Supersymmetry with tau final states in early data

Tau workshop 2009

Klaus Desch, Christian Limbach, Till Nattermann, Peter Wienemann, Carolin Zendler
University of Bonn

Outlook

- Introduction and Motivation
- The $\tau\tau$ invariant mass spectrum
- Reminder: The CSC method
- From 14 TeV to 10 TeV data
- Summary

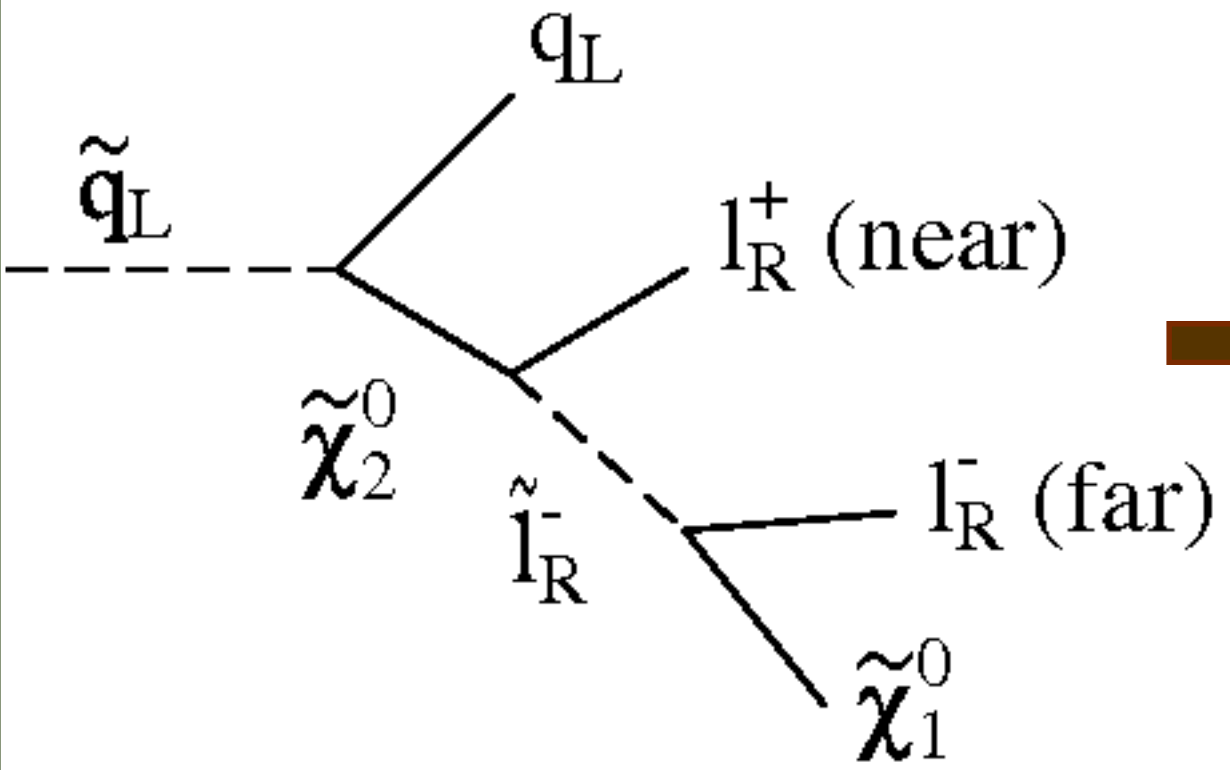
<u>mSUGRA bulk region point SU3:</u>

m_0 = 100 GeV tanβ = 6

$m_{1/2}$ = 300 GeV sgnμ= +

A_0 = -300 GeV

typical SUSY decay chain:



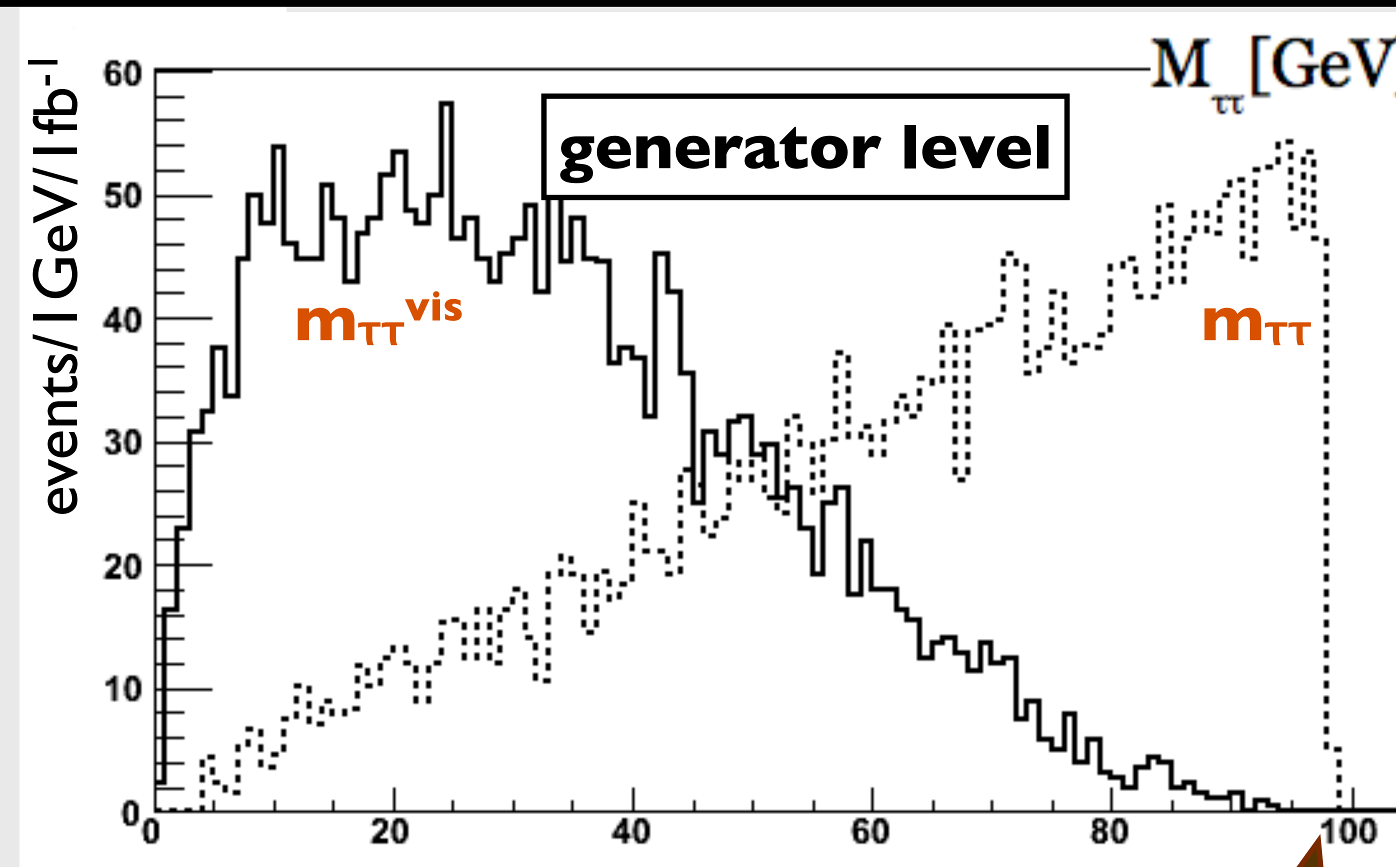
R-Parity conservation:

- lightest SUSY particle (LSP) stable, escapes detection → missing transverse energy
- long decay chains → many energetic jets, leptons; symmetric topology

- For SUSY discovery: need to show it ***is*** SUSY
 → first step: measure mass spectrum → derive parameters
- No mass peaks because of missing LSP → measure edges
- Dilepton mass spectrum holds information about SUSY masses involved in the decay chain: $\tilde{\chi}_1^0$, $\tilde{e}/\tilde{\mu}/\tilde{\tau}$, $\tilde{\chi}_2^0$

The ττ invariant mass spectrum

- $m_{\tau\tau}^{vis}$: sharp edge washed out due to escaping neutrino from τ decay
- little statistics left at edge
  → need to approximate shape



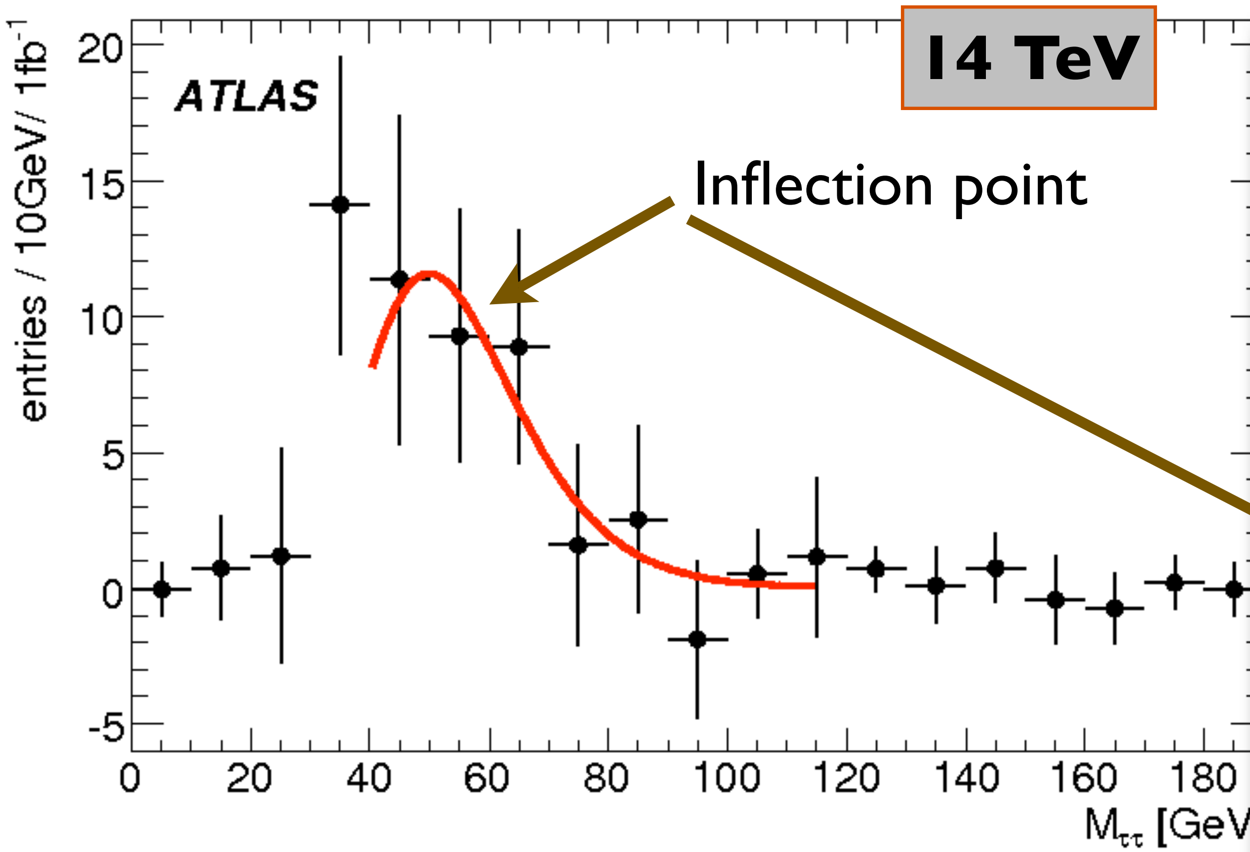
<u>Why taus?</u>

- BR($\chi_2^0 \longrightarrow l^+l^- \chi_1^0$) is larger for τ than e, μ due to R,L-mixing
  → increased with growing tanβ
- access to $\tilde{\tau}$ mass information:

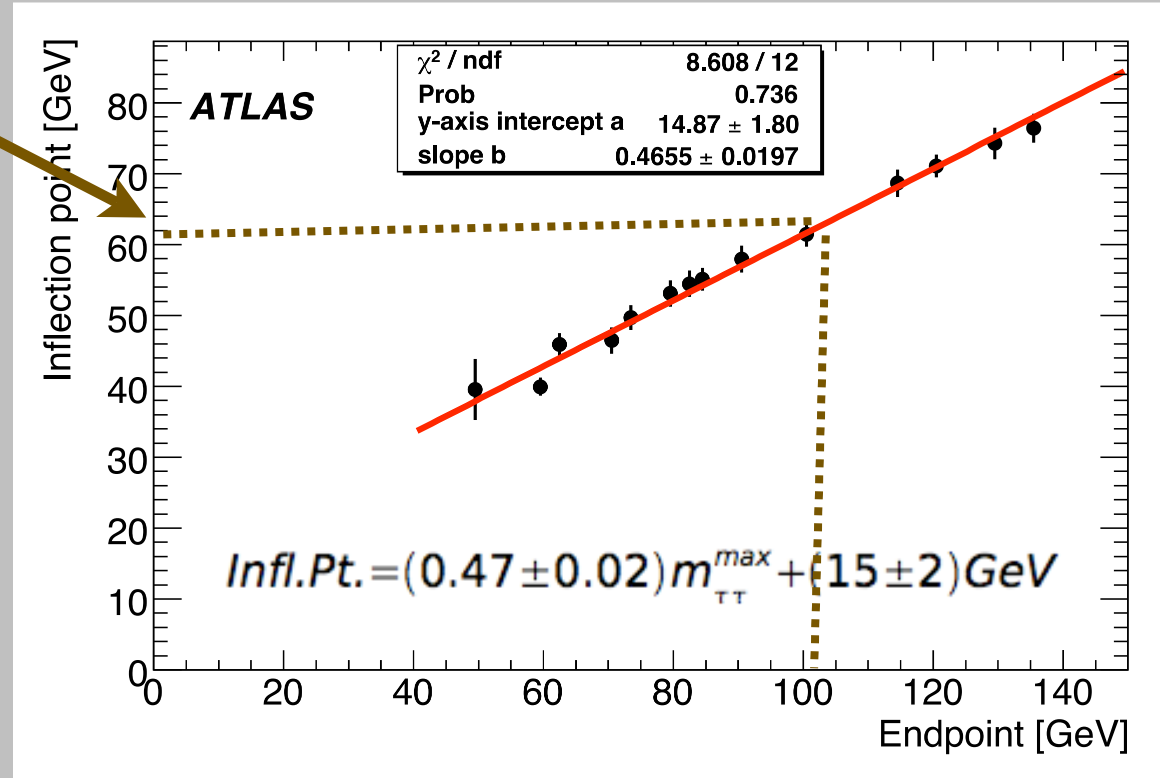
$$m_{\tau\tau}^{max} = \sqrt{\frac{(m(\tilde{\chi}_2^0)^2 - m(\tilde{\tau}_1)^2)\cdot(m(\tilde{\tau}_1)^2 - m(\tilde{\chi}_1^0)^2)}{(m(\tilde{\tau}_1)^2)}}$$

- shape of ditau mass spectrum also holds information about stau mixing angle → need ~50 fb^{-1} to measure both endpoint and tau polarization → not covered in this talk [JHEP04(2009)057]

The CSC method



- approximate shape
- measure inflection point
- calibration: (done with ATLFAST*)



→ measured endpoint:

(theory: 99 GeV)

$m_{\tau\tau}^{max}$ = 103 ± 5^{stat} ± 4.5^{syst} GeV (**10 fb^{-1}**)

102 ± 17^{stat} ± 5.5^{syst} GeV (**1 fb^{-1}**)

Leptonically decaying taus

<u>Post-CSC extension *by C. Limbach*</u>

include leptonically decaying taus:

- **ττ** (hh) channel: "had-had" = CSC-study — 42 %
- **τμ/τe** (hl) channel "had-lep": one hadronically decaying tau from tauRec + one electron or muon — 46 %
- **μe** (ll') channel "lep-lep": both taus decayed into leptons — 6 %

→ need different selections and **separate calibrations**:
- done on same samples as CSC study (rel.12)

→ use only opposite flavour (OF) combinations

→ 3 measurements of the endpoint instead of 1

Datasets for 10 TeV study

	ID	sample names
SU3	105403	mc08.105403.SU3_jimmy_susy.recon.AOD.e352_s462_r541
Z +Jets	107670-107675 107660-107665 107650-107655 107710-105515	mc08.10767*.AlpgenJimmyZtautauNp*_pt20.recon.AOD.e376_s462_r563 mc08.10766*.AlpgenJimmyZmumuNp*_pt20.recon.AOD.e376_s462_r563 mc08.10765*.AlpgenJimmyZeeNp*_pt20.recon.AOD.e376_s462_r563 mc08.10771*.AlpgenJimmyZnunuNp*_pt20_filt1jet.recon.AOD.e376_**a68**
W +Jets	107700-107705 107690-109795 107680-107685	mc08.10770*.AlpgenJimmyWtaunuNp*_pt20.recon.AOD.e368_s462_r563 mc08.10769*.AlpgenJimmyWmunuNp*_pt20.recon.AOD.e368_s462_r563 mc08.10768*.AlpgenJimmyWenuNp*_pt20.recon.AOD.e368_s462_r563
ttbar	105200 105204	mc08.105200.T1_McAtNlo_Jimmy.recon.AOD.e357_s462_r541 mc08.105204.TTbar_FullHad_McAtNlo_Jimmy.recon.AOD.e363_s462_r563
QCD (Jn)	105009-105015	mc08.10500*.J*_pythia_jetjet.recon.AOD.e344_s479_r541

Note: - some of the W+Jets and Z+Jets samples still affected by the event duplication bug

- $Z \rightarrow \nu\nu$ sample: ATLFAST II

From 14 TeV data to 10 TeV data

- LO CS: 20.85 pb → 5.48 pb
- CSC cuts optimized for 14 TeV data and 1 - 10 fb^{-1}
  → need to re-adjust to 10 TeV and to 200pb^{-1} - 1 fb^{-1}

ev. @1fb^{-1}	14 TeV	10 TeV
had-had	286	67
had-lep	519	117
lep-lep	414	110

event selection for 10/14 TeV:

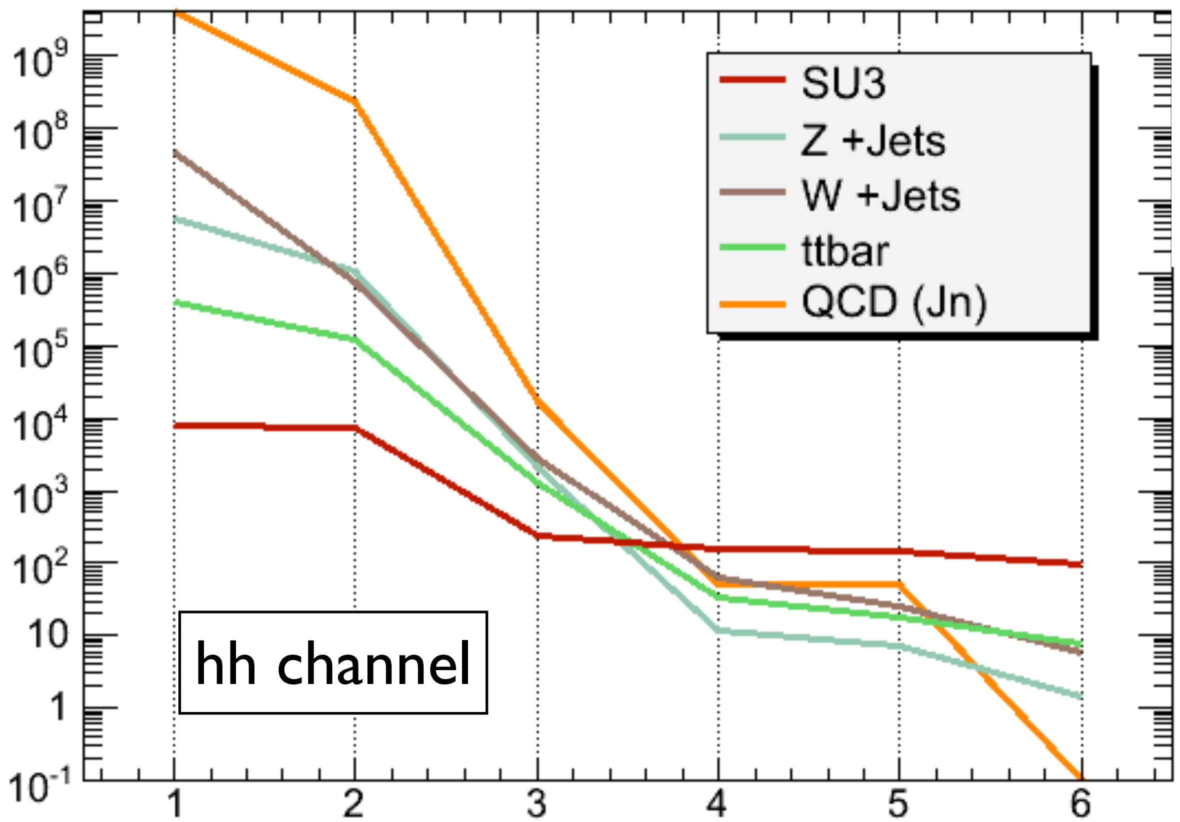
	14 TeV	10 TeV
hh	MET>230GeV, 4 jets: p_T>(220/40/40/40)GeV ≥2τ (Llh>4)	MET>200GeV, HT>450 GeV, Meff>290 GeV, ≥2τ (Llh>2)
hl	MET>250GeV, 3 jets: p_T>(160/100/50)GeV 1τ (Llh>4), 1 (μ/e)	MET>340GeV, HT>500GeV, 1τ (Llh>2), ≥1 (μ/e)
ll	MET>230GeV, 2 jets: p_T>(160/120)GeV 0τ , 1μ+1e	MET>240GeV, HT>500GeV, 0τ , ≥(1μ+1e)

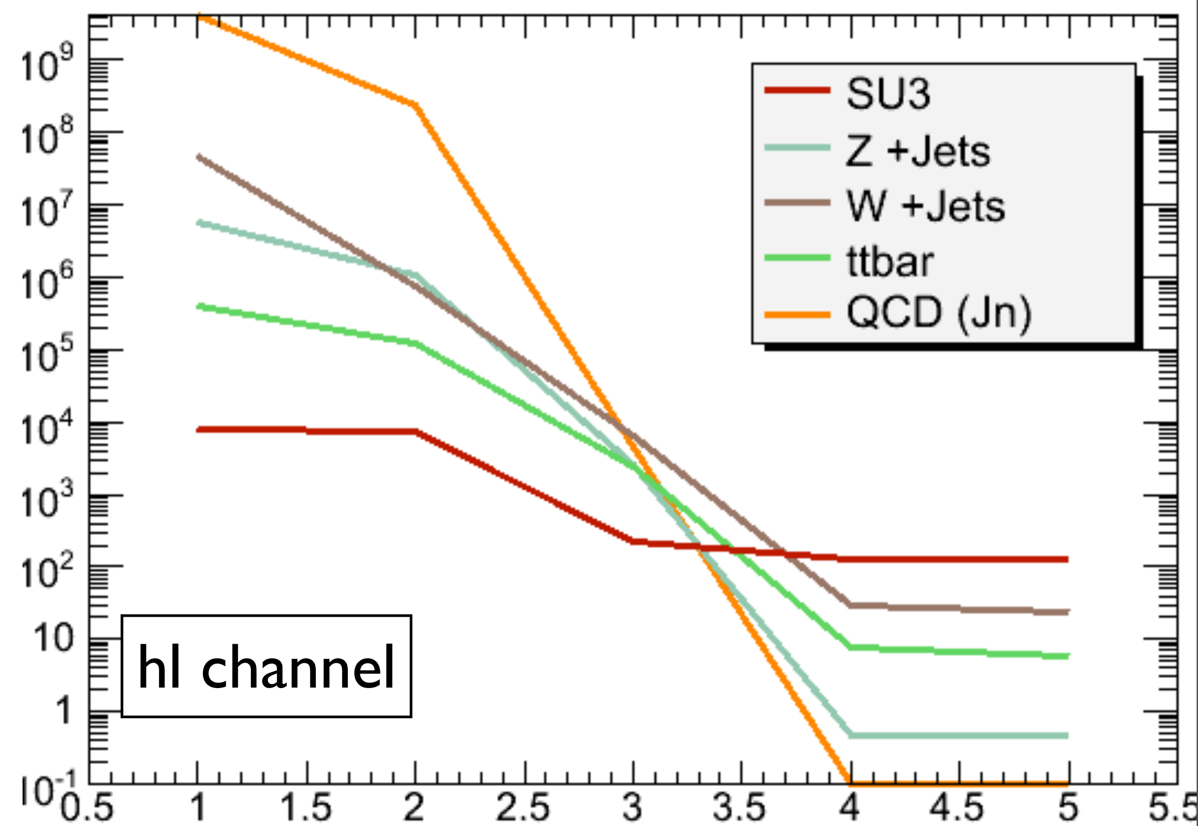
Definitions:

- Meff = MET + $\Sigma_{i=1}^{4}\, p_T^{jet\ i}$
- HT = $\Sigma_{i=1}^{NJet}\, p_T^{jet\ i}$ (if p_T^{jet}>20GeV)

Cut flows

Number of events @1fb^{-1}



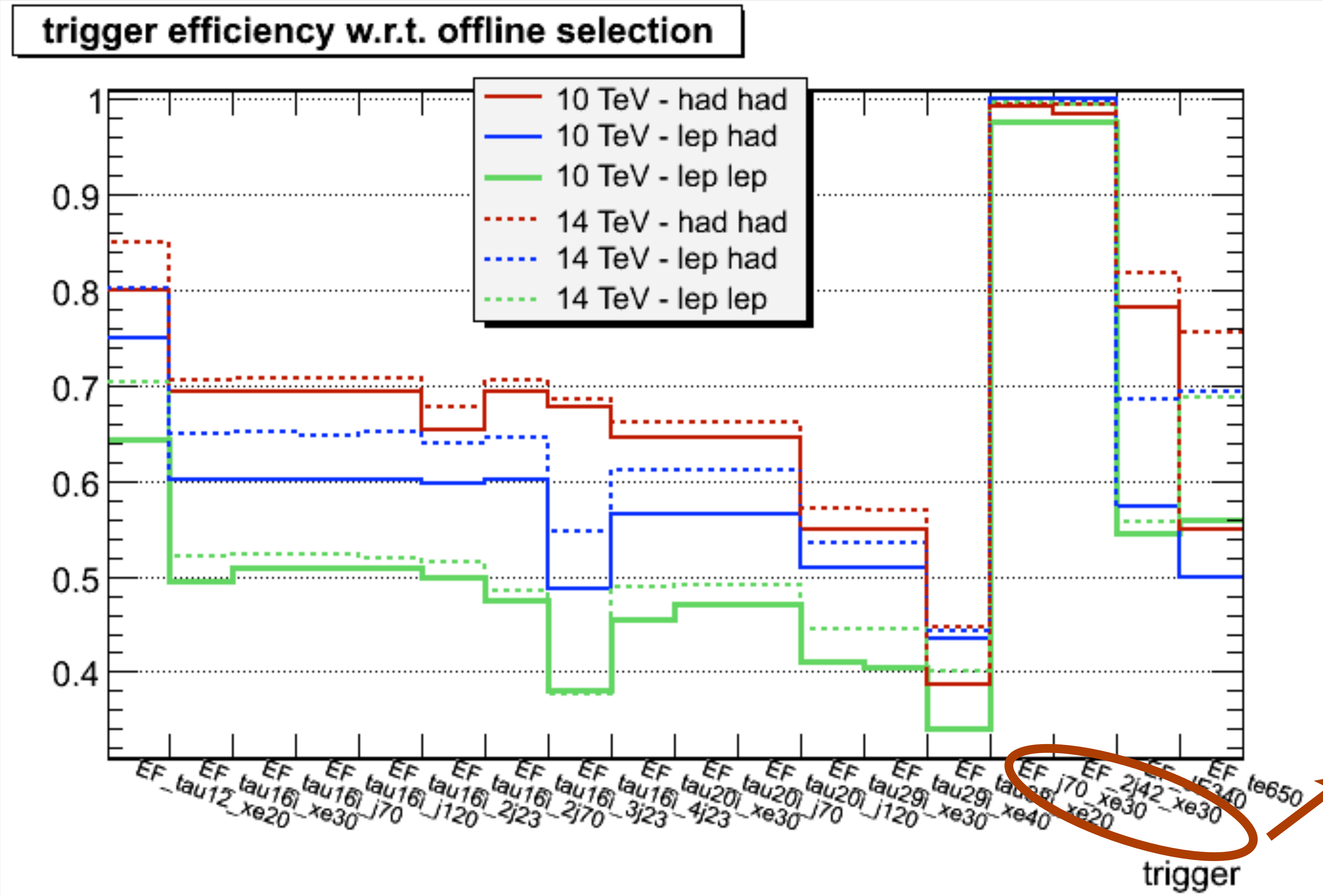


cuts:	-	Trigger	ΔR	MET	HT	Meff
sign:	0.002	0.5	1.5	12	14	23

cuts:	-	Trigger	ΔR	MET	HT
sign:	0.002	0.5	2	20	22

$$sign. = \frac{S}{\sqrt{BG}}$$

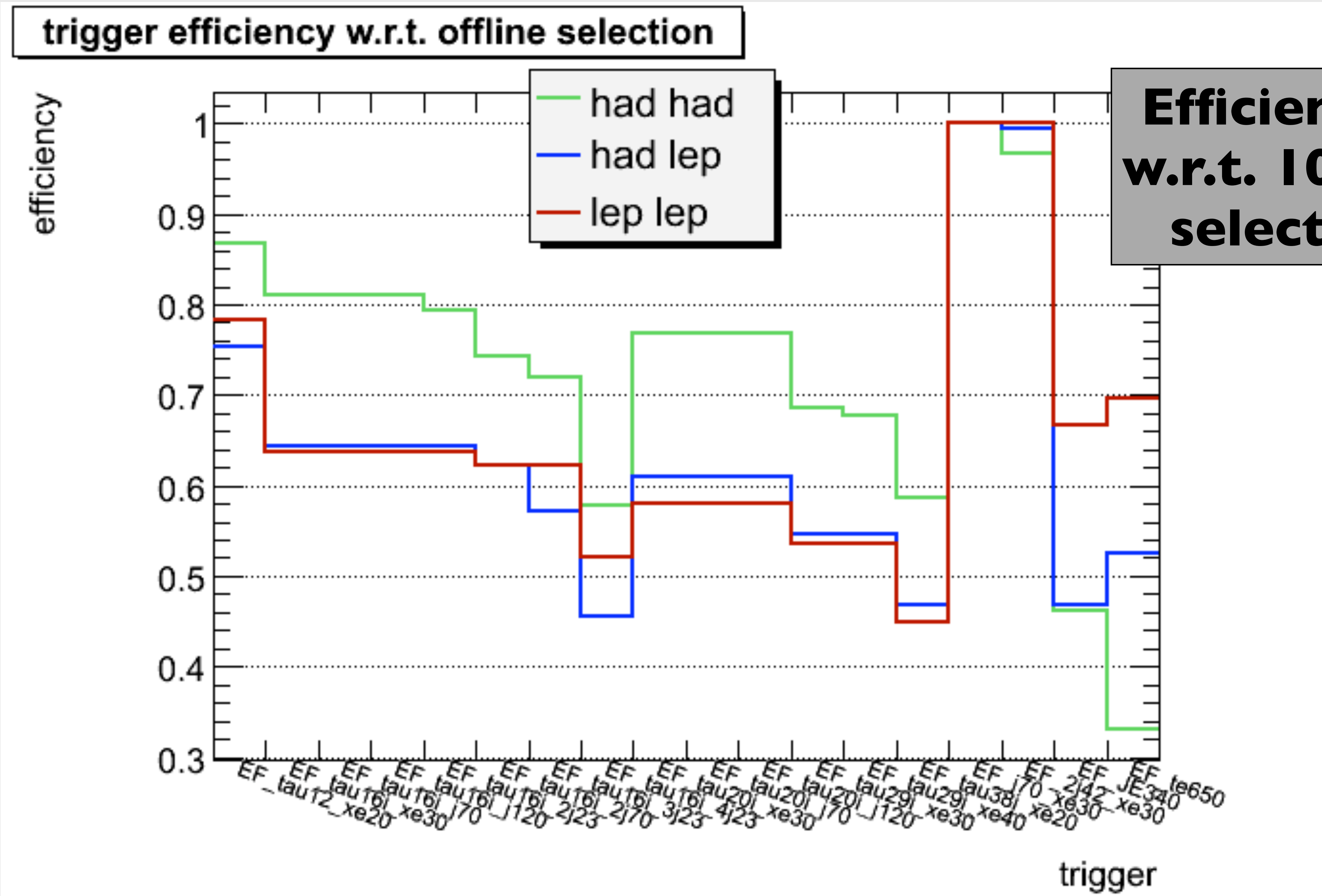
Trigger efficiencies: 10 TeV vs 14 TeV data



<u>highest efficiency:</u>
EF_j70_xe30
EF_2j42_xe30

Efficiencies w.r.t. 14 TeV selection

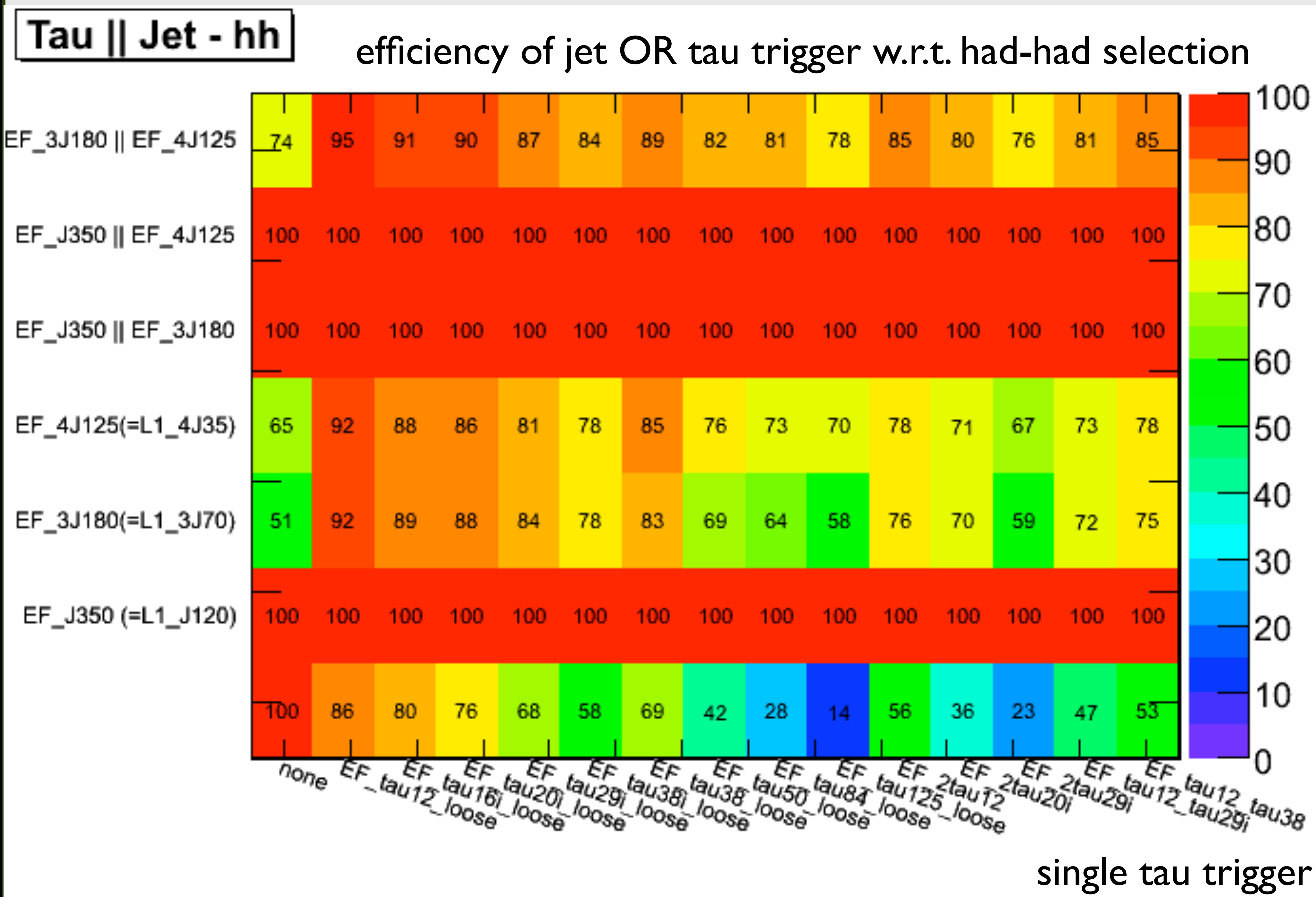
Trigger efficiencies w.r.t. 10 TeV selection



Efficiencies w.r.t. 10 TeV selection

Tau trigger as backup?

- can trigger on jet and/or MET with ~100% efficiency w.r.t. offline selected events; tau trigger possible backup?



- if e.g. MET trigger is not working: requiring jet OR tau trigger may improve efficiency compared to just using jet trigger

Tau/Lepton selection

sort by taus

$\geq 2\tau$

MET > 200 GeV
HT > 550 GeV
Meff > 300 GeV

had-had channel
$\tau^{\pm}\tau^{\mp}$ - $\tau^{\pm}\tau^{\pm}$
$\Delta R_{\tau\tau} < 3$
if more than one τ pair: ΔR_{min}

1τ, $\geq 1(\mu+e)$

MET > 340 GeV
HT > 500 GeV

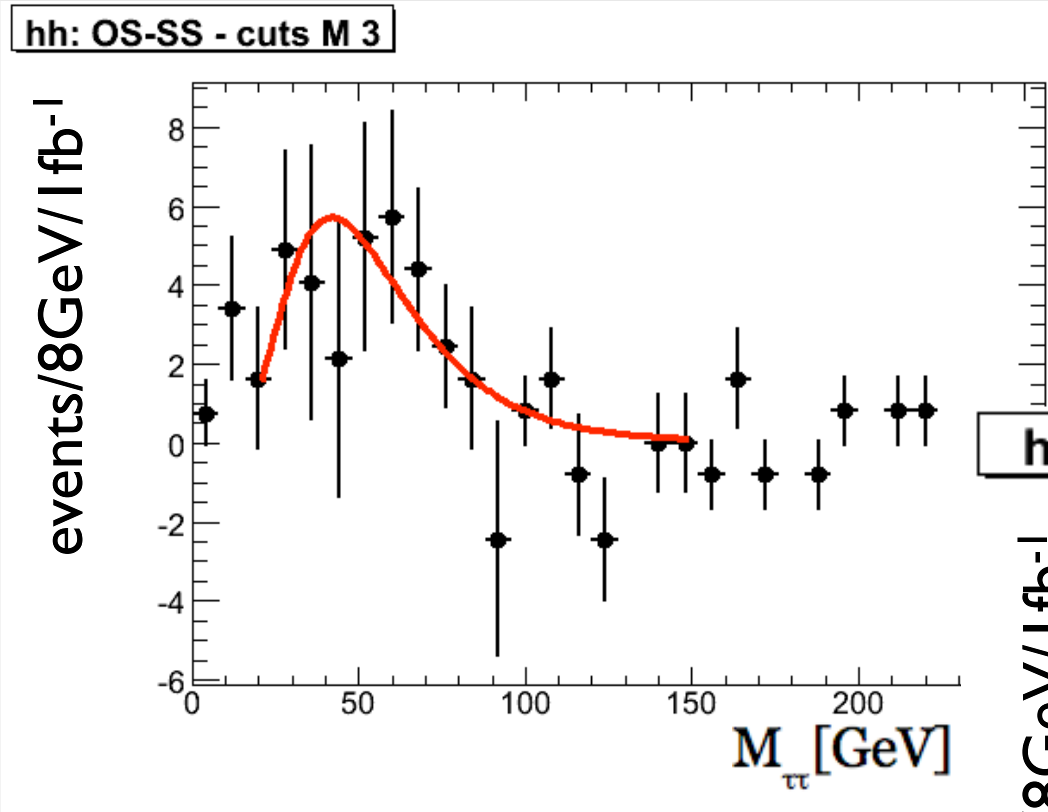
had-lep channel
$(\tau^{\pm}\mu^{\mp} + \tau^{\pm}e^{\mp})$ - $(\tau^{\pm}\mu^{\pm} + \tau^{\pm}e^{\pm})$
$\Delta R_{\tau l} < 2.8$
if more than one e,μ: ΔR_{min}

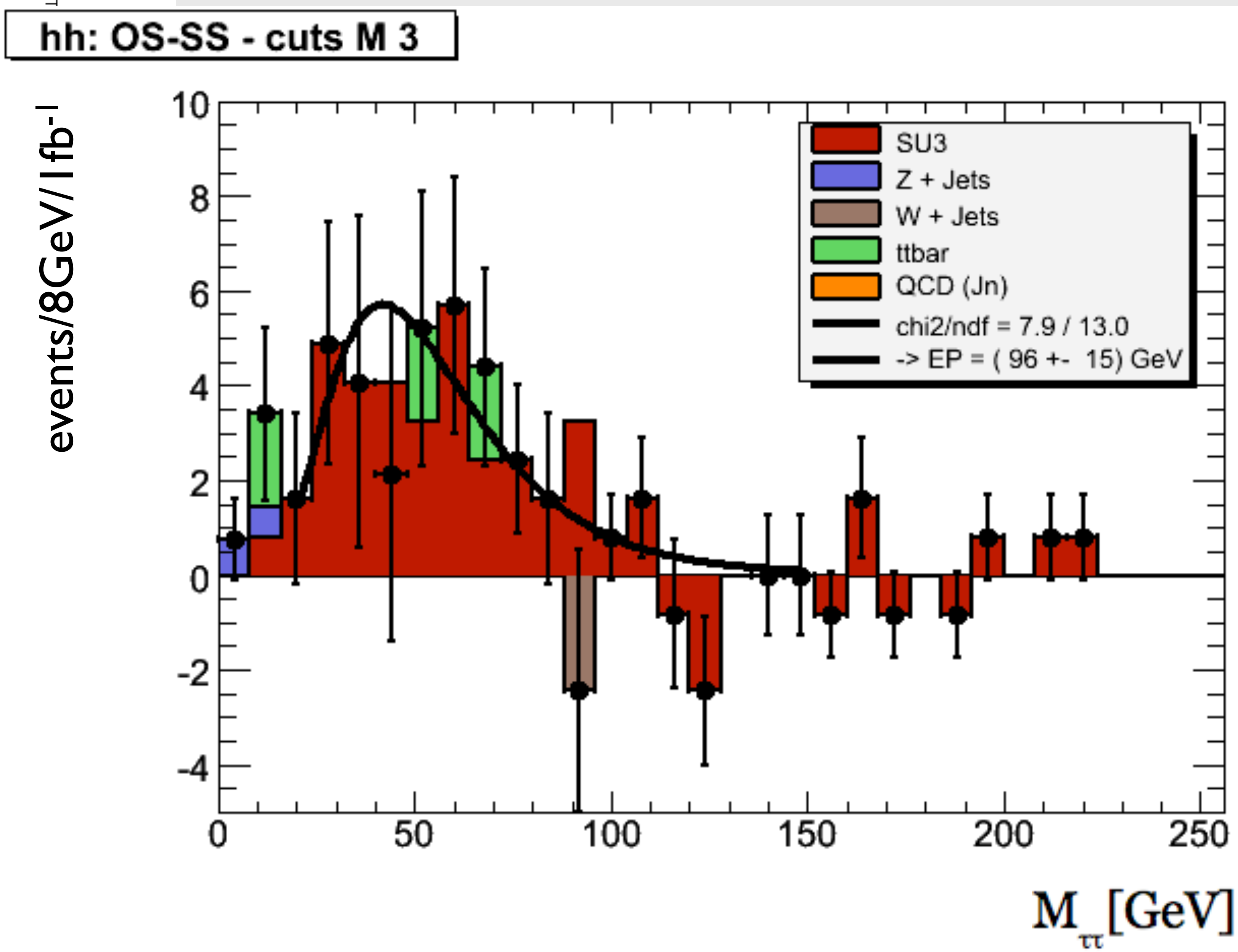
0τ, $\geq 2(\mu+e)$

MET > 240 GeV
HT > 500 GeV

lep-lep channel
$\mu^{\pm}e^{\mp}$ - $\mu^{\pm}e^{\pm}$
$\Delta R_{ll} < 2.8$
if more than one eμ pair: ΔR_{min}

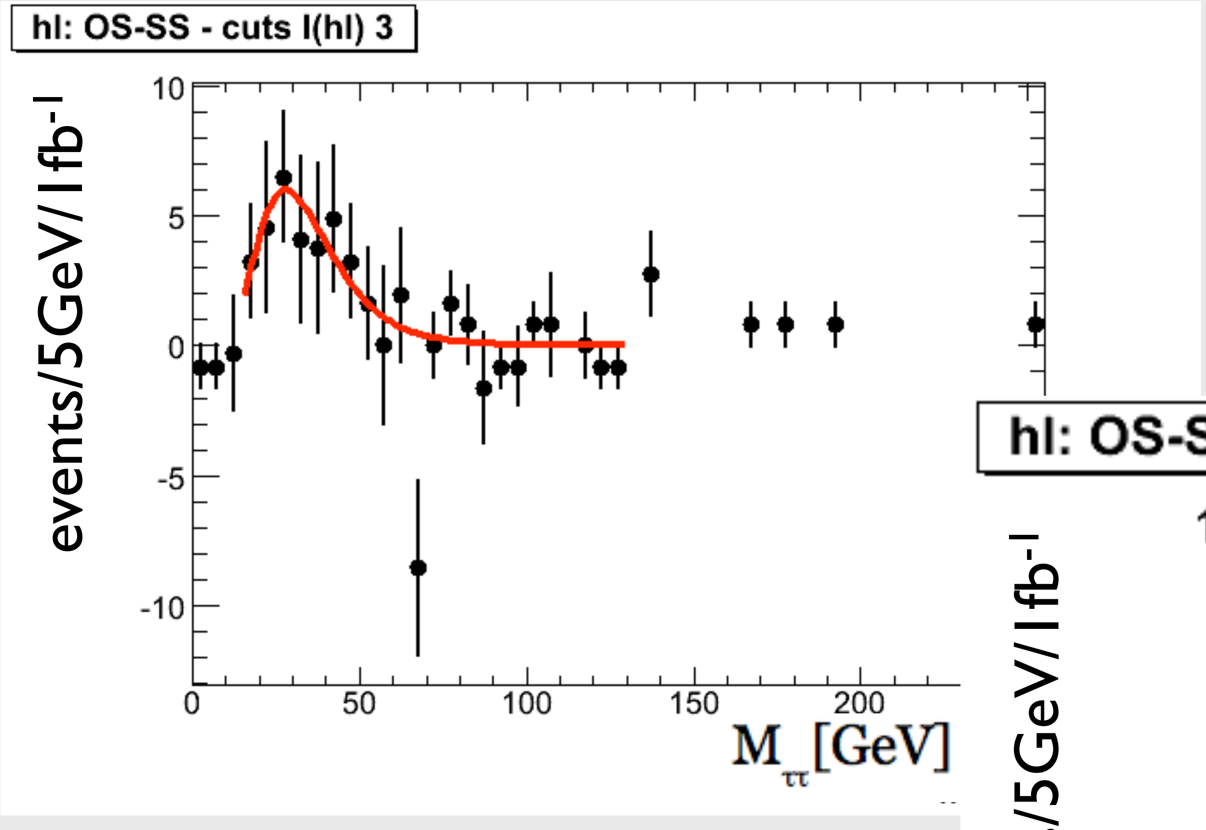
Invariant mass spectrum: hh

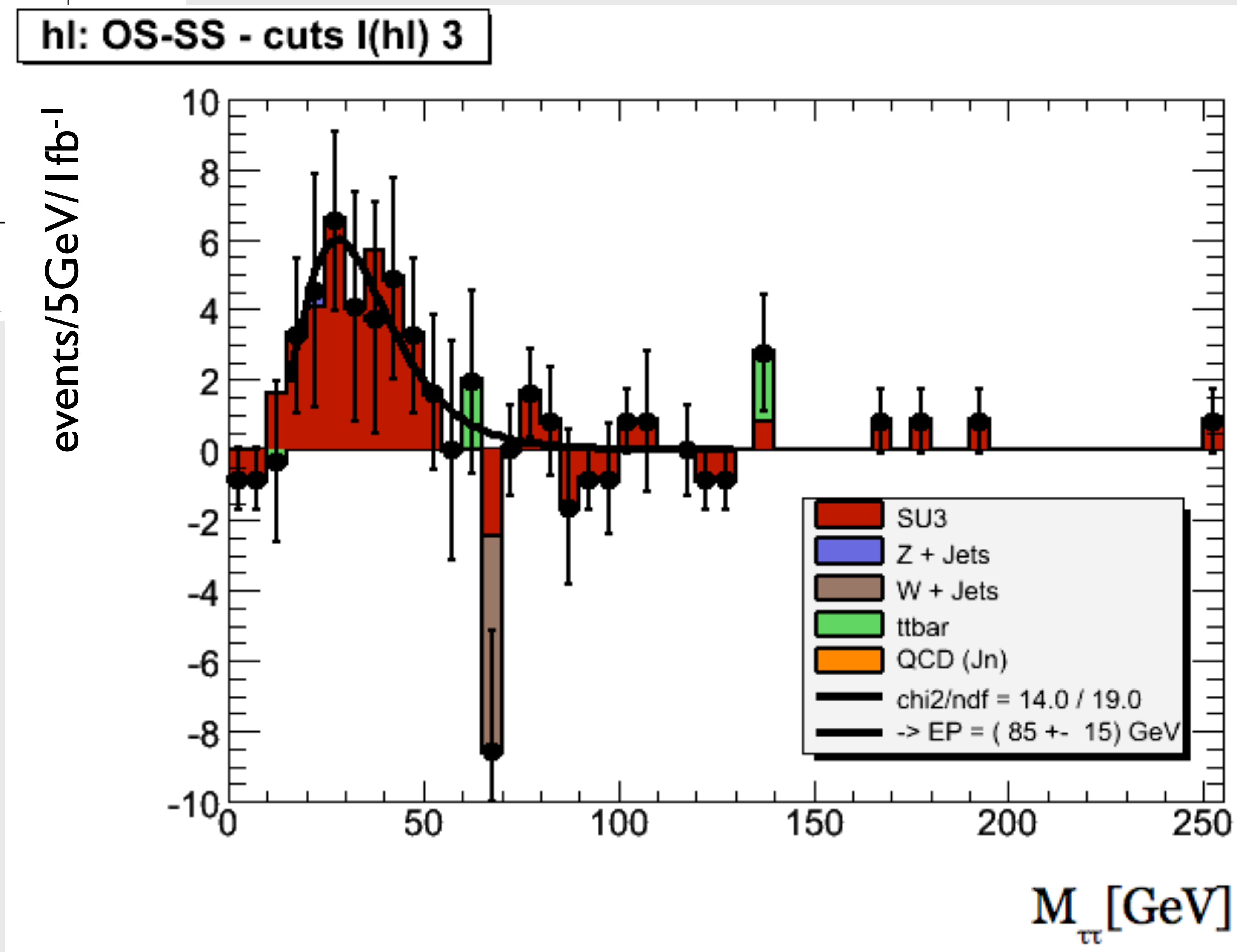




- Endpoint: (96 ± 15) GeV

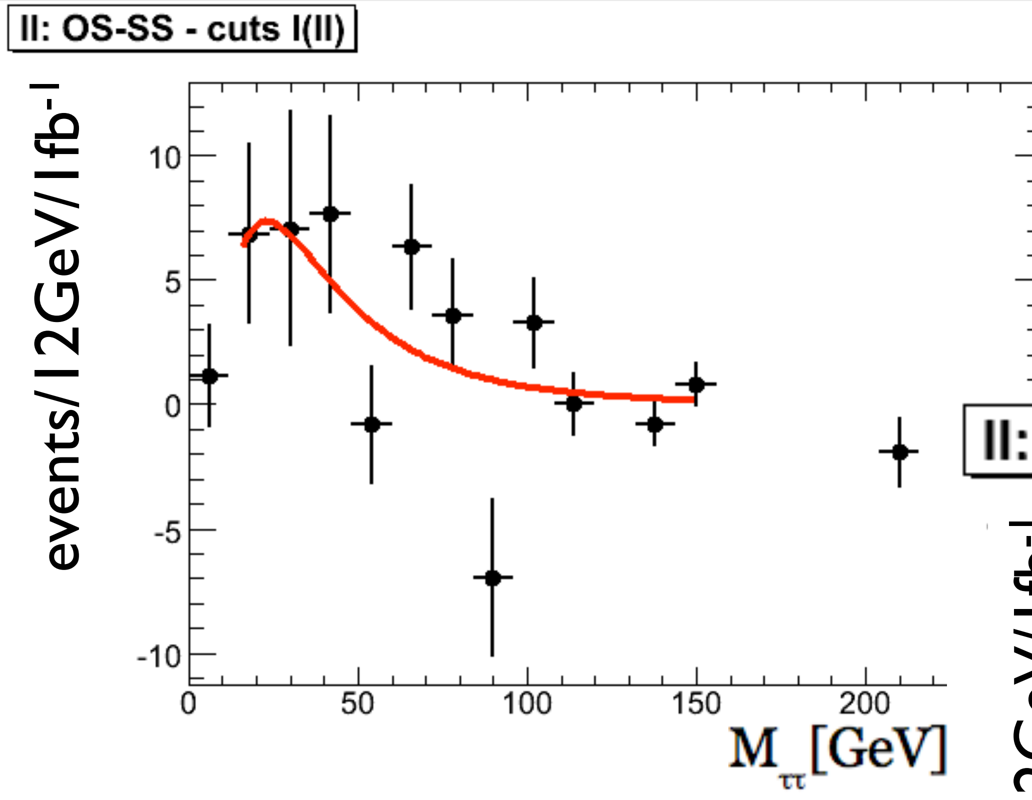
Invariant mass spectrum: hl

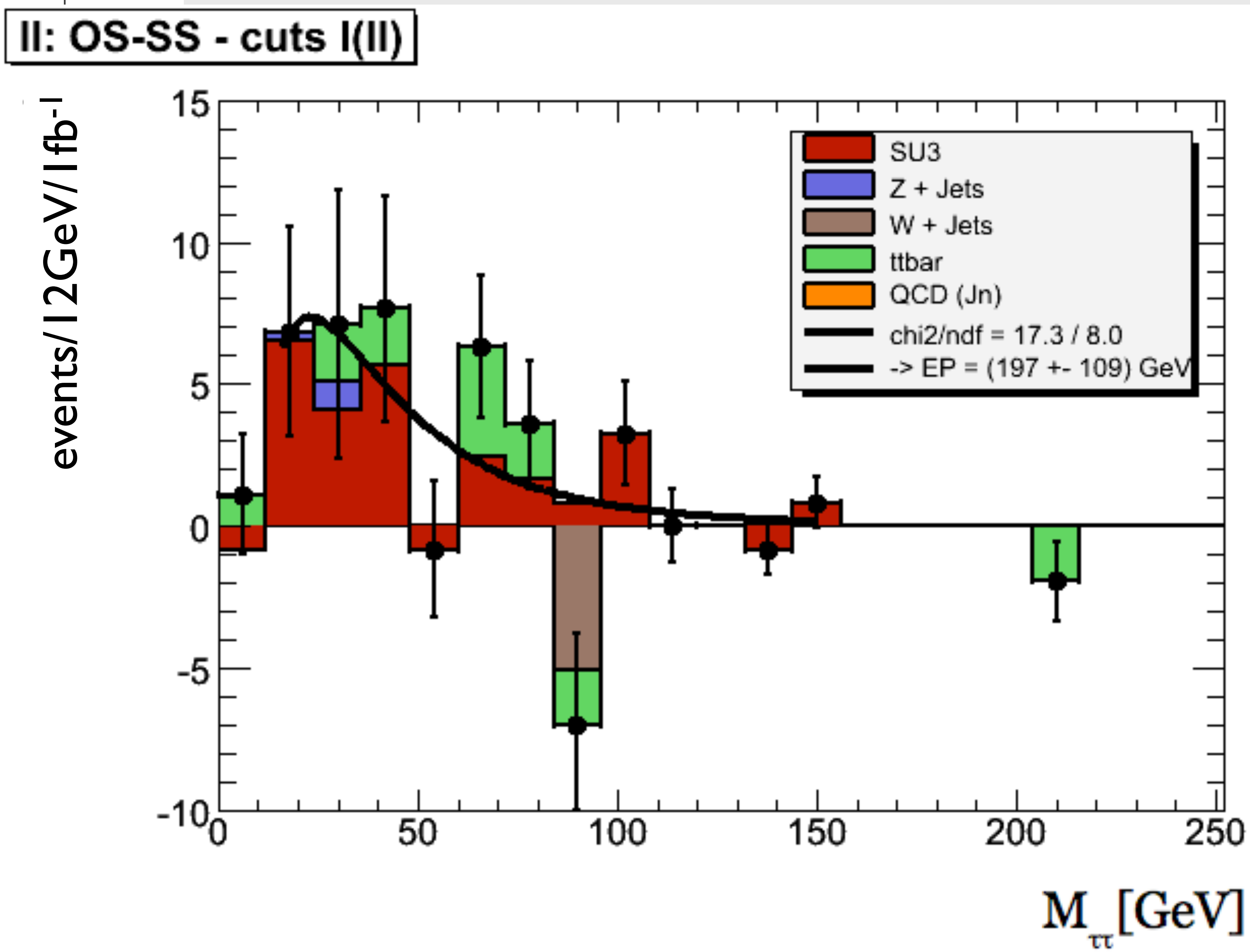




- Endpoint: (85 ± 15) GeV

Invariant mass spectrum: ll





- Endpoint: (197 ± 109) GeV

Endpoint measurement at 1 fb^{-1}

- <u>Endpoints with 1fb^{-1} 10 TeV data:</u>

hh: (96 ± 15) GeV

hl: (85 ± 15) GeV

ll: (197 ± 109) GeV

→ weighted mean: (91±11^{stat}) GeV

- <u>compare to:</u>

→ theoretical value (SU3): 99 GeV

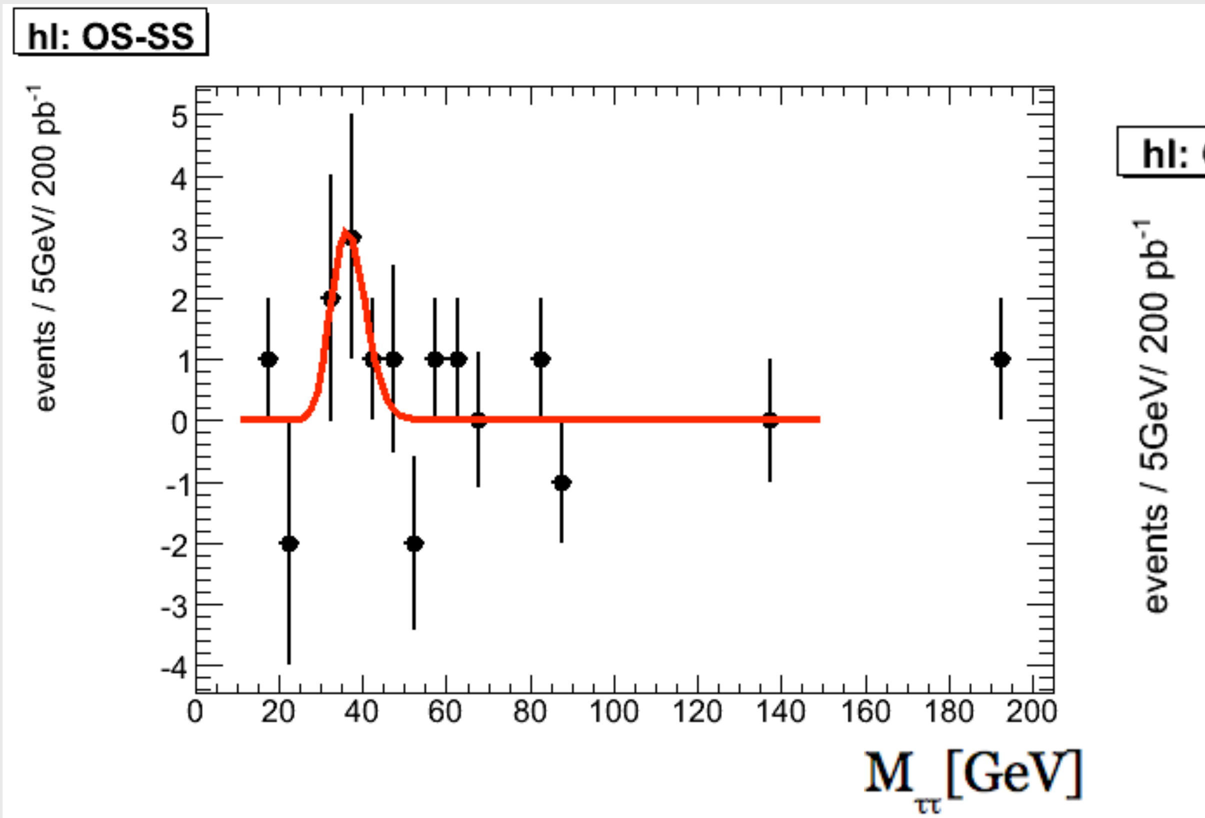
→ CSC result : (102 ± 17^{stat}) GeV

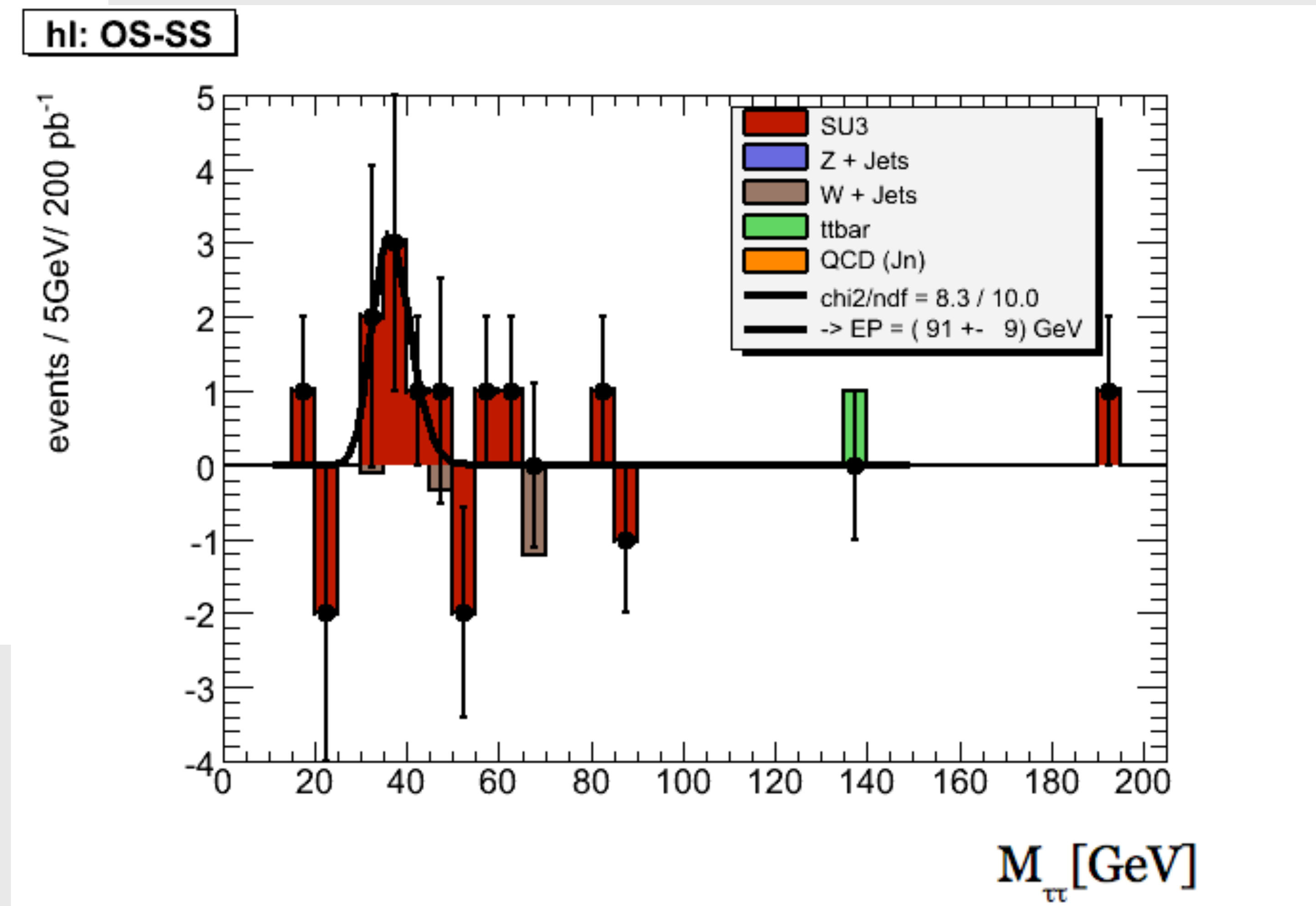
(1fb^{-1} 14 TeV data, only hh channel)

Note: systematics need yet to be included for 10 TeV study!

work in progress

...but what about 200pb^{-1}?





→ difficult.

Summary and conclusions

- Taus final states important for SUSY discovery
  - needed for SUSY parameter determination
- The ditau mass spectrum of taus from a $\tilde{\chi}_2^0$ decay holds important information about stau masses and mixing
- Endpoint can be measured with $1 fb^{-1}$ of 10 TeV data:
  - Include leptonically decaying taus → precision comparable to former (CSC) study: (14 TeV, only hadronically decaying taus considered)

    (91 ± 11^{stat}) GeV
- With only $200 pb^{-1}$ of 10 TeV data: anything but discovery may be difficult (depends on SUSY model / parameters)

- Next step: study of systematics

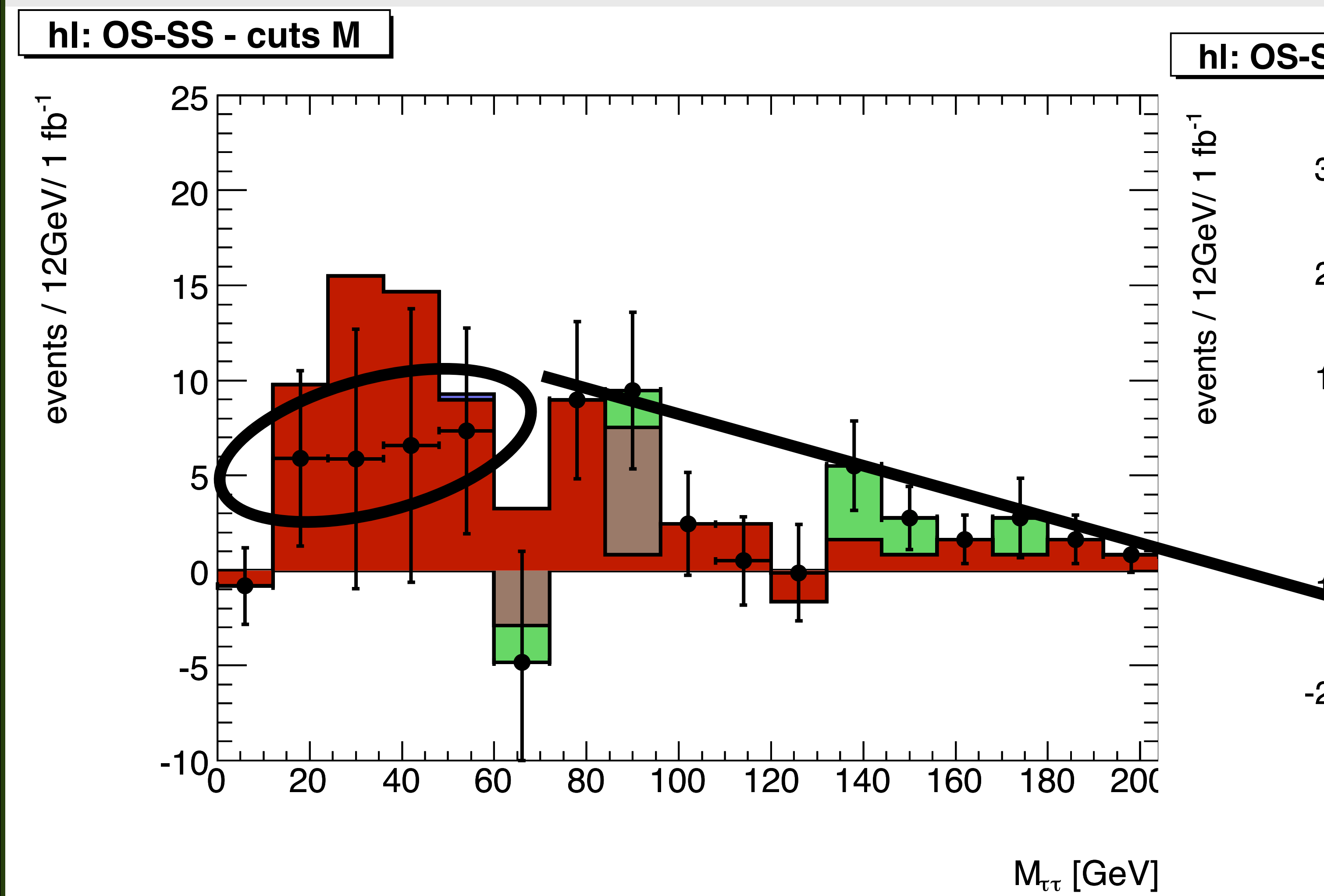
backup

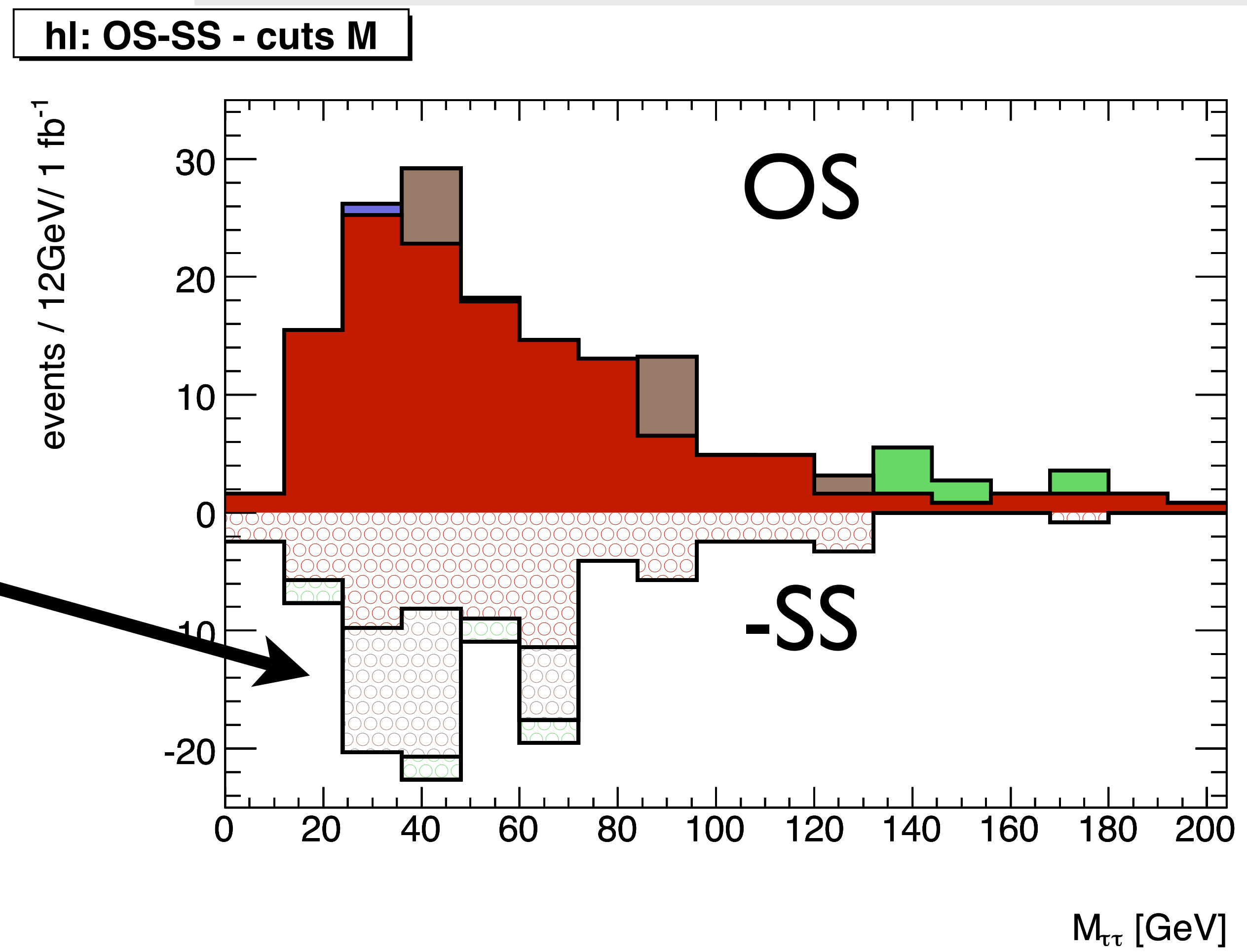
Cut flows

	no cut	trigger EF_j70_xe30	MET>200 GeV	HT>550 GeV	Meff>300 GeV
SU3	8149	7163	5145	3782	2818
Z+Jets	$5.7*10^{6}$	$1.1*10^{6}$	11115	1060	500
W+Jets	$4.8*10^{7}$	751255	16411	2011	887
ttbar	399606	123975	3125	1030	307
Jn	$1.3*10^{13}$	$2.4*10^{8}$	15498	10551	1358
Σ BG	$1.3*10^{13}$	$2.4*10^{8}$	46149	14651	3051
sign	0.002	0.46	24	31	51
sign 2				26	44

sign = S/sqrt(BG)

sign2 = S/sqrt(BG+ΔBG)
with
ΔBG = 50% for QCD
20% for Z,W,ttbar


hl: OS-SS - cuts M
events / 12GeV/ 1 fb-1
25
20
15
10
5
0
-5
-10
0
20
40
60
80
100
120
140
160
180
200
Mττ [GeV]


hl: OS-SS - cuts M
events / 12GeV/ 1 fb-1
OS
-SS
30
20
10
0
-10
-20
0
20
40
60
80
100
120
140
160
180
200
Mττ [GeV]

Full Datasets I

Dataset	CS [pb]	k-factor (NNLO)	N events	Lumi [fb-1]	
SU3: mc08.105403.SU3_jimmy_susy.recon.AOD.e352_s462_r541/	5.48	1.489	9999	1.225	
W->taunu (Alpgen):					
mc08.107700.AlpgenJimmyWtaunuNp0_pt20.recon.AOD.e368_s462_r563/	10178.28	1.22	324289	0.026	x
mc08.107701.AlpgenJimmyWtaunuNp1_pt20.recon.AOD.e368_s462_r563/	2106.92	1.22	103354	0.040	x
mc08.107702.AlpgenJimmyWtaunuNp2_pt20.recon.AOD.e368_s462_r563/	672.78	1.22	77913	0.095	x
mc08.107703.AlpgenJimmyWtaunuNp3_pt20.recon.AOD.e368_s462_r563/	204.58	1.22	43872	0.176	
mc08.107704.AlpgenJimmyWtaunuNp4_pt20.recon.AOD.e368_s462_r563/	56.79	1.22	120000	1.732	
mc08.107705.AlpgenJimmyWtaunuNp5_pt20.recon.AOD.e368_s462_r563/	18.37	1.22	3500	0.156	
Z->tautau (Alpgen):					
mc08.107670.AlpgenJimmyZtautauNp0_pt20.recon.AOD.e376_s462_r563/	893	1.22	110050	0.101	
mc08.107671.AlpgenJimmyZtautauNp1_pt20.recon.AOD.e376_s462_r563/	197.71	1.22	53678	0.223	x
mc08.107672.AlpgenJimmyZtautauNp2_pt20.recon.AOD.e376_s462_r563/	62.63	1.22	20925	0.274	x
mc08.107673.AlpgenJimmyZtautauNp3_pt20.recon.AOD.e376_s462_r563/	18.86	1.22	49184	2.138	x
mc08.107674.AlpgenJimmyZtautauNp4_pt20.recon.AOD.e376_s462_r563/	4.98	1.22	18300	3.012	
mc08.107675.AlpgenJimmyZtautauNp5_pt20.recon.AOD.e376_s462_r563/	1.39	1.22	5279	3.113	
ttbar (MC@NLO):					
mc08.105200.T1_McAtNlo_Jimmy.recon.AOD.e357_s462_r541/	202.86	1.07	111872	0.515	
mc08.105204.TTbar_FullHad_McAtNlo_Jimmy.recon.AOD.e363_s462_r563/	170.74	1.07	11270	0.062	
Jn (Pythia):					
mc08.105009.J0_pythia_jetjet.recon.AOD.e344_s479_r541/	1.17E+10	1	136641	0.000	
mc08.105010.J1_pythia_jetjet.recon.AOD.e344_s479_r541/	8.67E+08	1	109138	0.000	
mc08.105011.J2_pythia_jetjet.recon.AOD.e344_s479_r541/	5.60E+07	1	140636	0.000	
mc08.105012.J3_pythia_jetjet.recon.AOD.e344_s479_r541/	3.280E+06	1	51795	0.000	
mc08.105013.J4_pythia_jetjet.recon.AOD.e344_s479_r541/	1.516E+05	1	36703	0.000	
mc08.105014.J5_pythia_jetjet.recon.AOD.e344_s479_r541/	5.122E+03	1	100107	0.020	
mc08.105015.J6_pythia_jetjet.recon.AOD.e344_s479_r541/	1.119E+02	1	11150	0.100	

x affected by event duplication bug

Full Datasets II

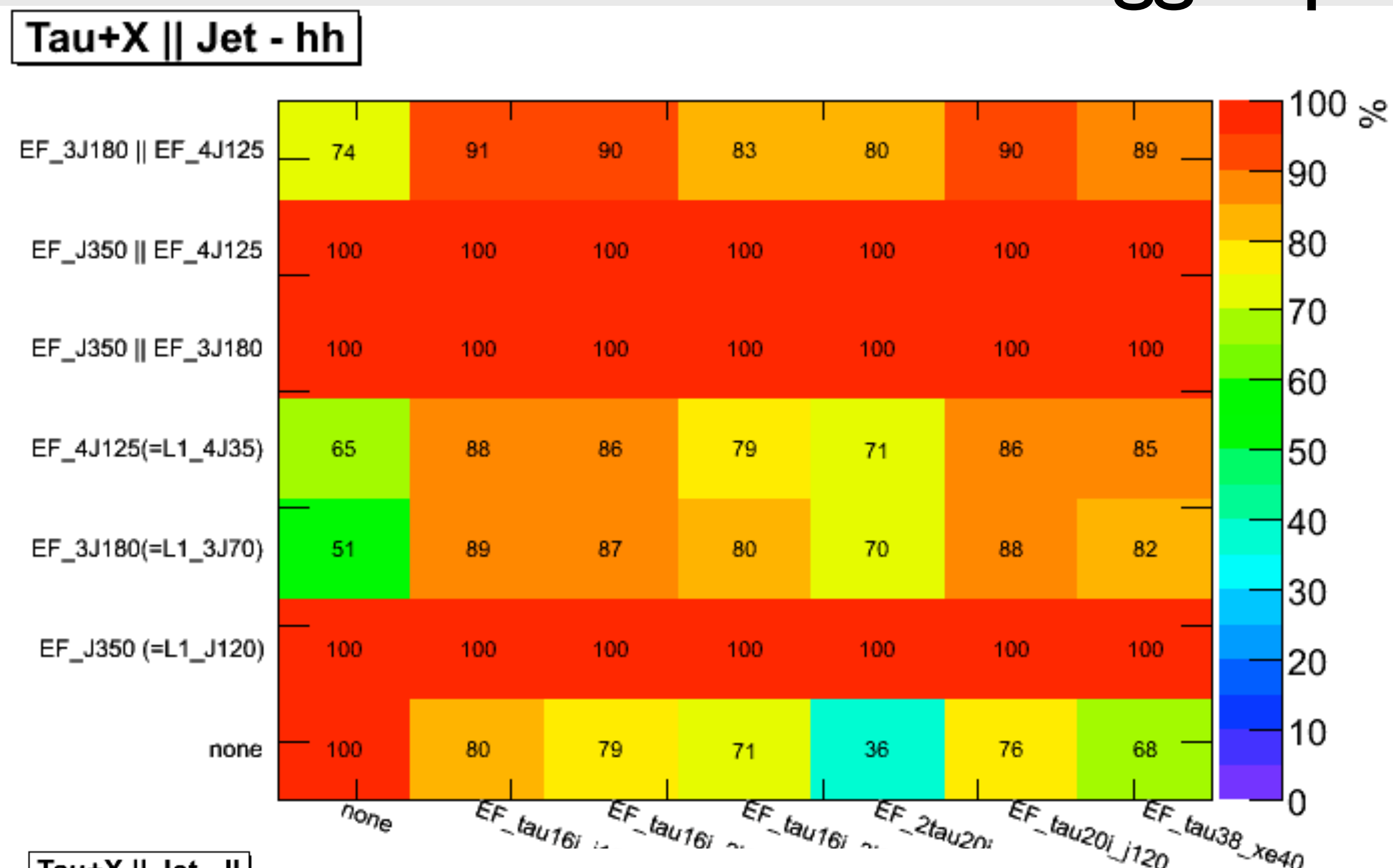
Dataset	CS [pb]	k-factor (NNLO)	N events	int Lumi	
W->munu (Alpgen):					
mc08.107690.AlpgenJimmyWmunuNp0_pt20.recon.AOD.e368_s462_r563	10125.7	1.22	295038	0.024	x
mc08.107691.AlpgenJimmyWmunuNp1_pt20.recon.AOD.e368_s462_r563	2155.53	1.22	141002	0.054	x
mc08.107692.AlpgenJimmyWmunuNp2_pt20.recon.AOD.e368_s462_r563	682.54	1.22	551997	0.663	x
mc08.107693.AlpgenJimmyWmunuNp3_pt20.recon.AOD.e368_s462_r563	203.85	1.22	15993	0.064	
mc08.107694.AlpgenJimmyWmunuNp4_pt20.recon.AOD.e368_s462_r563	57.01	1.22	11900	0.171	
mc08.107695.AlpgenJimmyWmunuNp5_pt20.recon.AOD.e368_s462_r563	17.59	1.22	3500	0.163	
W->enu (Alpgen):					
mc08.107680.AlpgenJimmyWenuNp0_pt20.recon.AOD.e368_s462_r563	10184.75	1.22	430037	0.035	x
mc08.107681.AlpgenJimmyWenuNp1_pt20.recon.AOD.e368_s462_r563	2112.45	1.22	60247	0.023	x
mc08.107682.AlpgenJimmyWenuNp2_pt20.recon.AOD.e368_s462_r563	676.07	1.22	101838	0.123	x
mc08.107683.AlpgenJimmyWenuNp3_pt20.recon.AOD.e368_s462_r563	205.26	1.22	44811	0.179	x
mc08.107684.AlpgenJimmyWenuNp4_pt20.recon.AOD.e368_s462_r563	57.45	1.22	11969	0.171	x
mc08.107685.AlpgenJimmyWenuNp5_pt20.recon.AOD.e368_s462_r563	17.86	1.22	3250	0.149	
Z->mumu (Alpgen):					
mc08.107660.AlpgenJimmyZmumuNp0_pt20.recon.AOD.e376_s462_r563	895.27	1.22	122177	0.112	x
mc08.107661.AlpgenJimmyZmumuNp1_pt20.recon.AOD.e376_s462_r563	198.59	1.22	60973	0.252	x
mc08.107662.AlpgenJimmyZmumuNp2_pt20.recon.AOD.e376_s462_r563	63.49	1.22	102605	1.325	x
mc08.107663.AlpgenJimmyZmumuNp3_pt20.recon.AOD.e376_s462_r563	18.7	1.22	62720	2.749	x
mc08.107664.AlpgenJimmyZmumuNp4_pt20.recon.AOD.e376_s462_r563	4.99	1.22	11470	1.884	x
mc08.107665.AlpgenJimmyZmumuNp5_pt20.recon.AOD.e376_s462_r563	1.37	1.22	5442	3.256	
Z->ee (Alpgen):					
mc08.107650.AlpgenJimmyZeeNp0_pt20.recon.AOD.e376_s462_r563	898.44	1.22	235721	0.215	
mc08.107651.AlpgenJimmyZeeNp1_pt20.recon.AOD.e376_s462_r563	197.8	1.22	57532	0.238	x
mc08.107652.AlpgenJimmyZeeNp2_pt20.recon.AOD.e376_s462_r563	62.26	1.22	203943	2.685	x
mc08.107653.AlpgenJimmyZeeNp3_pt20.recon.AOD.e376_s462_r563	18.76	1.22	62912	2.749	
mc08.107654.AlpgenJimmyZeeNp4_pt20.recon.AOD.e376_s462_r563	4.97	1.22	18000	2.969	x
mc08.107655.AlpgenJimmyZeeNp5_pt20.recon.AOD.e376_s462_r563	1.43	1.22	5230	2.998	
Z->nunu(Alpgen + ATLFAST II)					
mc08.107710.AlpgenJimmyZnunuNp0_pt20_filt1jet.recon.AOD.e376_a68	5254	1.22	52009	0.811	
mc08.107711.AlpgenJimmyZnunuNp1_pt20_filt1jet.recon.AOD.e376_a68	1224.1	1.22	56680	0.079	
mc08.107712.AlpgenJimmyZnunuNp2_pt20_filt1jet.recon.AOD.e376_a68	413.6	1.22	68030	0.171	
mc08.107713.AlpgenJimmyZnunuNp3_pt20_filt1jet.recon.AOD.e376_a68	121	1.22	2010	0.015	
mc08.107714.AlpgenJimmyZnunuNp4_pt20_filt1jet.recon.AOD.e376_a68	34	1.22	75761	1.883	
mc08.107715.AlpgenJimmyZnunuNp5_pt20_filt1jet.recon.AOD.e376_a68	9.6	1.22	20648	1.781	

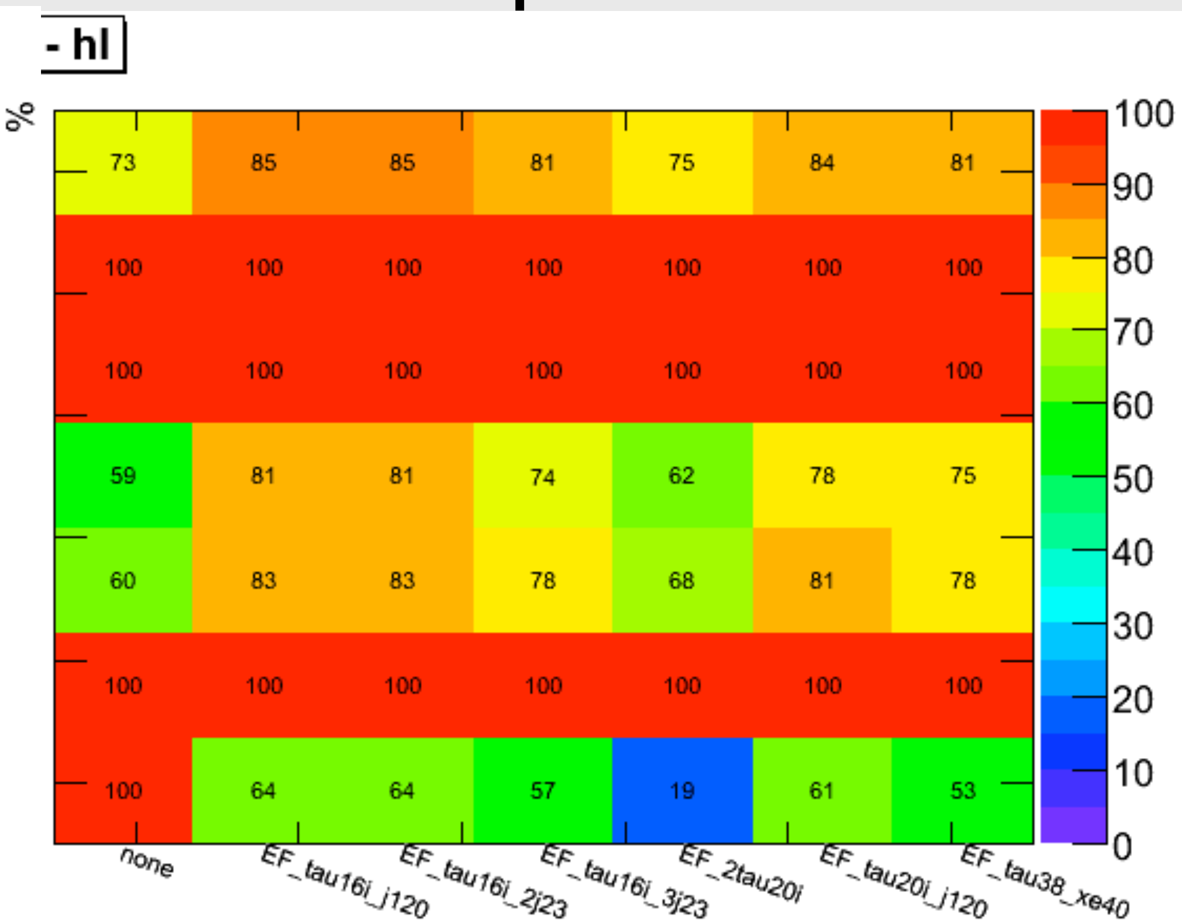
x affected by event duplication bug

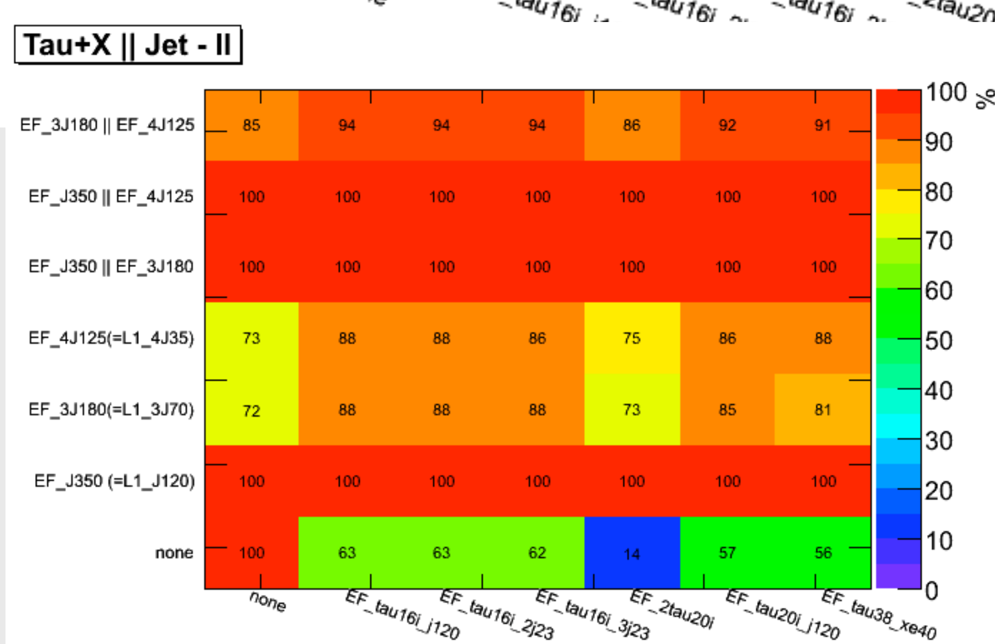
<u>ATLFAST samples:</u>
- HEC fully working
  -> ignored ev. with objects in that region
- no trigger information
  -> estimate by reconstructed objects

backup: Without MET Trigger

- can trigger on jet and/or MET with ~100% efficiency w.r.t. offline selected events; tau trigger possible backup?







Invariant Mass Spectrum: 200pb^{-1}