reprocessing d'autunno**
- Osservazione di $W \rightarrow \tau\nu$
 - Milano + Bonn
 - **CONF note in approvazione:** 0.546 pb^{-1} , 78 eventi, 22.9 fondo)
 - Misura della sezione d'urto sul campione 2010
 - **Canale poco coperto in ATLAS: aiuto benvenuto!**
- Misura di $Z \rightarrow \tau\tau$
 - Milano + Friburg + Pennsylvania + Cracovia+Washington
 - Prospettive di osservazione su 50 pb^{-1}
 - Ci sono già le prima indicazioni
 - **Canale di base per calibrazione delle scale di τ -jet e E_T^{miss}**
- Entrambe le misure permettono di certificare la capacità di ATLAS di identificare il τ :
 - **VBF per $h \rightarrow \tau\tau$, $H/A \rightarrow \tau\tau$, $H^\pm \rightarrow \tau\nu$**



E_T^{miss} Performance in data



People in Italy involved in E_T^{miss} studies:

- **MILANO:** D. Cavalli, C. Pizio, S. Resconi, R. Simoniello
→ Develop/implement/maintain MissingET package for E_T^{miss} reconstruction and calibration. Commissioning of E_T^{miss} in data and study of performance
- **FRASCATI:** M. Antonelli, M. Testa
→ Energy flow calibration of TC outside objects

CONF Notes on E_T^{miss} in data:

- ATL-CONF-2010-008: **E_T^{miss} Performance at 0.9 and 2.36 TeV**
(co-editor D. Cavalli)
- ATL-CONF-2010-038: **E_T^{miss} Performance at 7 TeV**
(co-editor S. Resconi)
- ATL-CONF-2010-057: **Calibrated E_T^{miss} Performance at 7 TeV**
(co-editor D. Cavalli)

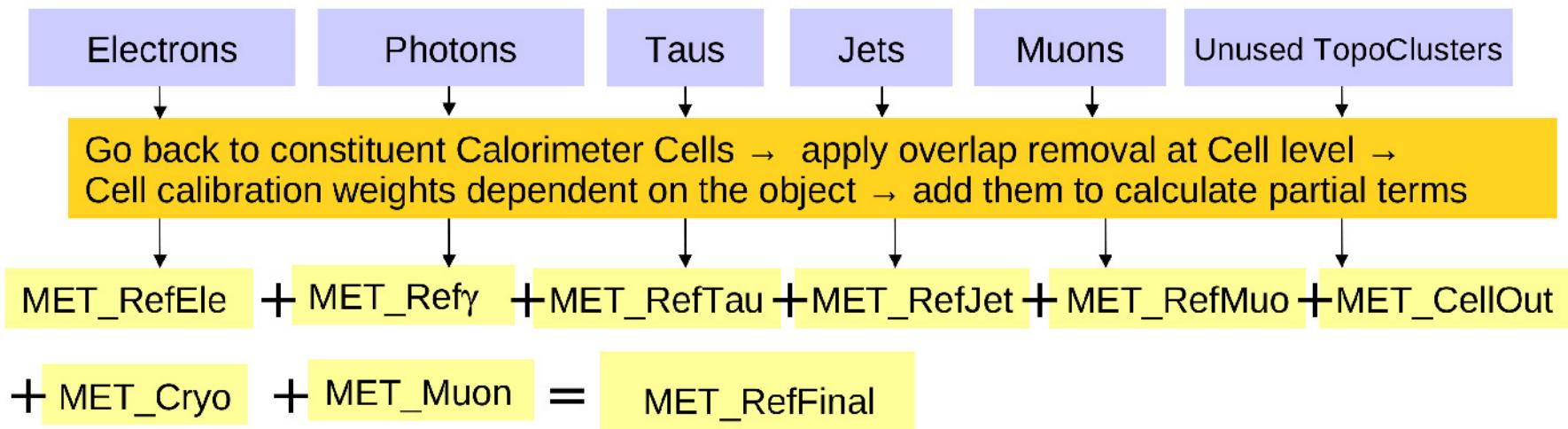


E_T^{miss} commissioning

E_T^{miss} commissioning in steps of increasing complexity:

- 1) E_T^{miss} from cells in TopoClusters at EM Scale: **MET_Topo**
- 2) Calibrated E_T^{miss} applying Local Calibration Weights (LCW) to all TopoCluster cells: **MET_LocHadTopo**
- 3) Add Muon term:
$$\text{MET_LocHadTopo} + \text{MET_MuonBoy} - \text{MET_RefMuon_track}$$

→ Now it is time to definitively move to the final calibration step, the **Refined Calibration**





Release 16 status and plans

- **Main improvements:**
 - Jet contribution split in **SoftJet** ($7 < p_T < 20$) and **RefJet** ($p_T > 20$)
 - **Eflow calibration:** use track p_T removing the associated clusters and add tracks which do not seed a TopoCluster
- **New default calibration for MET_RefFinal in release 16:**
 - Electrons properly calibrated with **CalibHit**
 - Jets with $p_T > 20\text{GeV}$: **LCW + JES(NI)**
 - Double counting problem:
JES includes **showering correction** but E_T^{miss} already uses **all calorimeter cells**
 - Increase cone size: from AntiKt4 to AntiKt6 to reduce double counting effect
 - Factorisation of response and showering
→ will test using response without showering
 - Jets with $7 \text{ GeV} < p_T < 20 \text{ GeV}$ and Taus: **LCW**
 - TopoClusters outside reconstructed objects: **Eflow+LCW**
 - **to be fully validated in different physics analyses:**
evaluate systematic on jets (LCW+JES) and MET_CellOut (LCW+Eflow)
 - **MET_RefFinal_EM** also available to allow the use of the present default for jets:
EM+EMJES + systematics



Osservazione di $W \rightarrow \tau\nu$



Persone coinvolte:

- **MILANO:** A. Andreazza, L. Dell'Asta
→ in collaborazione con J. Kroseberg e G. Nunes-Hanninger (uni Bonn)

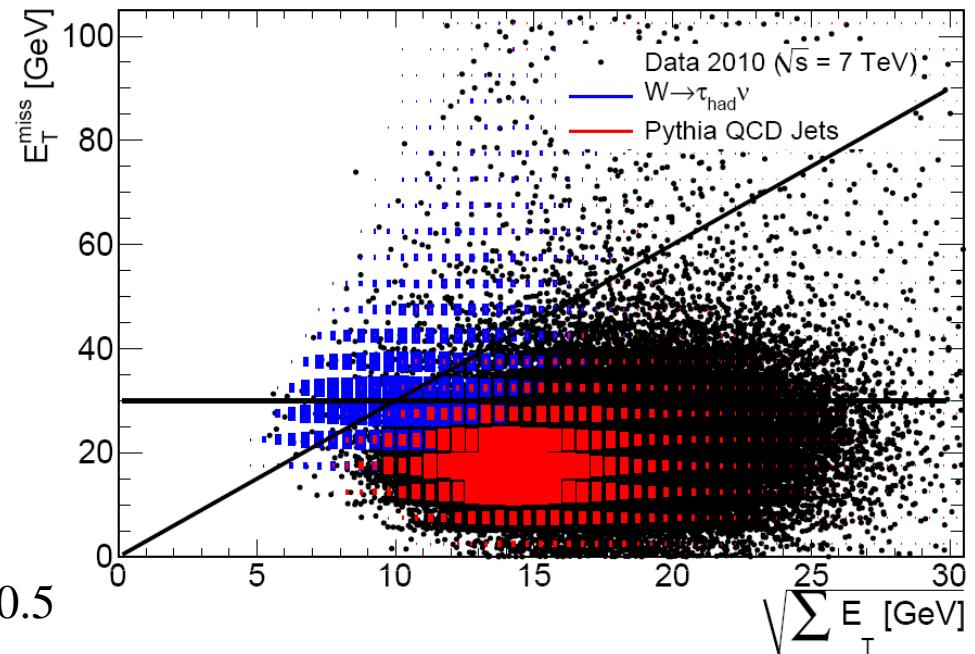
CONF Notes on data:

- ATLAS-CONF-2010-059:
Reconstruction of hadronic tau candidates in QCD events at ATLAS with 7 TeV proton-proton collisions
- ATLAS-CONF-2010-086:
Tau Reconstruction and Identification Performance in ATLAS
- ATL-COM-CONF-2010-057:
Observation of $W \rightarrow \tau\nu$ Decays with the ATLAS Experiment
(co-editor A. Andreazza)



Selection

- **Data sample** 546 nb^{-1} :
 - DESD_MET, up to period D2
 - GRL (tau + CaloOnlyMET)
 - Trigger:
`EF_tauNoCut_hasTrk6_EFxe15_noMu`
- **Event cleaning**
 - at least one vertex with $\text{Ntrk} \geq 4$
 - jet vetoes: require no jet in the event with
 - „jet_isGood“ < 2 (AntiKt4H1TopoJets)
 - $p_T > 20 \text{ GeV}$, and $1.3 < |\eta| < 1.7$
 - $p_T > 20 \text{ GeV}$ and $\min(\Delta\phi(\text{jet}, \text{MET})) < 0.5$
 - **Remove events with fake E_{Tmiss}**
- **Event signature**
 - $E_{\text{Tmiss}} > 30 \text{ GeV}$ (LocalHadTopo)
 - τ -jet with tight identification and $20 < p_T < 60$
- **Lepton veto:**
 - no loose electron with $p_T > 5 \text{ GeV}$
 - no combined muon with $p_T > 5 \text{ GeV}$
 - additional electron veto in τ candidate



- **Final QCD background rejection**

$$S_{E_{\text{T}}^{\text{miss}}} = \frac{E_{\text{T}}^{\text{miss}}}{0.5[\text{GeV}^{1/2}] \sqrt{\sum E_{\text{T}}}} > 6$$

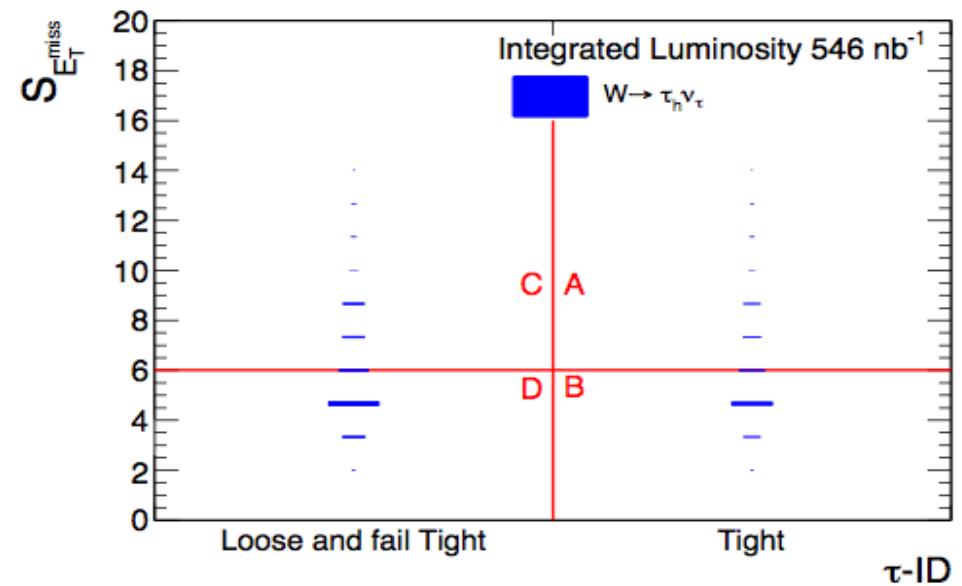
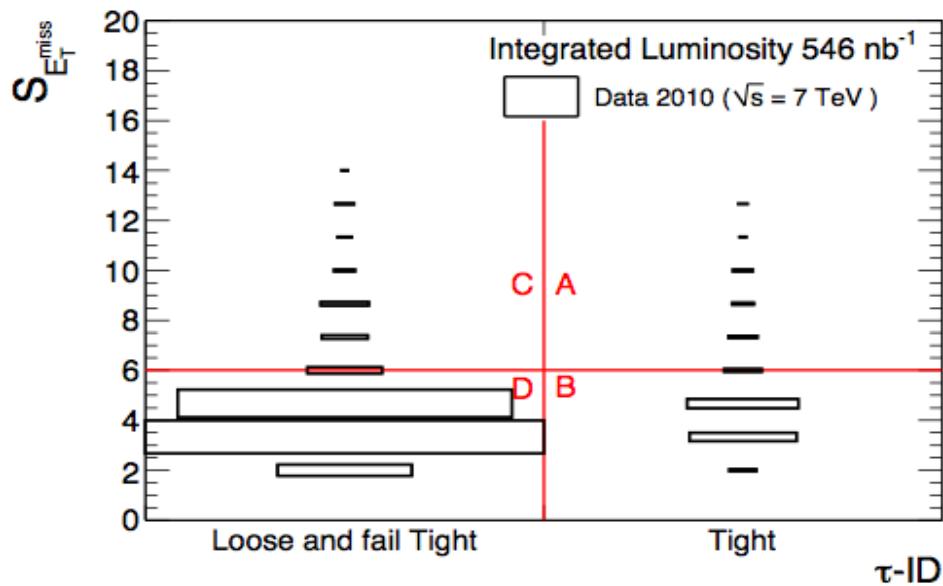


QCD Background: estimation from data

ABCD method (2D side bins)

- Divide data in 4 independent data samples:
 - one signal dominated region (A)
 - three QCD background dominated regions (B, C, D)
- Samples selected with criteria on:
 - E_T^{miss} significance
 - tau ID

$$N_{QCD}^A = N^B \frac{N^C}{N^D}$$



Method based on two assumptions:

- 1) the background **shape** is the same in the control and signal regions (*the two discriminating variables are uncorrelated*)
- 2) no signal **contamination** in the control regions



ABCD method: signal contamination

Region	A	B	C	D
Data	78	607	254	7107
$W \rightarrow \tau_h \nu_\tau$	55.3 ± 1.4	39.5 ± 1.2	71.0 ± 1.6	54.2 ± 1.4
EW	11.8 ± 0.4	6.5 ± 0.2	44.5 ± 0.7	22.1 ± 0.5
c_i		0.69 ± 0.02	1.72 ± 0.05	1.14 ± 0.03

$$c_i = \frac{N_{\text{sig}}^i + N_{\text{EW}}^i}{N_{\text{sig}}^A + N_{\text{EW}}^A},$$

from MC

- Corrections must be applied:

$$N_{\text{QCD}}^A = (N^B - c_B(N^A - N_{\text{QCD}}^A)) \frac{N^C - c_C(N^A - N_{\text{QCD}}^A)}{N^D - c_D(N^A - N_{\text{QCD}}^A)}$$

QCD background events in region A: $N_{\text{QCD}}^A = 11.1 \pm 2.3 \text{ (stat.)}$

Observed excess of events: $55.1 \pm 10.5 \text{ (stat.)}$



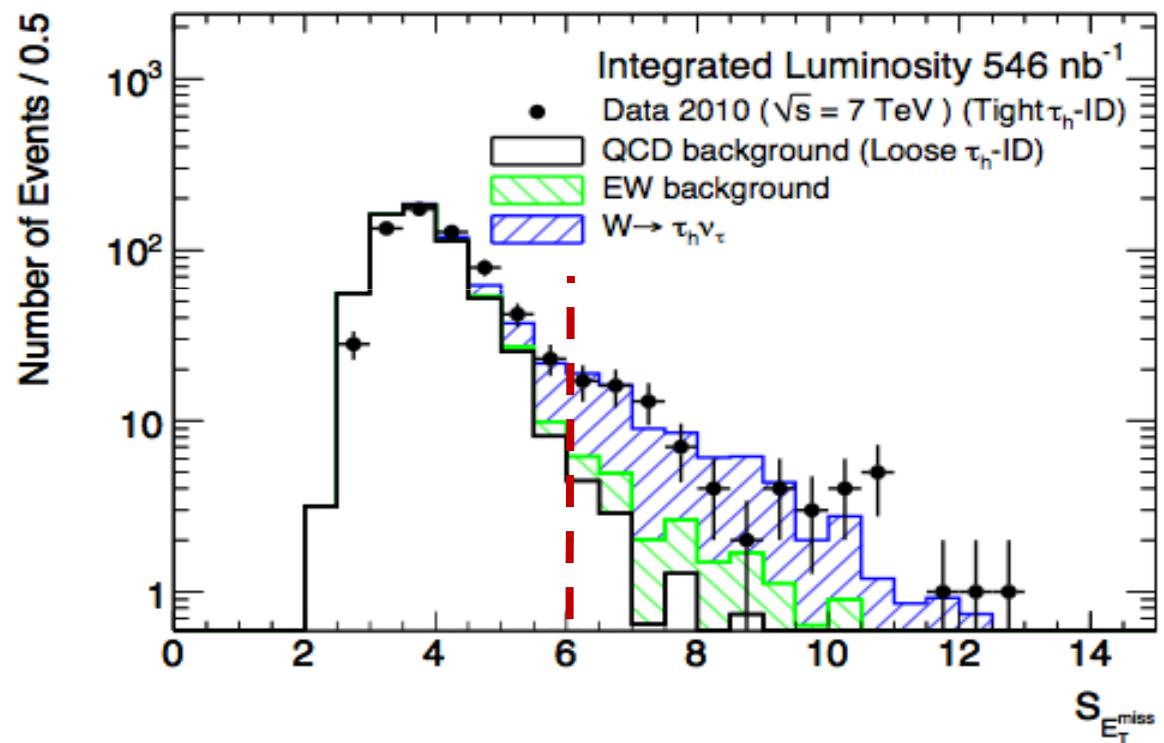
Correlations in ABCD method

- In this context:

correlation = dependence of E_T^{miss} significance on $\tau\text{-ID}$

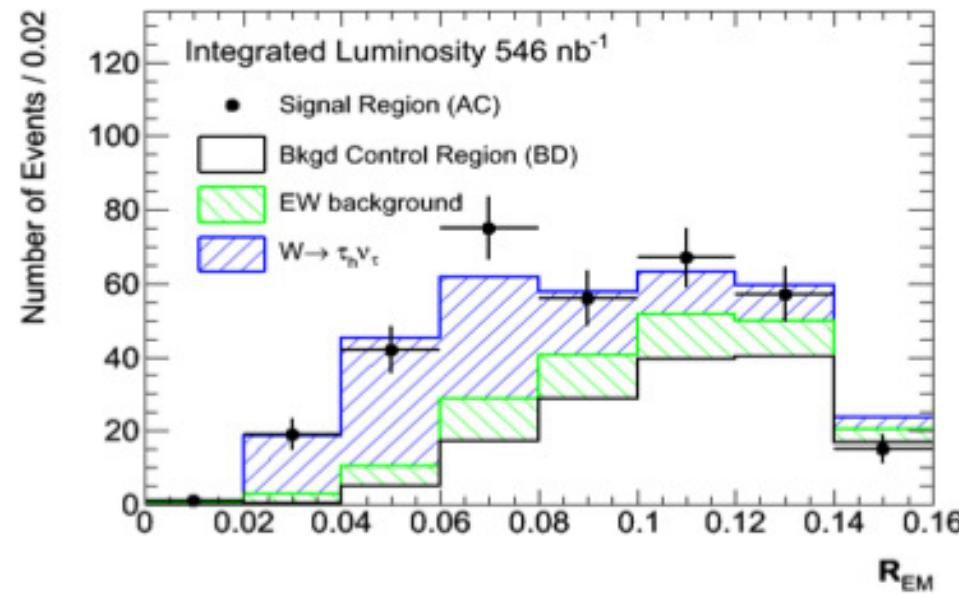
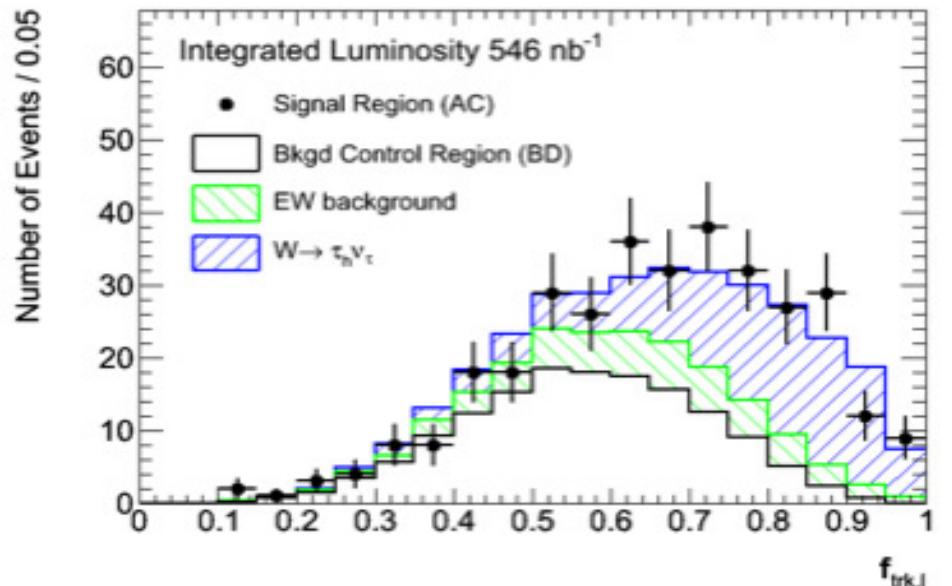
- Many test performed:

- τp_T dependence
 - number of tracks
 - medium vs. tight $\tau\text{-ID}$
 - **variation of E_T^{miss} significance cut**
- The latter is, by far, the most relevant:
 - due to disagreement in shape at E_T^{miss} significance ≈ 5
 - **29% uncertainty on QCD background**



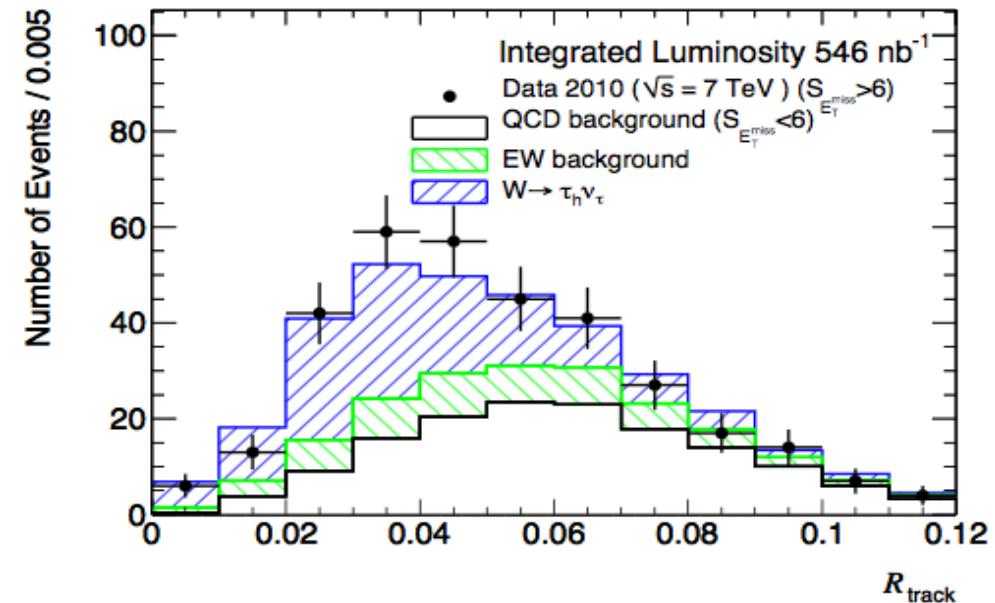


Are these real taus?



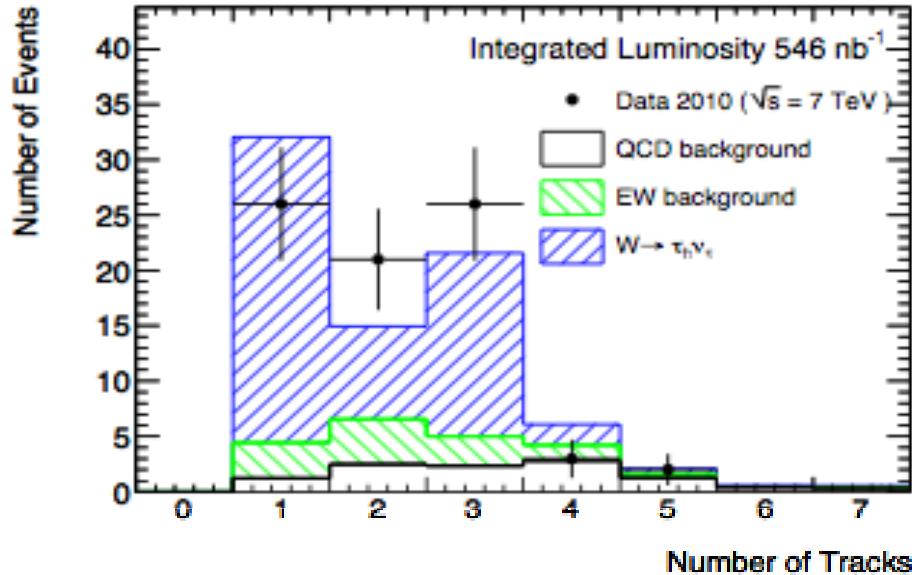
□ Distributions for **TauID variables** in regions AC (E_T^{miss} significance > 6)

□ QCD background extracted from regions BD (E_T^{miss} significance < 6)

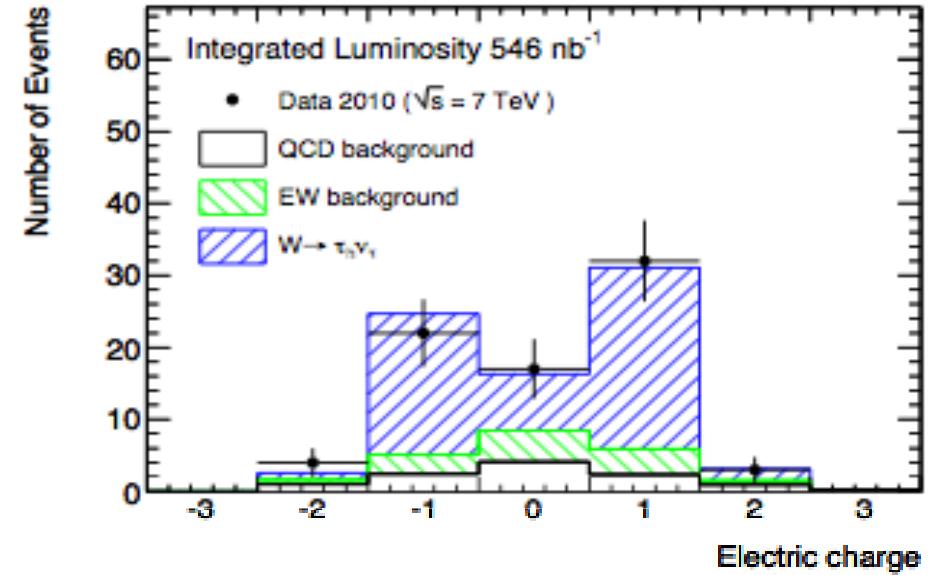




Are these real taus?



(a)



(b)

- ❑ Distributions for **signal region A** (E_T^{miss} significance $> 6 \&\&$ tight tau ID)
- ❑ QCD background extracted from regions C (E_T^{miss} significance $< 6 \&\&$ loose tau ID) and normalized to the number of events expected in region A.



Systematics and results

	signal	EW background	QCD background
Central values [events]	55.3	11.8	11.1
Statistical error [events]	± 1.4	± 0.4	± 2.3
Systematic uncertainties			
Theoretical cross section	$\pm 5\%$	$\pm 5\%$	—
Luminosity	± 11	$\pm 11\%$	—
Energy scale	$\pm 21\%$	$\pm 14\%$	—
Electron veto	—	$\pm 11\%$	—
Muon veto	—	$\pm 16\%$	—
Pile-up	± 1	$\pm 0.2\%$	—
Monte Carlo model	$\pm 16\%$	$\pm 17\%$	—
QCD background estimation	—	—	$\pm 29\%$
Total systematic uncertainty [events]	± 16.1	± 3.7	± 3.2

- Observed events: 78
 - QCD background $11.1 \pm 2.3 \pm 3.2$ events
 - EW background $11.8 \pm 0.4 \pm 3.7$ events
 - **excess events** $55.1 \pm 10.5 \pm 5.2$ events
- Probability of excess due to background fluctuation is 2.2×10^{-9} (6.1σ)



Verso la misura della sezione d'urto

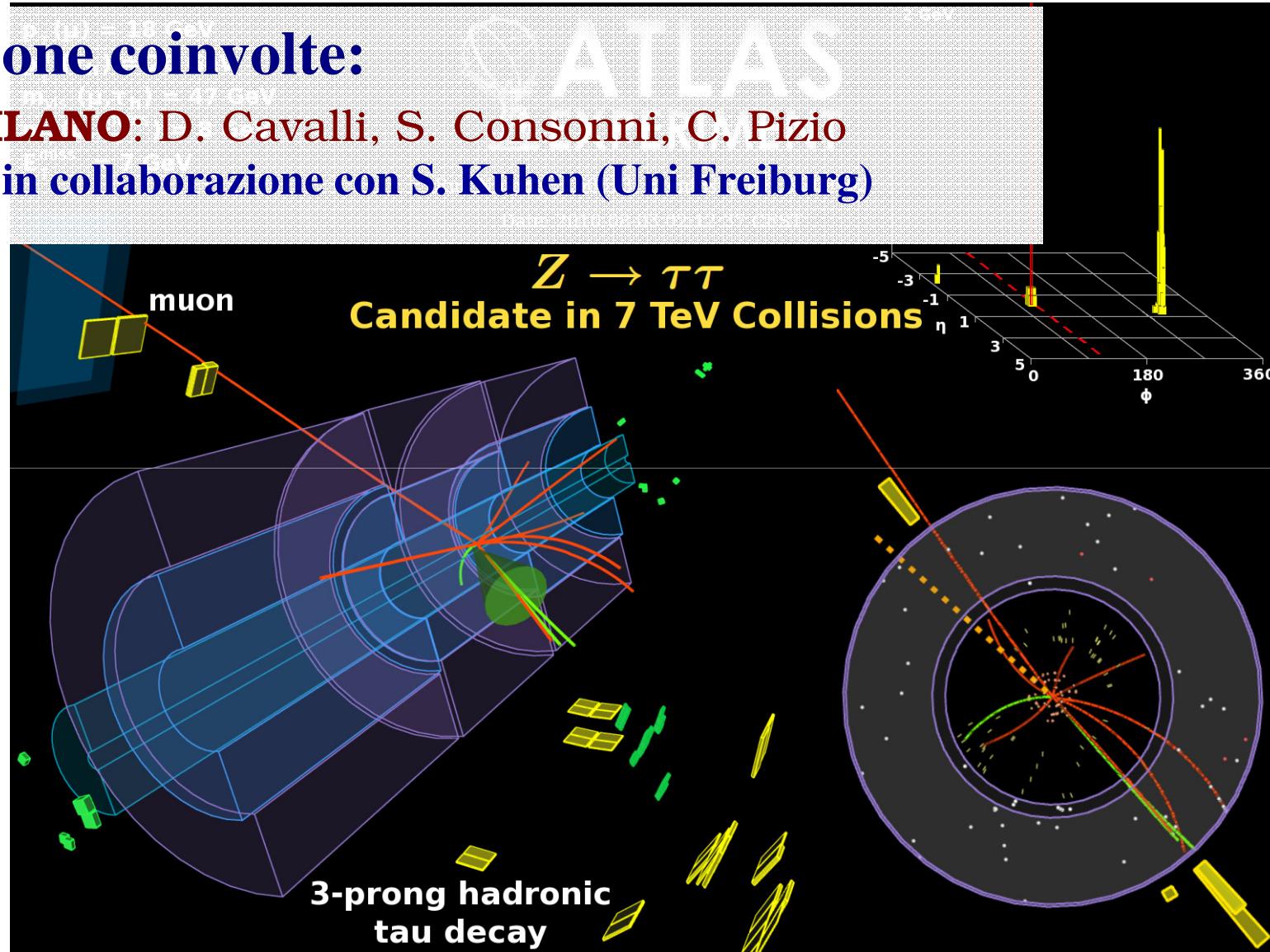
- Chiaramente una misura di calibrazione:
 - certificazione dell'identificazione dei τ
- La selezione basata su E_T^{miss} per l'analisi $W \rightarrow \tau_h v$ è estremamente sensibile alle incertezze sistematiche su E_T^{miss} and ΣE_T :
 - E_T^{miss} e **la significanza** sono i fattori limitanti per una misura della sezione d'urto:
 - 26% sull'accettanza del segnale
 - 29% sulla stima del fondo di QCD
 - 22% sulla stima del fondo EW
 - **Due possibilità per migliorare:**
 - **migliore MC tuning** in modo da avere ΣE_T affidabile nel MC
 - ottenere un S/B sufficiente con **τ -ID multivariata**, invece della significanza di E_T^{miss}
- **Altri argomenti su cui sarebbe utile un aiuto:**
 - metodi alternativi per la stima del fondo di QCD
 - stima del fondo da $W+getti$
 - >80% del fondo da $W \rightarrow \mu\nu$ è dato da getti + **inefficienze nella riscostruzione dei μ**
 - ~lo stesso per $W \rightarrow e\nu$ dopo il voto sugli elettroni



Analisi $Z \rightarrow \tau_{\text{lep}}\tau_{\text{had}}$

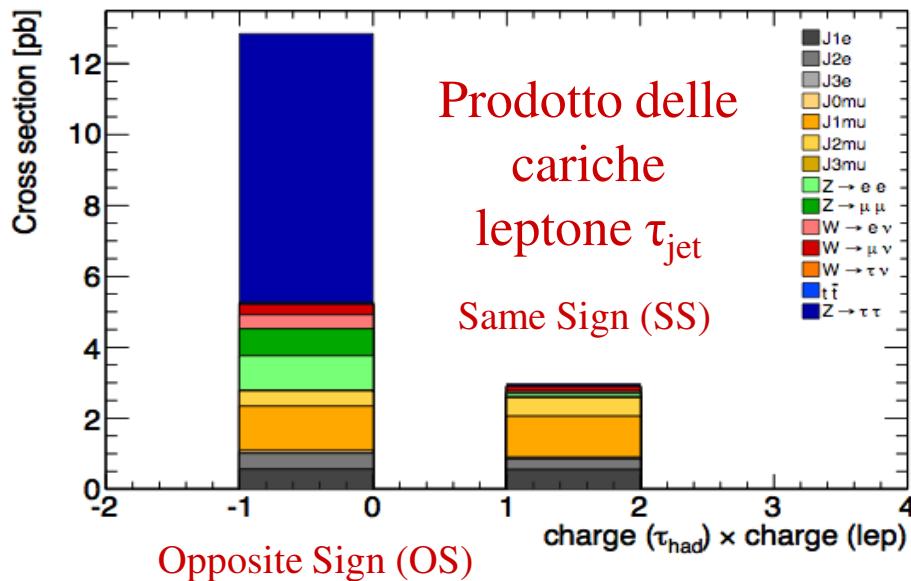
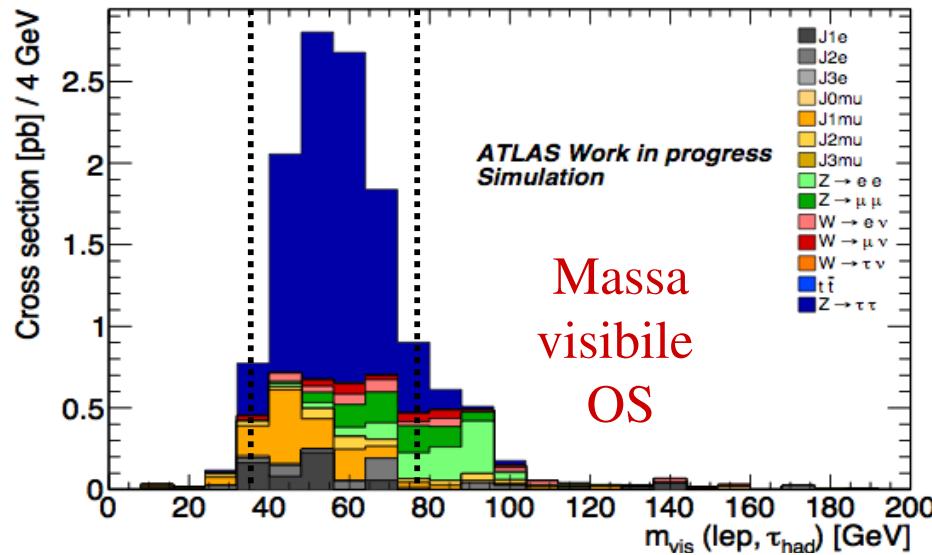
Personne coinvolte:

- **MILANO:** D. Cavalli, S. Consonni, C. Pizio
→ in collaborazione con S. Kuhen (Uni Freiburg)





Analisi Monte Carlo per 50 pb⁻¹



L'analisi soffre da molti fondi: QCD, $W, Z \rightarrow ll$
⇒ si applicano tagli pesanti
Per una luminosità di 50 pb⁻¹
massa visibile in [0, 200] GeV ([35, 75] GeV)
• **380 ± 10 (355 ± 10) eventi di segnale**
• **271 ± 16 (171 ± 10) eventi di fondo**
• rapporto segnale rumore
S/B = 1.40 ± 0.09 (2.07 ± 0.13)

- Gli eventi di **segnale OS**
- Fondo **QCD OS-SS simmetrico**
Sottraendo SS: S/B = 3.5 ± 0.3
- Per **$W \rightarrow ll + \text{jets}$ OS > SS**: si potrà **correggere** (usando una regione di controllo)
- In studio criteri per la riduzione del fondo Z
- Ulteriore metodo di stima basato sulla molteplicità di tracce



L'analisi sui dati reali (canale μ)

	Data	Monte Carlo $Z \rightarrow \tau\tau$	Monte Carlo all backgrounds + $Z \rightarrow \tau\tau$	Data/MC
GRL	21424980	1303(3)	$1.5436(10) \times 10^6$	-
Collision candidate	10801572	1297(3)	$1.5406(10) \times 10^6$	-
Trigger	221128	136.2(9)	203900(500)	-
Cleaning	221108	136.0(9)	203800(500)	-
Lepton selection	22176	81.6(7)	25100(100)	0.885(8)
Lepton isolation	8025	74.2(7)	8670(60)	0.93(1)
Lepton $p_T < 40$ GeV	8025	74.2(7)	8670(60)	0.93(1)
τ -jet selection	70	10.7(3)	83(1)	0.8(1)
$\Sigma \cos \Delta\phi > -0.15$	34	9.7(2)	34.7(8)	1.0(2)
$m_T < 50$ GeV	32	9.5(2)	32.8(8)	1.0(2)
Dilepton veto	31	9.4(2)	28.7(7)	1.1(2)
1 or 3 tracks τ -jet	21	7.9(2)	14.9(4)	1.4(3)
τ -jet unit charge	21	7.8(2)	14.5(4)	1.4(3)
Opposite sign	15	7.7(2)	12.1(4)	1.2(3)
m_{vis} [0, 200] GeV	15	7.7(2)	12.0(4)	1.2(3)
m_{vis} [35, 75] GeV	12	7.2(2)	9.5(3)	1.3(4)
$E_T^{\text{miss}} > 20$ GeV	4	1.39(9)	1.8(1)	2(1)
$\Delta\phi < 2.9$	2	0.64(6)	0.80(7)	3(2)
m_{inv} [0, 200] GeV	0	0.45(5)	0.47(5)	0
m_{inv} [60, 150] GeV	0	0.44(5)	0.46(5)	0

$\int \mathcal{L} = 3 \text{ pb}^{-1}$

- Analisi preliminare un solo vertice, canale μ
- Fattore di correzione** per il contributo QCD (data driven, notato in altre analisi)
- Accordo dati/MC** indicativamente buono
- Indicazioni di osservazione**



Analisi $Z \rightarrow \tau_{\text{lep}}\tau_{\text{had}}$: prospettive



- **Terminare gli studi per l'osservazione** (conferenze invernali)
 - Vertex reweighting in progress
 - Nel gruppo si stanno studiando svariate tecniche data-driven complementari
 - Per valutare bene fondo e mantenere le sistematiche sotto controllo è necessaria più statistica
- **Determinazione della scala di energia dei τ_{jet}** con 50 pb^{-1} (o meno?)
- Analisi di **massa invariante** a 7 TeV per ottenere **maggior purezza** e determinare la **scala di energia trasversa mancante**
- Misura della **sezione d'urto**

A/H $\rightarrow \tau\tau$, sensibilità per la scoperta già con 1 fb^{-1} !



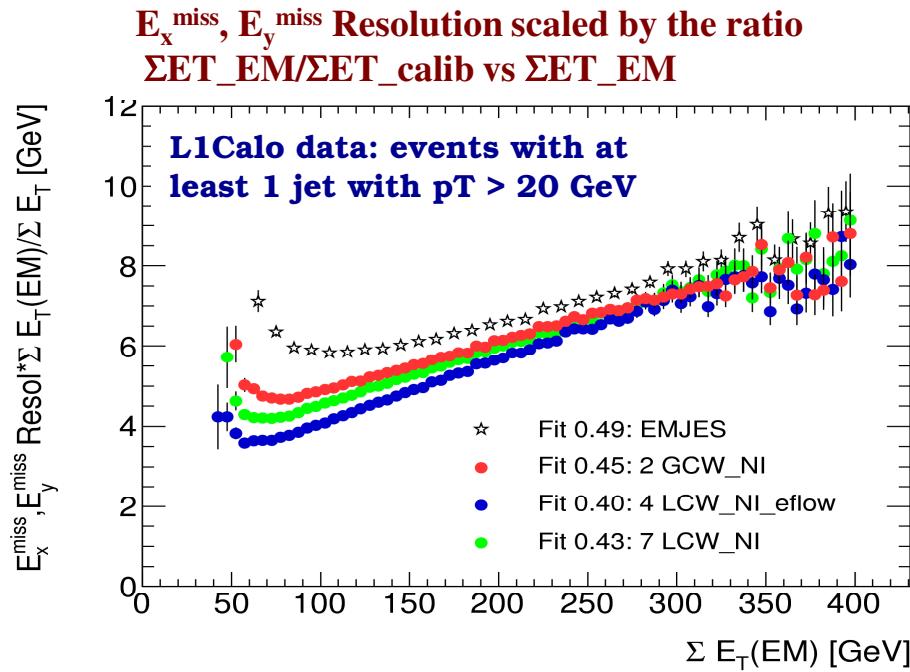
Conclusioni

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Refined E_T^{miss} : choice of best calibration

Outcome of Pisa Hadronic Calibration Workshop (Sep 2010)



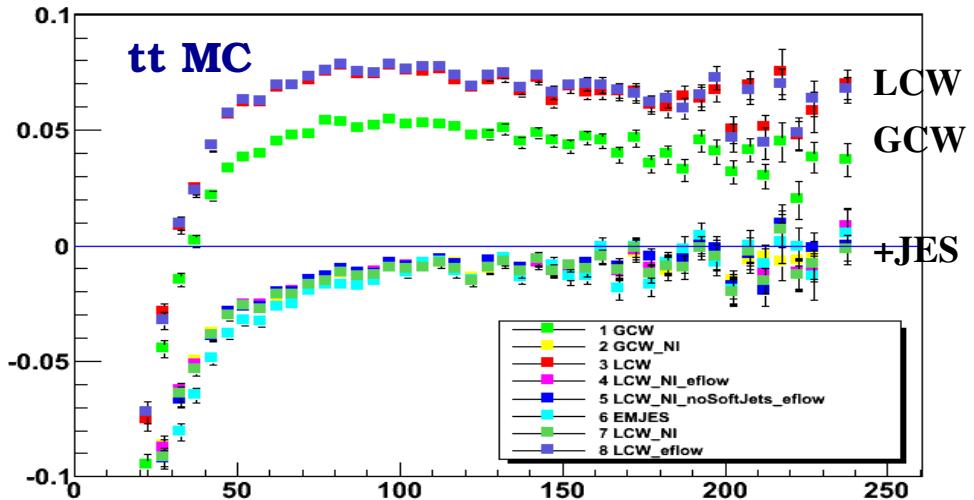
Better linearity when the JES(NI) is applied to jets

- Eflow calib of CellOut:**
- has small effect on linearity
 - improves diagnostic plot in $Z \rightarrow ll$ events

- Better resolution using calibrated jets+JES(NI) respect to EM jets+EMJES
- Local Hadron Calibration (LCW) better respect to Global Calibration (GCW)
- CellOut Eflow calibrated improves resolution

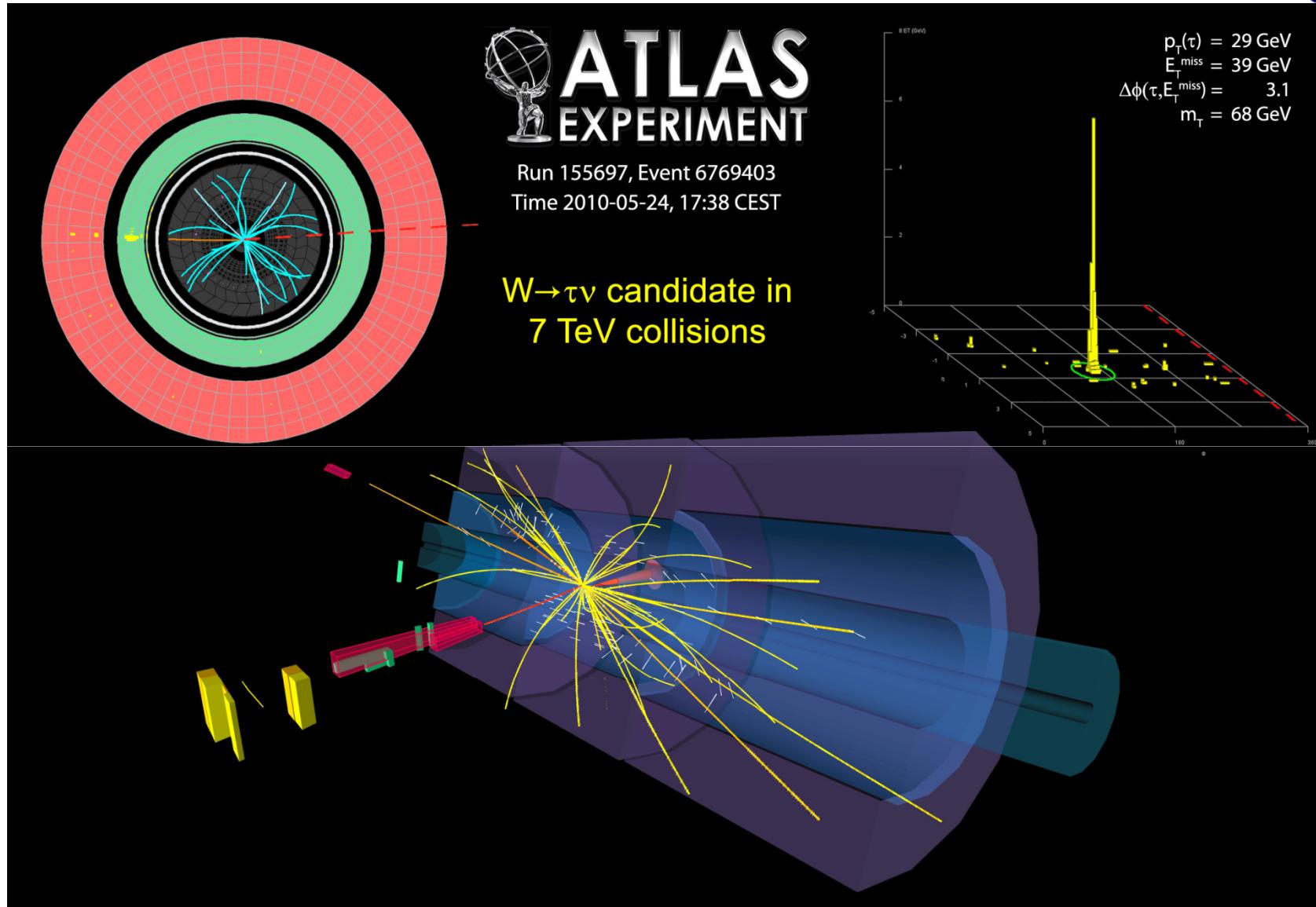
Best resolution with:
Local Calib (LCW) + JES(NI) + Eflow

Linearity = $(\text{MET}_\text{Truth} - \text{MET}_\text{RefFinal}) / \text{MET}_\text{Truth}$





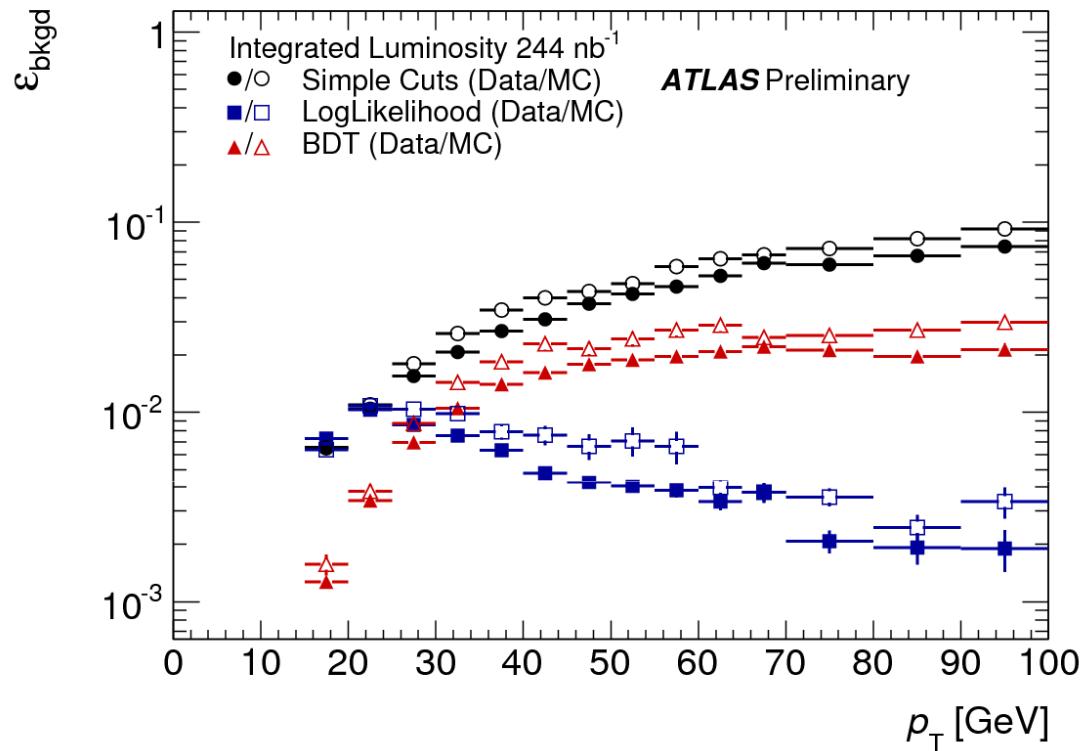
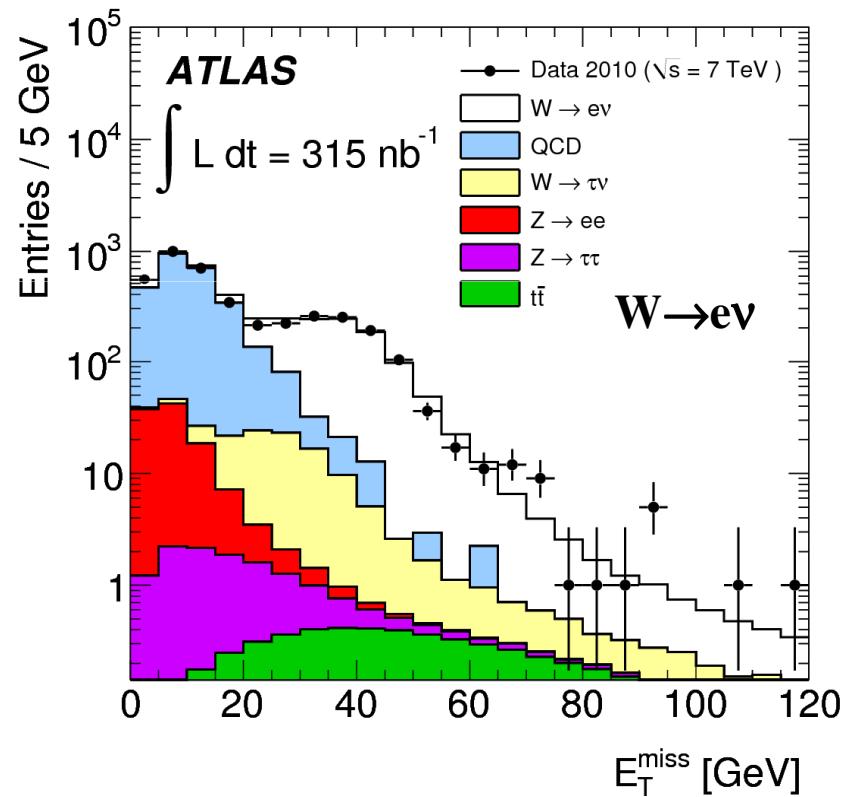
Osservazione di $W \rightarrow \tau\nu$





What's different with other W analysis?

1) Fully hadronic final state (larger QCD background)



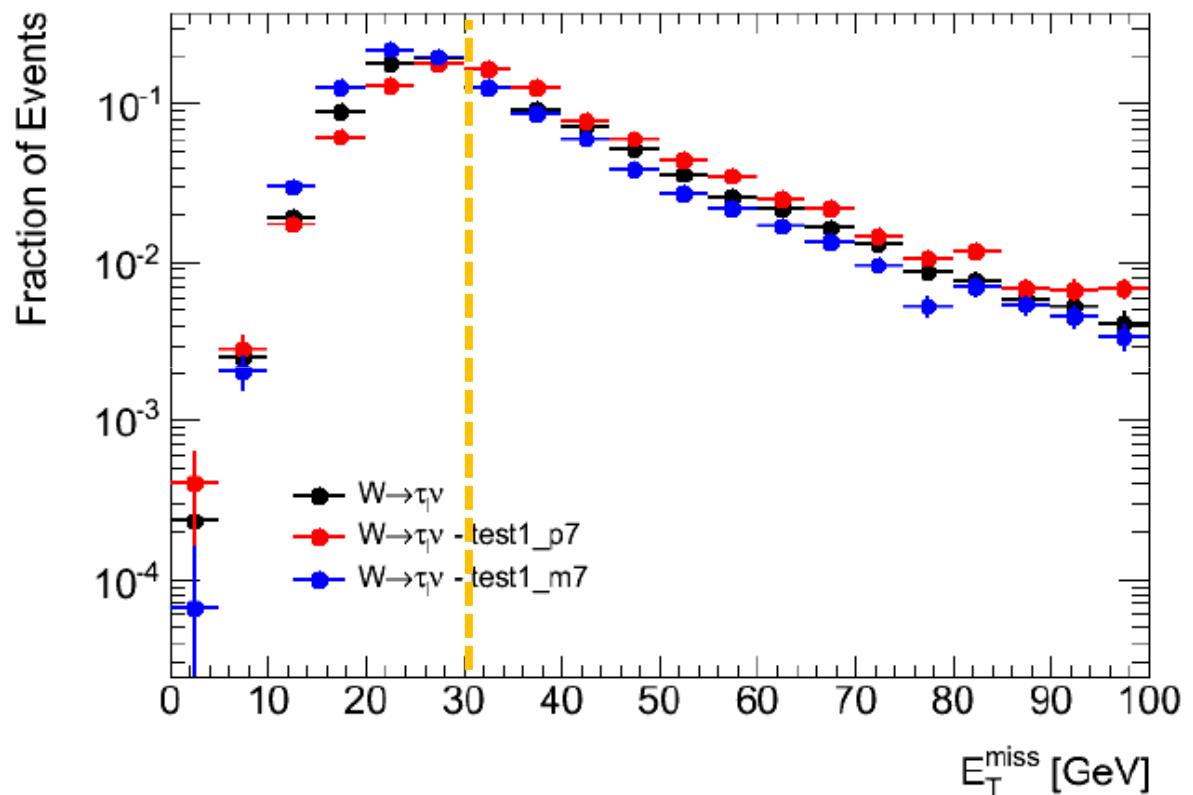
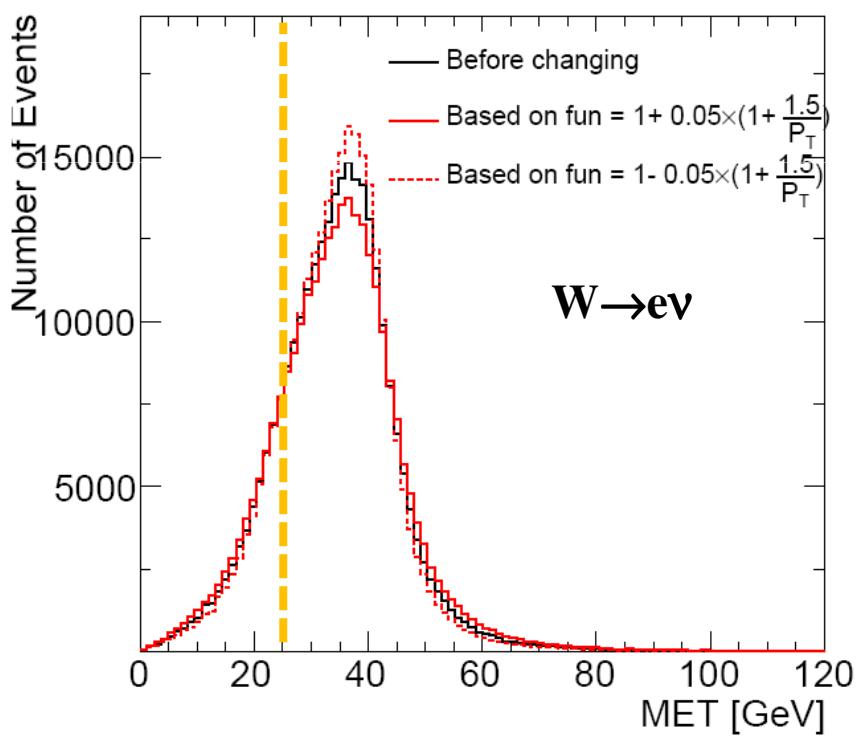
- Cut based τ -id does not provide enough rejection
- Improved **BDT** and **Likelihood** discriminators not validated yet.



What's different with other W analyses?

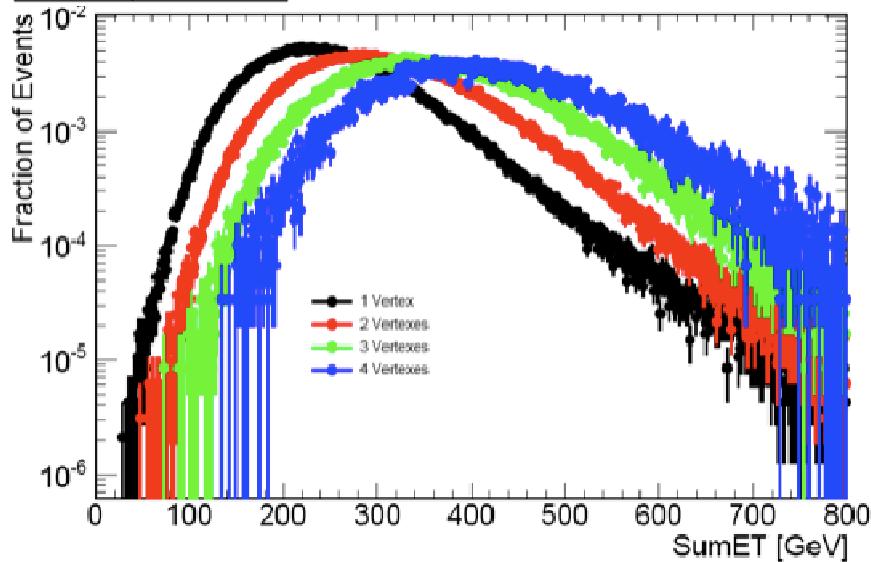
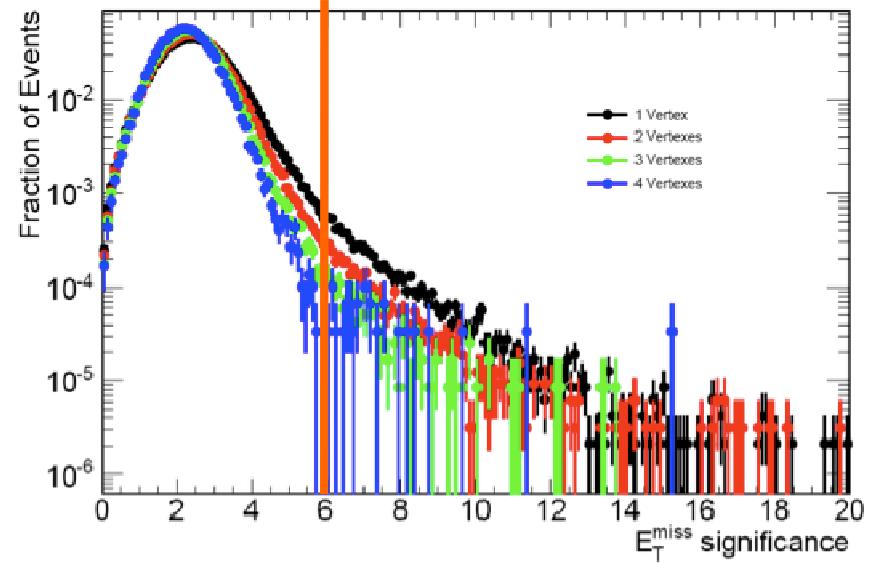
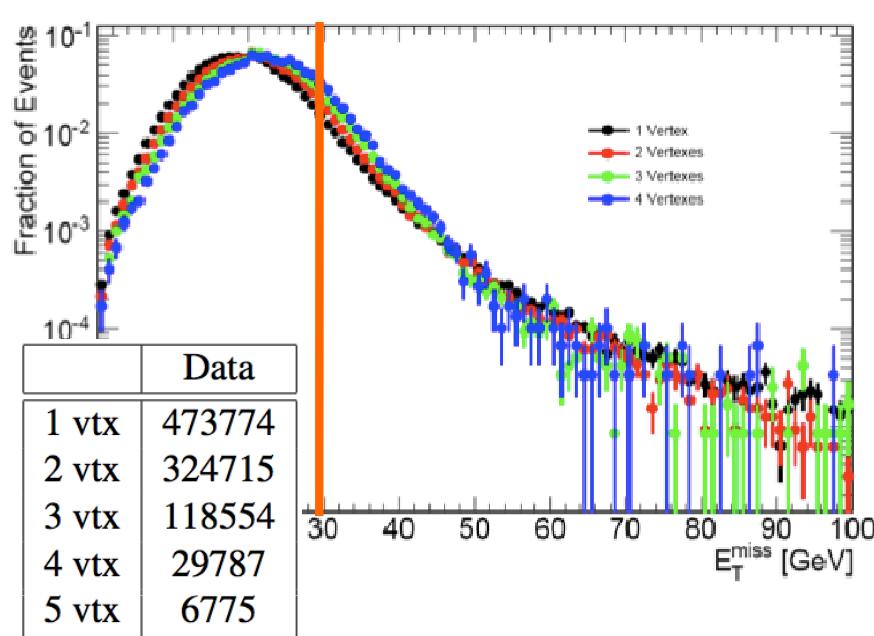
2) smaller E_T^{miss}

(more sensitive to cut variation)





Pile up correction



- Pile up strongly affects E_T^{miss} and its significance.
- QCD is more strongly suppressed than signal events.
- Monte Carlo with pile up are rescaled to have the same vertex multiplicity in data.



Cut Flow Table

	Data	$W \rightarrow \tau_h v_\tau$	$W \rightarrow e v_e$	$W \rightarrow \mu v_\mu$	$W \rightarrow \tau_\ell v_\tau$	$Z \rightarrow ee$	$Z \rightarrow \mu\mu$	$Z \rightarrow \tau\tau$
Trigger	986439	954.5 ± 5.2	3560.7 ± 3.4	521.4 ± 1.6	296.5 ± 2.8	75.3 ± 0.2	59.7 ± 0.2	115.1 ± 0.7
QCD jets rejection	415951	728.3 ± 4.7	2735.3 ± 3.5	400.7 ± 1.5	229.4 ± 2.6	24.5 ± 0.1	45.1 ± 0.1	71.4 ± 0.6
$E_T^{\text{miss}} > 30 \text{ GeV}$	29686	411.5 ± 3.8	1828.3 ± 3.3	317.1 ± 1.3	121.9 ± 1.9	1.13 ± 0.03	34.4 ± 0.1	35.4 ± 0.4
τ selection	2408	118.0 ± 2.1	1482.0 ± 3.1	26.6 ± 0.4	34.4 ± 1.0	0.59 ± 0.02	3.24 ± 0.04	11.9 ± 0.3
Lepton rejection	685	94.8 ± 1.9	6.7 ± 0.2	4.9 ± 0.2	2.3 ± 0.3	<0.005	0.11 ± 0.01	4.2 ± 0.2
$S_{E_T^{\text{miss}}} > 6$	78	55.3 ± 1.4	4.2 ± 0.2	3.7 ± 0.1	1.8 ± 0.2		0.08 ± 0.01	2.0 ± 0.1

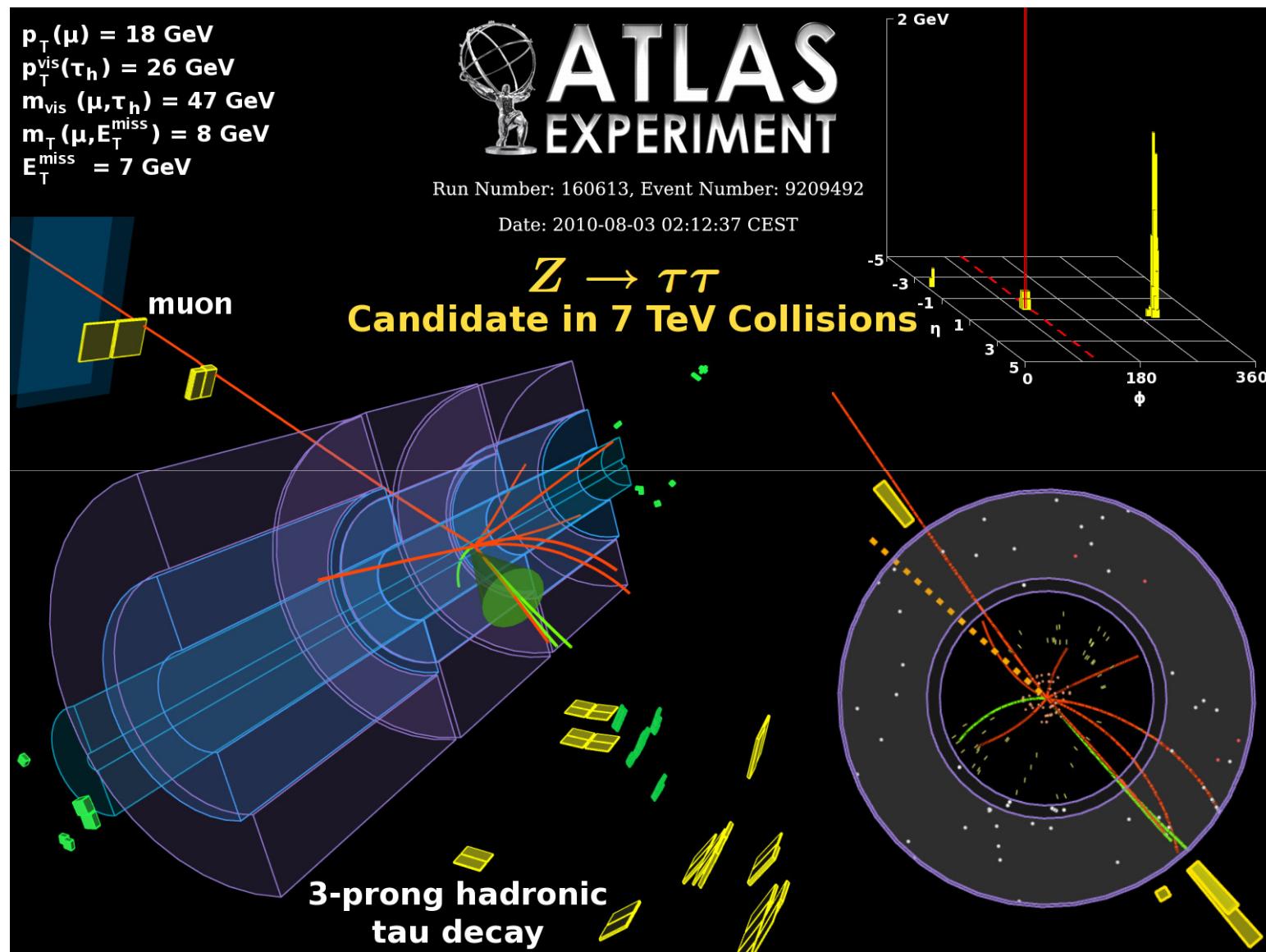
Statistical uncertainty only

- ✓ 78 events selected in data
- ✓ from Monte Carlo:
 - ✓ **55.3 ± 1.4 signal events expected**
 - ✓ **11.8 ± 0.4 EW background events** expected
 - ✓ ttbar background negligible, not included
- ✓ for QCD:
 - ✓ simulated statistics is too low to give a good estimate
 - ✓ cross section is affected by huge uncertainties
 - ➔ have to determine it from data

	J0	J1	J2	J3	J4	J5	J6
Events	1399184	1395383	1397078	1397430	1397401	1391612	1347654
Skimming	1053	9412	77978	316343	676161	980236	1139266
GRL	1053	9412	77978	316343	676161	980236	1139266
Trigger	16	1418	41340	273176	627235	917572	1082208
CollCand	16	1418	41340	273176	627233	917568	1082206
JetClean	15	1383	40624	268933	615844	898534	1061743
JetVeto	12	1156	29716	179205	382279	547382	731452
DeltaPhi jet	12	937	13112	50031	96314	116397	117289
METcut	0	18	364	1353	3859	9246	17461
τ_h -ID	0	0	39	209	962	2603	4332
τ_h -ID Et	0	0	22	58	91	184	309
τ_h -ID eta	0	0	22	57	91	184	306
τ_h -ID lep	0	0	20	49	74	163	266
LeptVeto	0	0	13	37	57	117	167
METSign	0	0	1	2	1	4	3



Analisi $Z \rightarrow \tau_{\text{lep}}\tau_{\text{had}}$

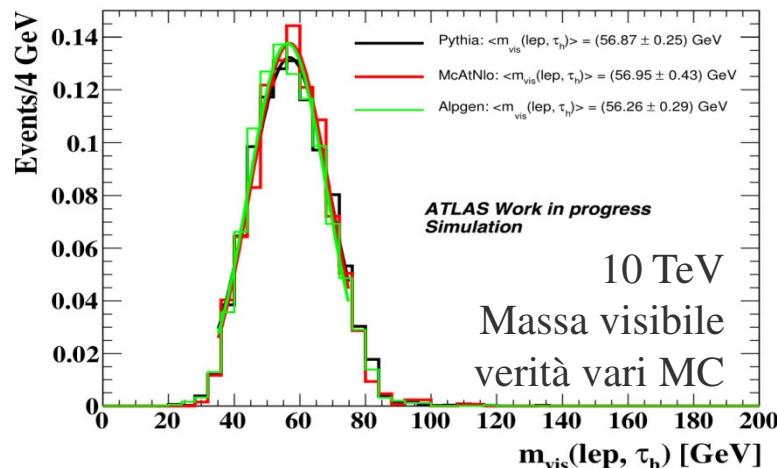




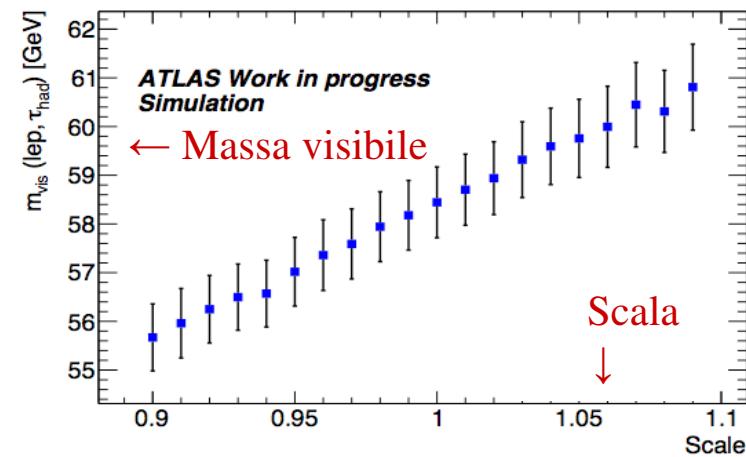
Scala di energia dei τ_{jet} coi primi 50 pb^{-1}

Massa visibile:
proporzionale alla scala di energia dei τ_{jet} .

Paragone della massa visibile ricostruita con la referenza da verità Monte Carlo:
1% sistematica (diversi MC, stima a 10 TeV)



Considerando varie **sistematiche** (scala leptoni, referenza Monte Carlo, spostamenti reco-truth, sottrazione fondi) e l'incertezza statistica:
con 50 pb^{-1} 4.8% incertezza sulla scala



paragone dopo la sottrazione dei fondi
3.2% sistematica: spostamento del picco dovuto a fondi residui (Z)

