A. Nikitenko Imperial College, UK / ITEP Moscow

Tau Trigger optimization in CMS. Calorimeter.

Algorithms and performance of Lvl-1 and Lvl-2 Calorimeter Tau triggers for Higgs channels with τ-jets in the final state :

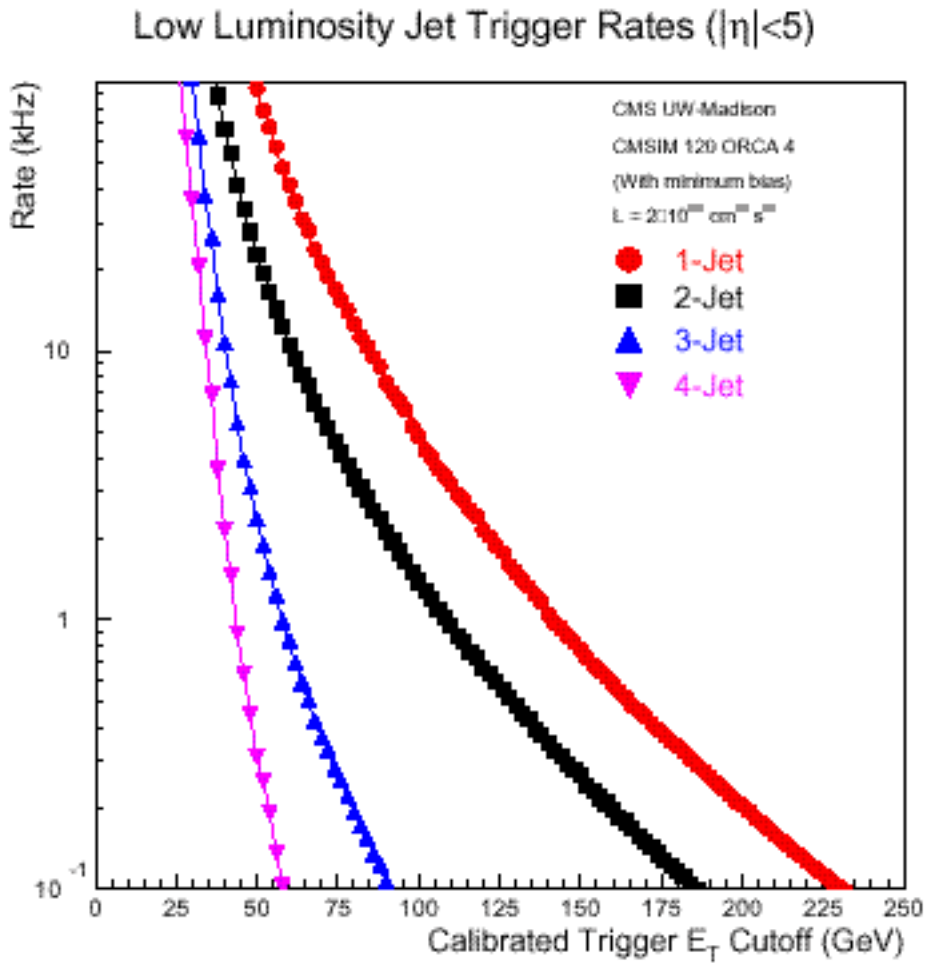
SUSY A^0/H^0 -> 2 τ ->2 τ-jet, e/μ + τ-jet,

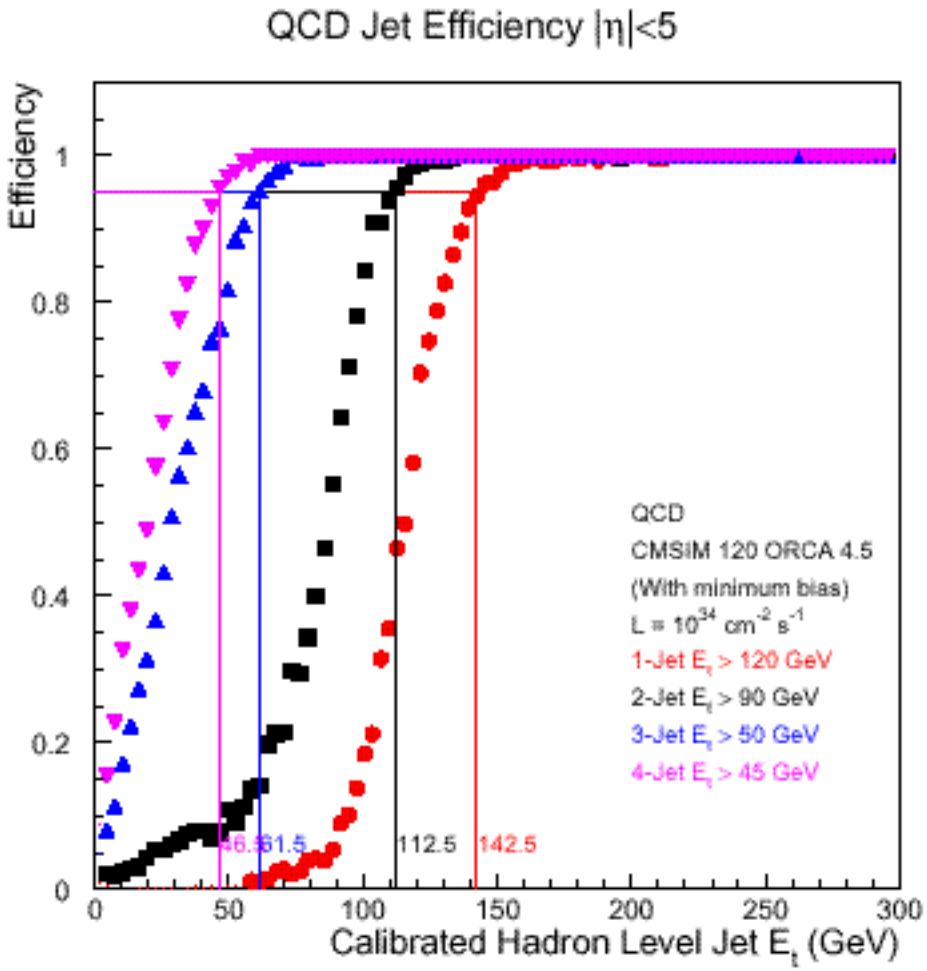
SUSY H^+->$\tau\nu$ -> τ-jet, $M_{A/H}$ > 200 GeV

WORKSHOP ON b / tau PHYSICS AT THE LHC, HIP, Helsinki, 3.05-1.06.2002

What was a problem for taus from Higgs with a "normal" Lvl-1 Jet triggers ?

Updated Jet Rates and Efficiencies

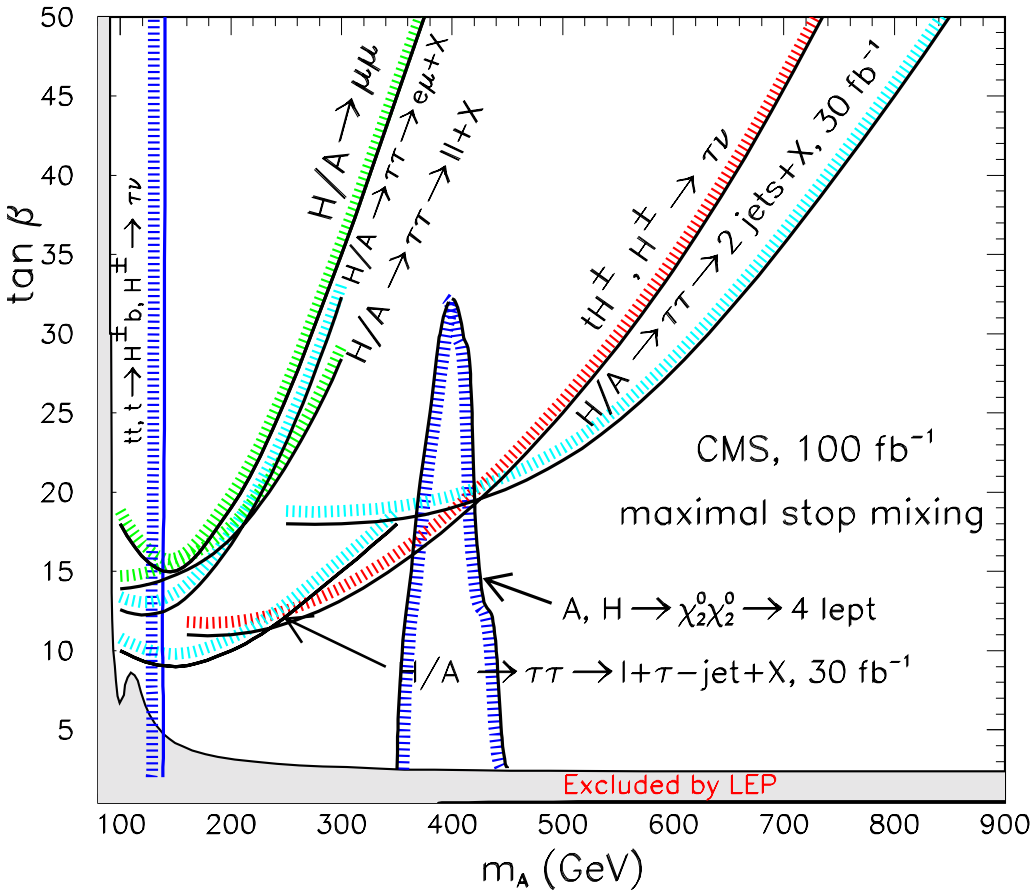


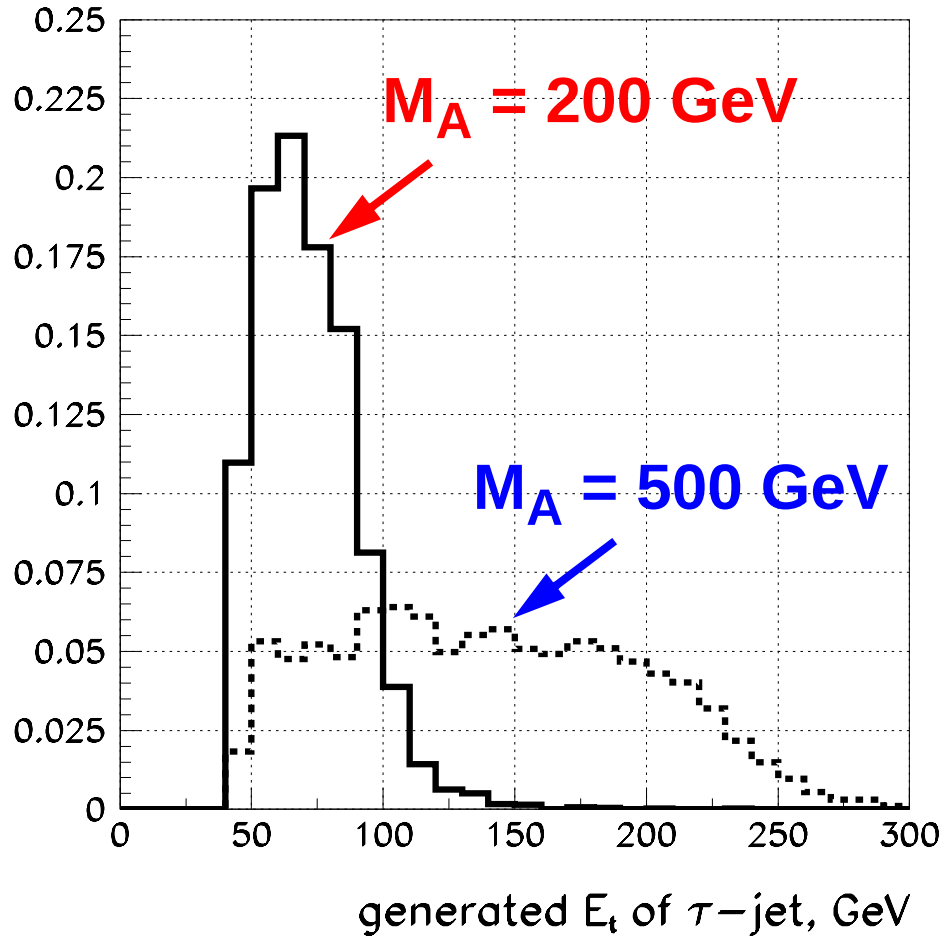


Single jet at 120 GeV: 2.2 kHz and 95% efficiency point = 143 GeV

Dijet at 90 GeV: 2.1 kHz and 95% efficiency point = 113 GeV

Lvl-1 Jet and di-Jet thresholds at ~ 2 kHz for $L=2\times10^{33}cm^{-2}s^{-1}$ ~ 120 and 90 GeV are too high for SUSY $A^0/H^0 \to 2\tau$-jet of M_H = 200 - 300 GeV



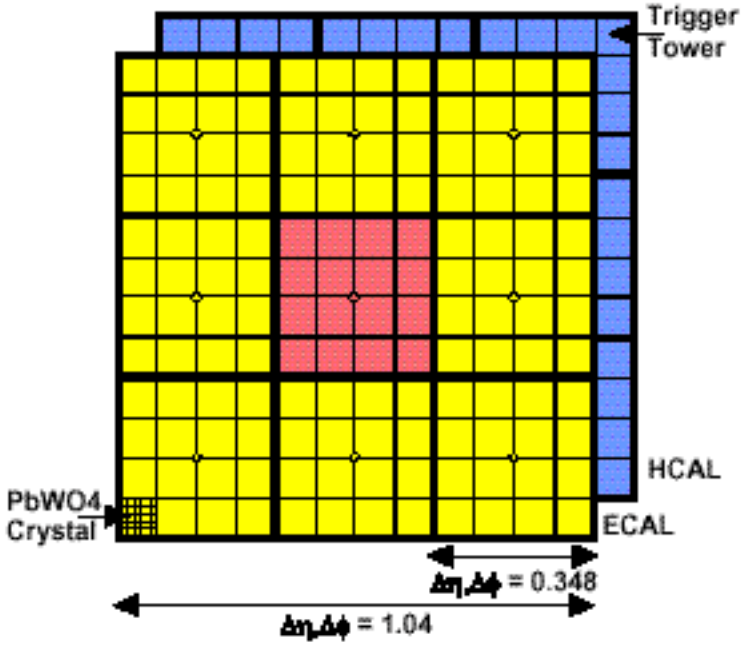


Lvl-1 Tau trigger has been adopted in CMS to enhance efficiency of low E_T τ -jets , therefore to increase trigger efficiency for $A^0/H^0 \to 2\tau$ channels with hadronic tau decays for not too heavy MSSM Higgses

First version of Lvl-1 Tau algorithm in new CMS Jet trigger design (March 2000)

Jet Algorithm

Input from E/HCAL: Programmable 8-bit nonlinear scale converted to 10-bit linear scale for sums to obtain jet E_T



Active towers counted after a trigger tower level programmable threshold. τ-veto bit formed by requiring that there be no more than 2 active ECAL or HCAL towers in a 4x4 region

Jet or τ E_T

- 12x12 trigger tower E_T sums in 4x4 region steps with central region > others

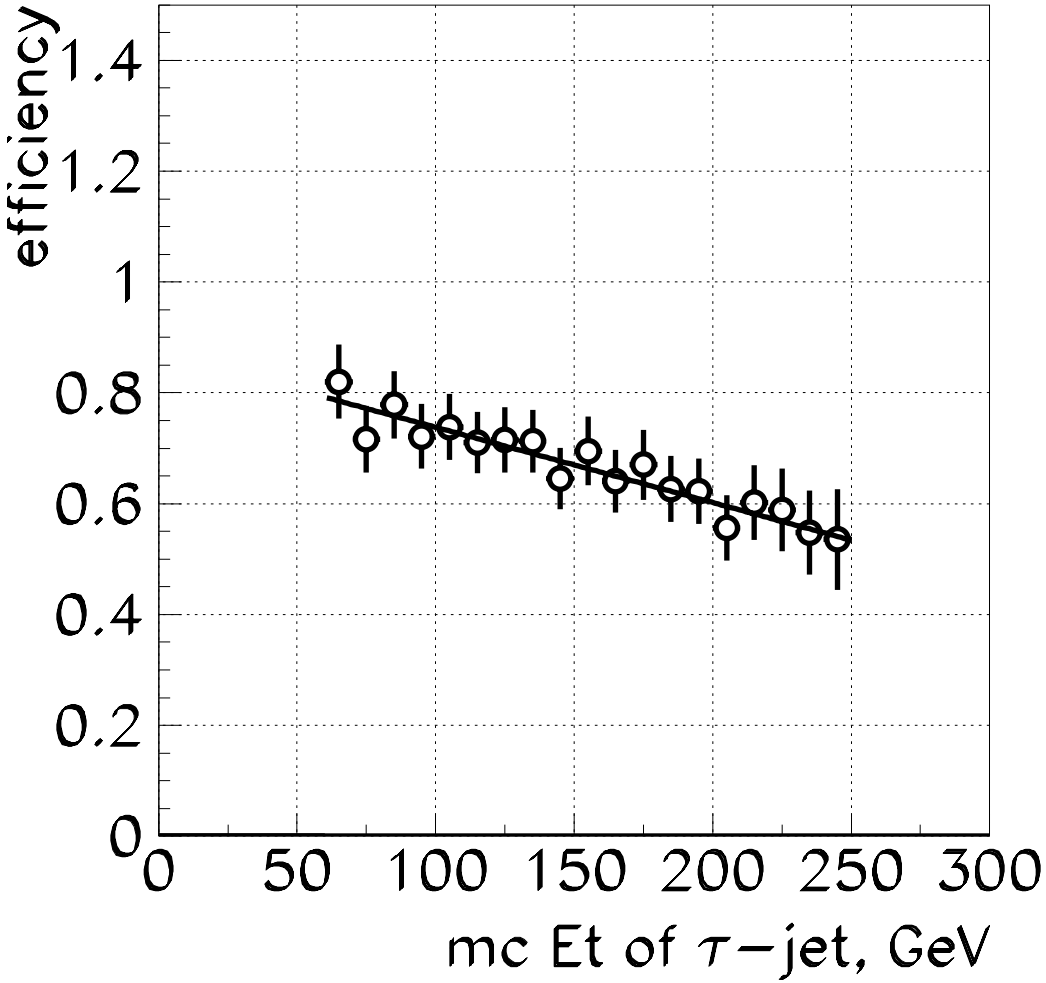
τ algorithm

- redefine jet as τ-jet if none of the nine 4x4 region τ-veto bits are on

Output

- top 4 τ-jets and top 4 jets in central rapidity, and top four jets in forward rapidity

Efficiency for A/H->2τ->2J , M=200 GeV was increased by factor ~ 2 (from 0.30 to 0.64) in comparizon with old CMS Jet triggers at the same rate ~ 4-5 kHz, BUT efficiency of

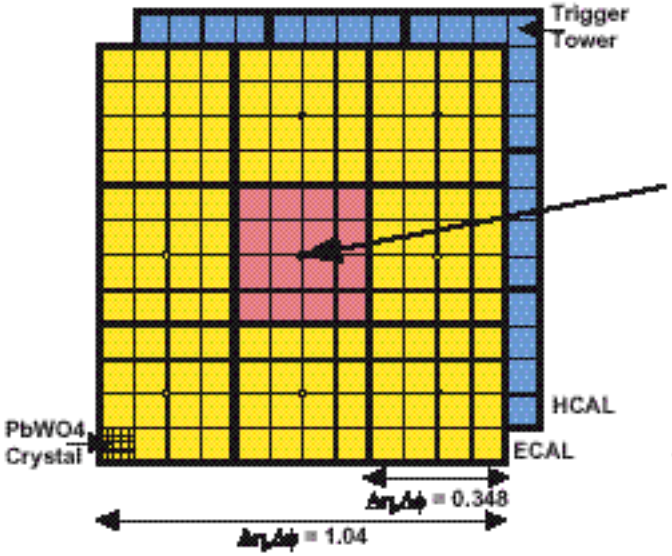


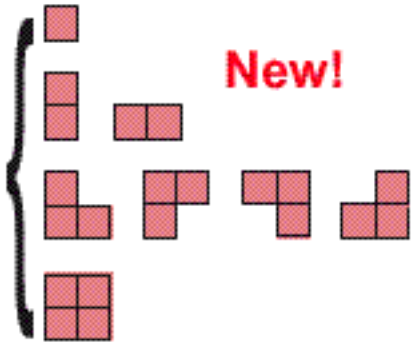
Lvl-1 Tau id went down with increasing of E_T tau jet

The current version of Lvl-1 Tau algorithm

Jet/τ Algorithm

Input from E/HCAL: Programmable 8-bit nonlinear scale converted to 10-bit linear scale for sums to obtain jet E_T





τ-veto bit formed by requiring a single contiguous group of less than four active towers in each 4x4 region

Jet or τ E_T

- 12x12 trigger tower E_T sums in 4x4 region steps with central region > others,
- *central region above a programmable threshold (5 GeV for this study).*

τ algorithm

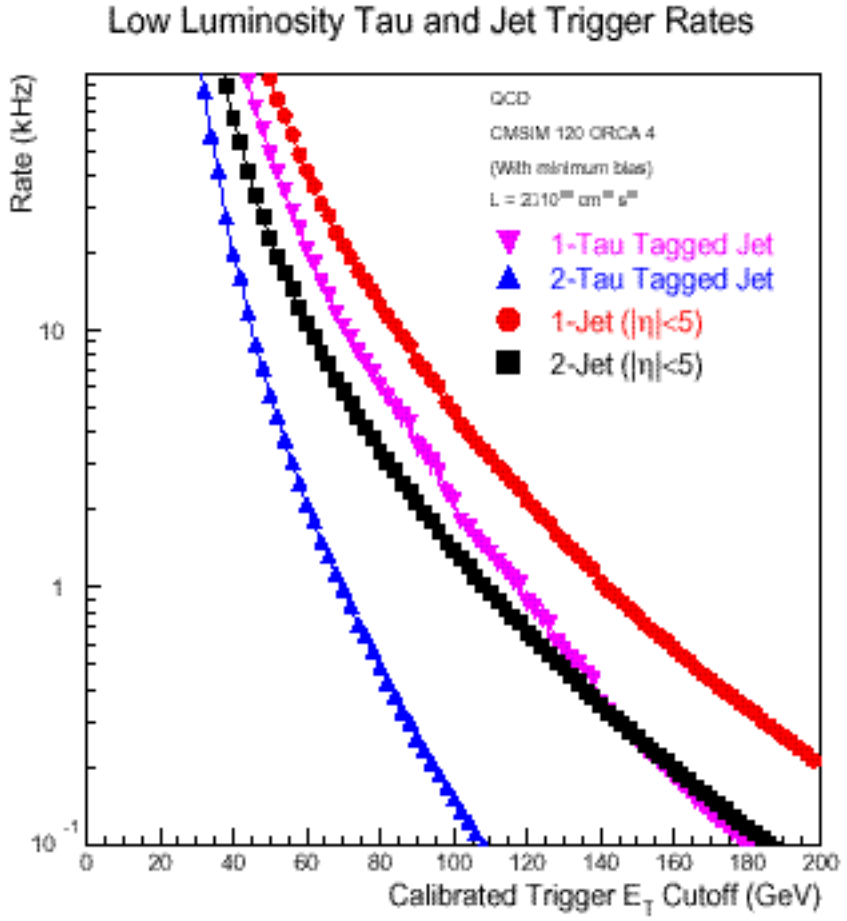
- redefine jet as τ-jet if none of the nine 4x4 region τ-veto bits are on

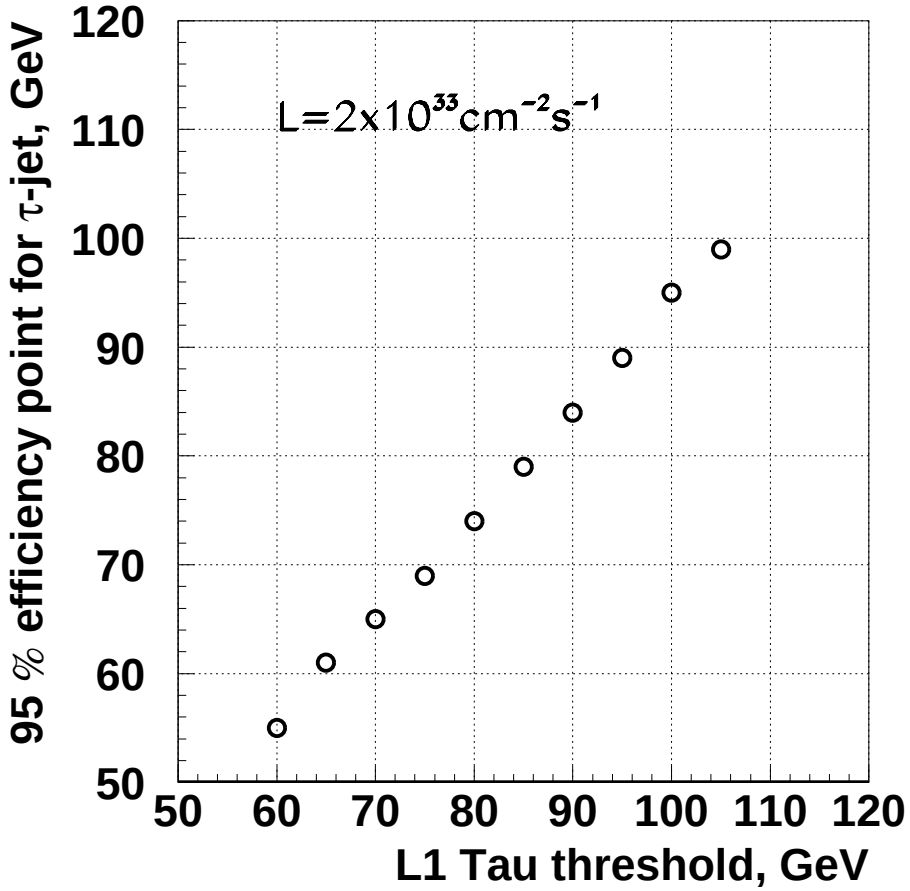
Output

- top 4 τ-jets and top 4 jets in central rapidity, and top four jets in forward rapidity

Rates Lvl-1 Jets & Taus with new Tau algo.

Updated τ Rates



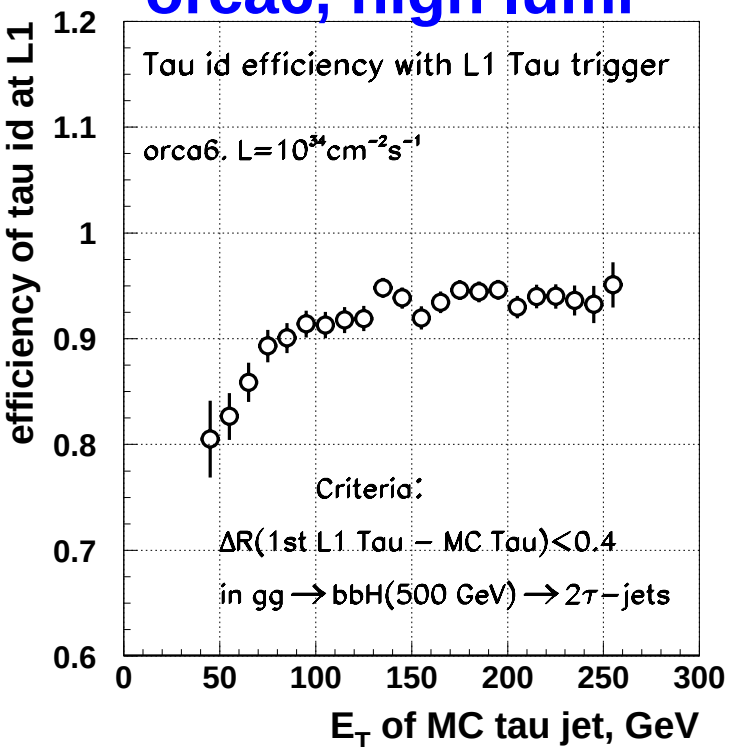


Uses data from FNAL for $\mathcal{L}=2\times10^{33}$

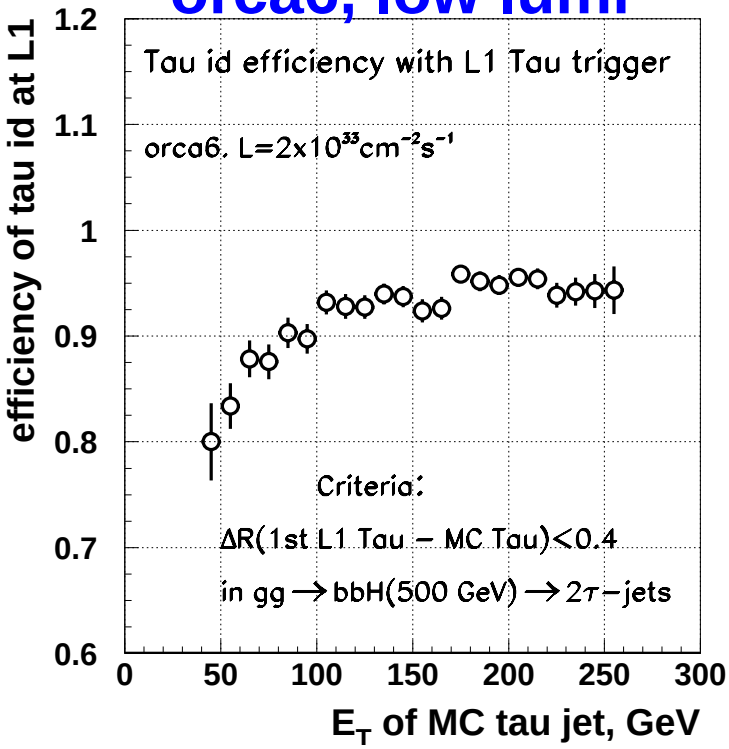
Lvl-1 Jets/Taus are calibrated on MC "generic" qcd jets.
Energy corrections depend on E_T and η of Lvl-1 Jet

L1 Tau id vs $E_T^{\tau\text{-jet}}$

orca6, high lumi

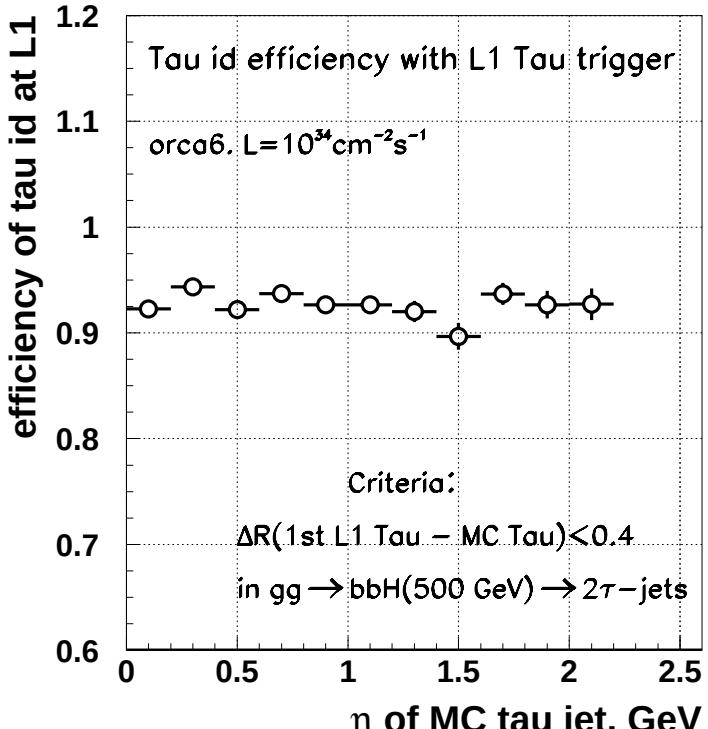


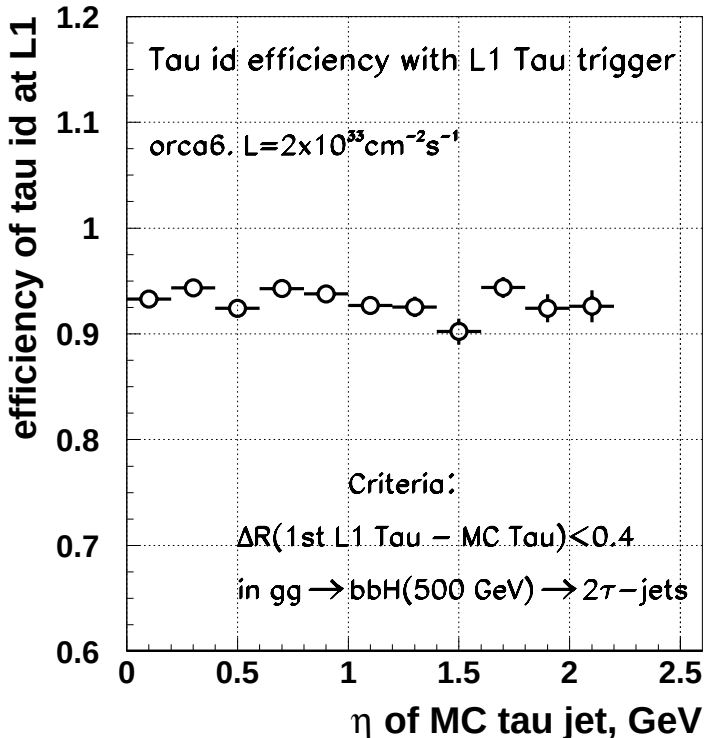
orca6, low lumi



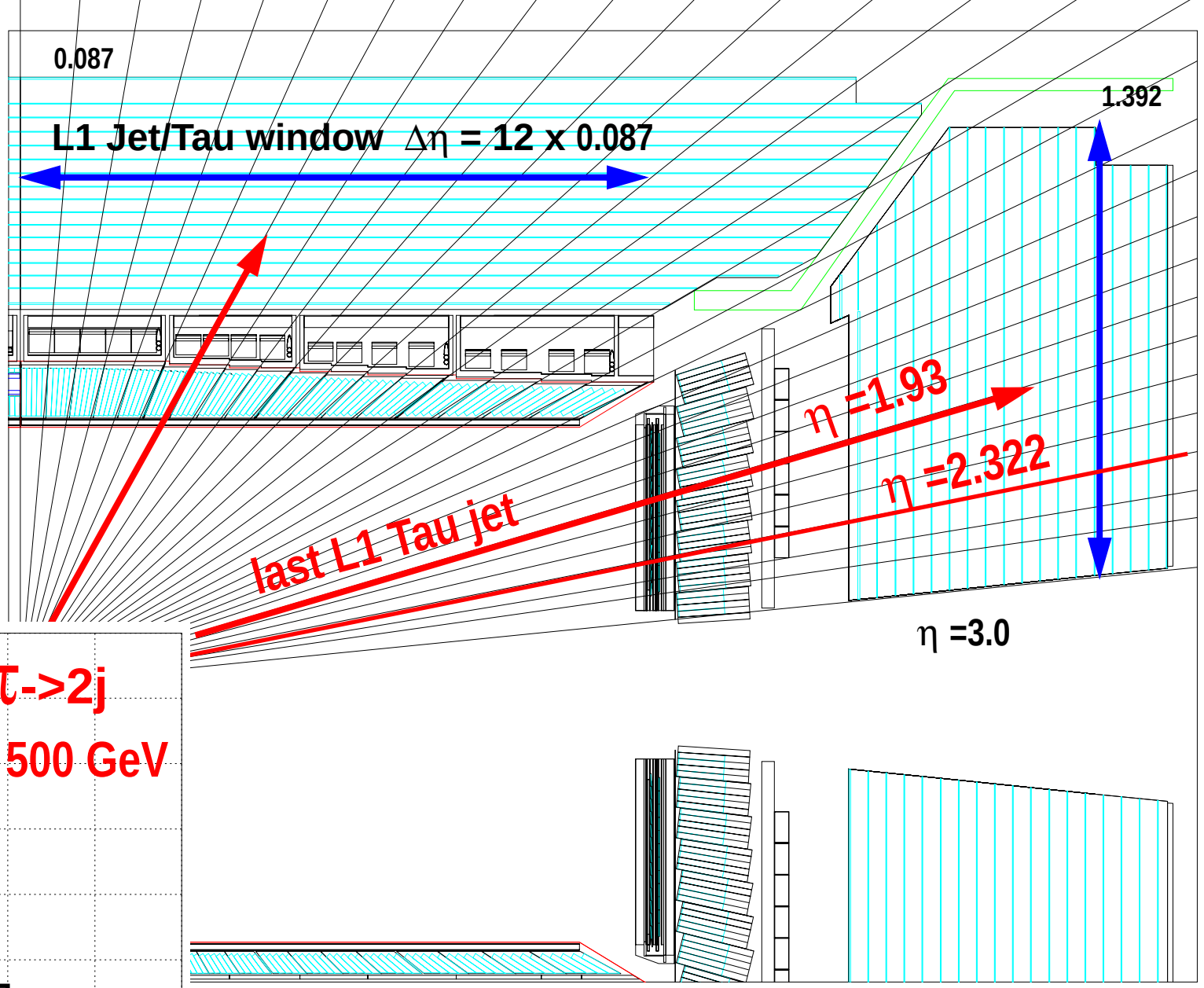
$\eta^{\tau\text{-jet}}$

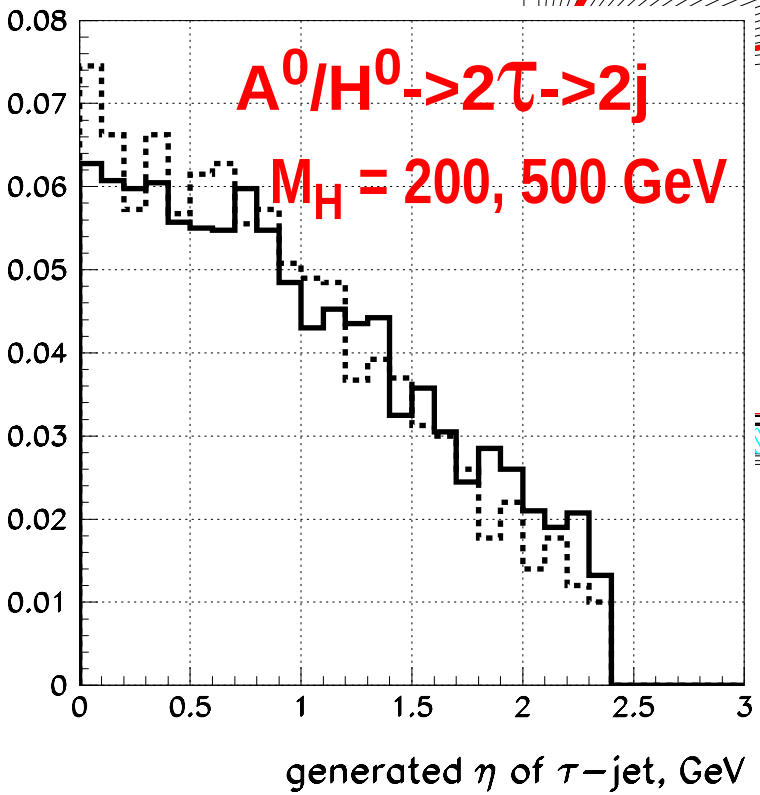
for first tau-jet in A->2τ->2j





L1 Tau trigger works up to $|\eta| < 2$,





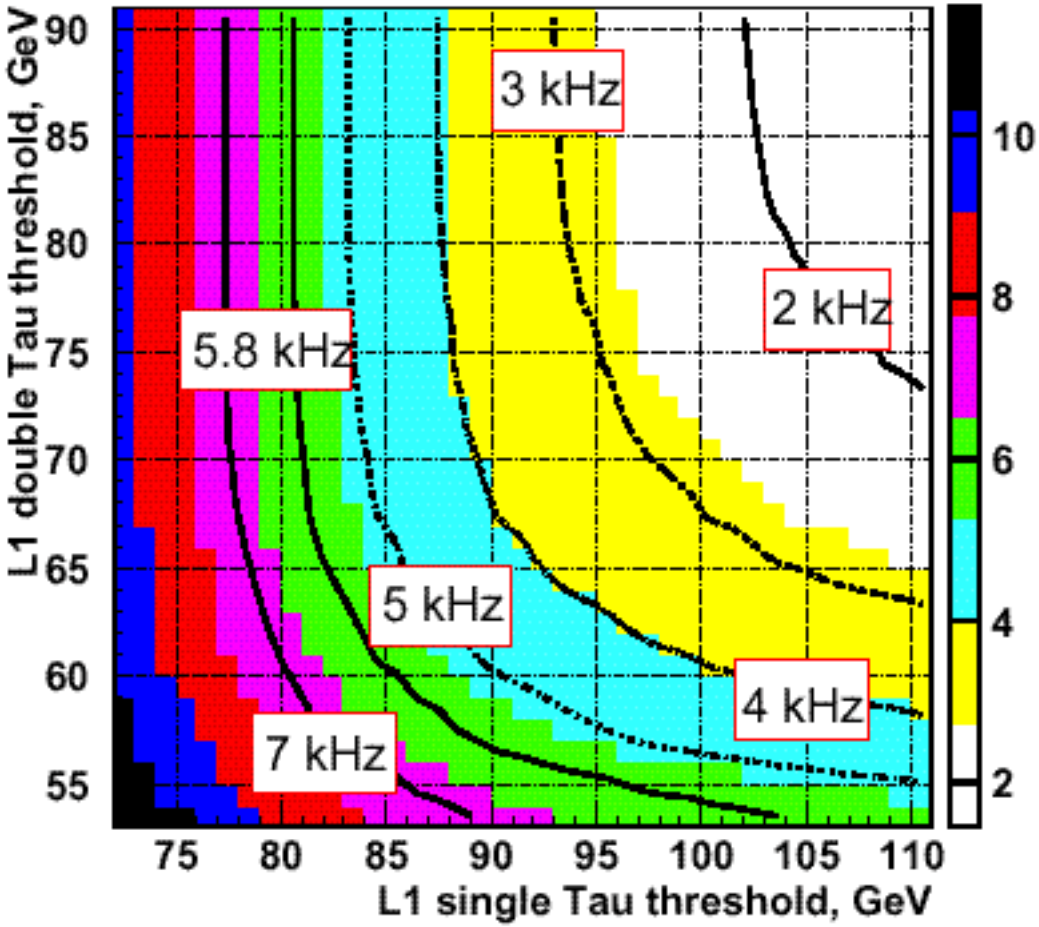
since we use tracker $|\eta| < 2.4$ for tau id at High Level Trg.

Optimization of the Lvl-1 Tau thresholds for A^0 / H^0-> 2τ -> 2jet and H^+-> τν -> jet

efficiency of tau signals at 3.0 kHz L1 rate of 1T or 2T

L1 threshold, GeV		efficiency	
1Tau	2 Tau	H->2τ-jets M=200 GeV	H^+->τ-jet M=200 GeV
105	64	(0.54) 0.75	0.79
103	65	(0.56) 0.75	0.80
100	67	(0.60) 0.76	0.82
98	69	(0.63) 0.76	0.82
95	75	(0.68) 0.75	0.83
93	80	(0.71) 0.74	0.84
92	90	(0.72) 0.72	0.84

number in parenthesis for H->2tau is efficiency for single L1 Tau trigger



A. Nikitenko, R. Kinnunen

Optimization of the Lvl-1 individual and combined triggers and thresholds for A/H->2τ->lepton+jet (I)

L1 for H->2τ->e+jet, M_H = 200 GeV

one order of triggers (Dec 2001). Olivier van der Aa

L1 trigger	Threshold GeV	efficiency*		Rate, kHz	
		individual	cumulative	individual	cumulative
e	23	0.73	0.73	3.0	3.0
T	80	0.65	0.87	6.0	9.0
e+T	17&42	0.73	0.92	2.0	10.3

let's try to change an order of triggers (Paris question in Dec 2001)

L1 trigger	Threshold GeV	efficiency*		Rate, kHz	
		individual	cumulative	individual	cumulative
e	23	0.73	0.73	3.0	3.0
e+T	17&42	0.73	0.82	2.0	4.3
T	80	0.65	0.91	6.0	10.3

- *e or (e&T) is better than e or T, since brings less rate for about the same efficiency.*
- *T > 80 GeV looks optimistic now, most probably be > 100 GeV*

* efficiency relative to pythia preselected events p_t^e > 14 GeV, $p_t^{\tau\text{-jet}}$ > 30 GeV, $|\eta^{\tau,e}|$ <2.4,

Optimization of the Lvl-1 individual and combined triggers and thresholds for A/H->2τ->lepton+jet (II)

L1 for H->2τ->μ+jet, M_H = 200 GeV

Marcin Konecki

the same conclusion as for e+J can be made for μ+J from tables below :

L1 trigger	Threshold GeV	efficiency*		Rate, kHz	
		individual	cumulative	individual	cumulative
μ	16	0.46	0.46	2.5	2.5
T	80	0.27	0.50	6.0	8.5
μ+T	10&50	0.22	0.52	0.45	8.7

L1 trigger	Threshold GeV	efficiency*		Rate, kHz	
		individual	cumulative	individual	cumulative
μ	16	0.46	0.46	2.5	2.5
μ+T	10&50	0.22	0.50	0.45	2.8
T	80	0.27	0.52	6.0	8.7

- ***μ or (μ & T) is better than μ or T, since brings less rate for about the same efficiency.***

* efficiency relative to all H->ττ->μ+τ-jet events, no any preselection.

After Lvl-1 we use at High Level Trigger tau jet selection with :

- ***ECAL - narrow cluster from τ jet (this talk)***
- ***pixels and regional tracking - isolation (G. Bagliesi talk)***

we tried several variables to quantify a ***local energy deposit in the ECAL***

- collimation parameter P_C defined as

$$P_C = \sum_{\Delta R_i < 0.13} E_{ti} / \sum_{\Delta R_i < r_{cut}} E_{ti}$$

- isolation parameter P_{isol} defined as

P_{isol} found to be the best

$$P_{isol} = \sum_{\Delta R_i < r_{cut}} E_{ti} - \sum_{\Delta R_i < 0.13} E_{ti}$$

- electromagnetic jet radius R_{em}

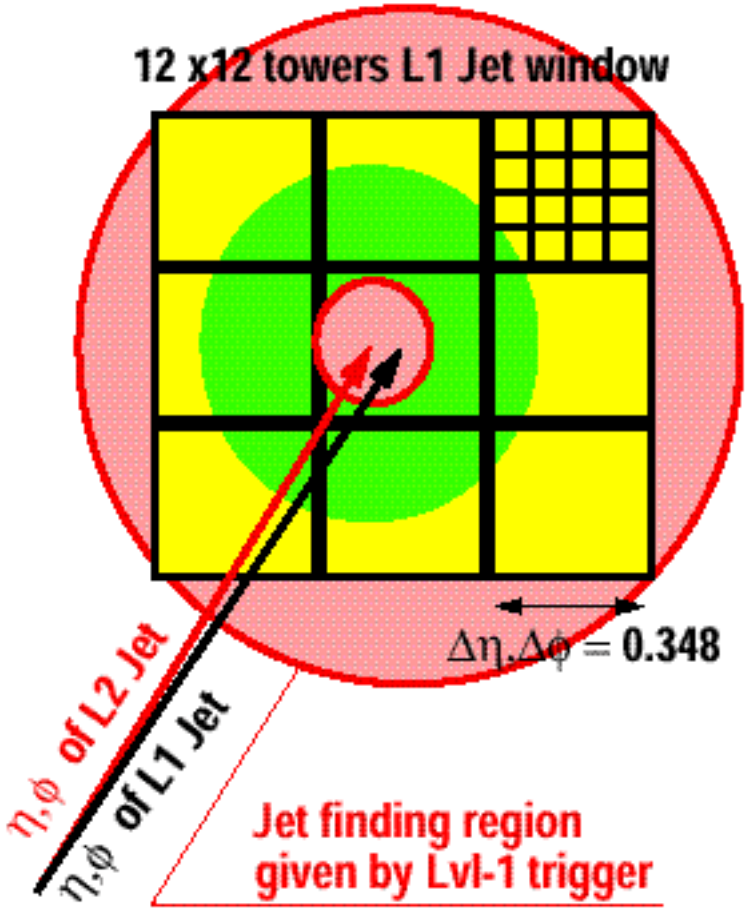
$$R_{em} = \sum_{\Delta R_i < 0.13} \Delta R_i \times E_{ti} / \sum_{\Delta R_i < r_{cut}} E_{ti}$$

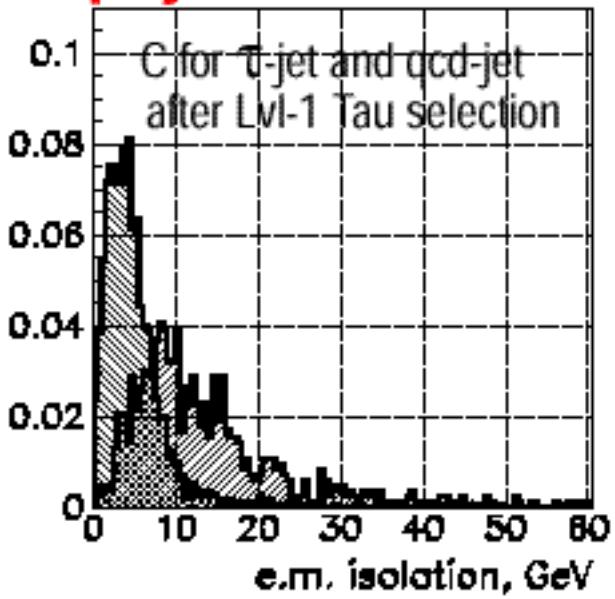
Tau id at High Level Trigger using ECAL data

Tau identification at Lvl-2

Narrowness of τ jets :

- reconstruct jet in region given by Lvl-1 trigger
- use $C=\Sigma E^{em}_T(0.13 < R < 0.40)$
- accept jet as τ if $C < C^{max}$



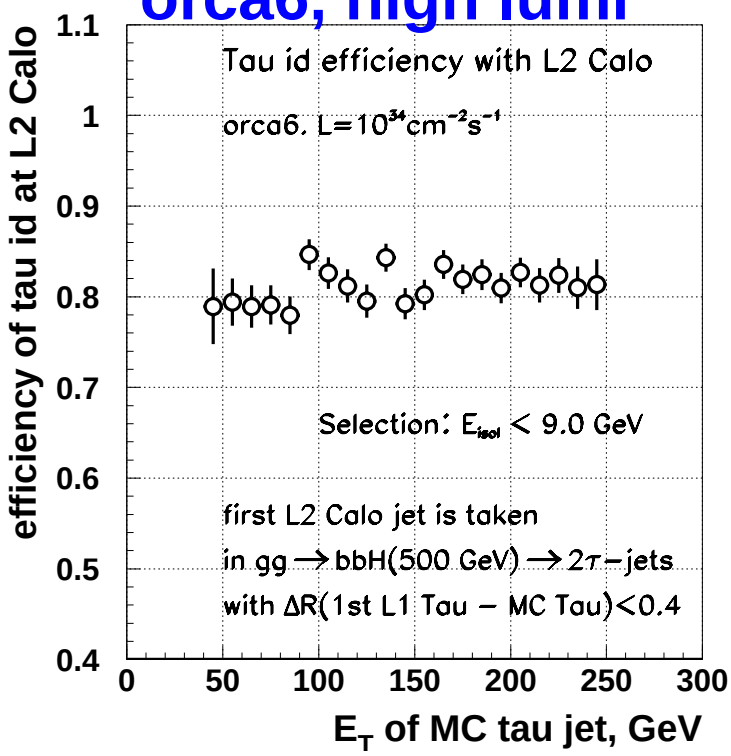


L2 CaloTau id vs $E_T^{\tau\text{-jet}}$

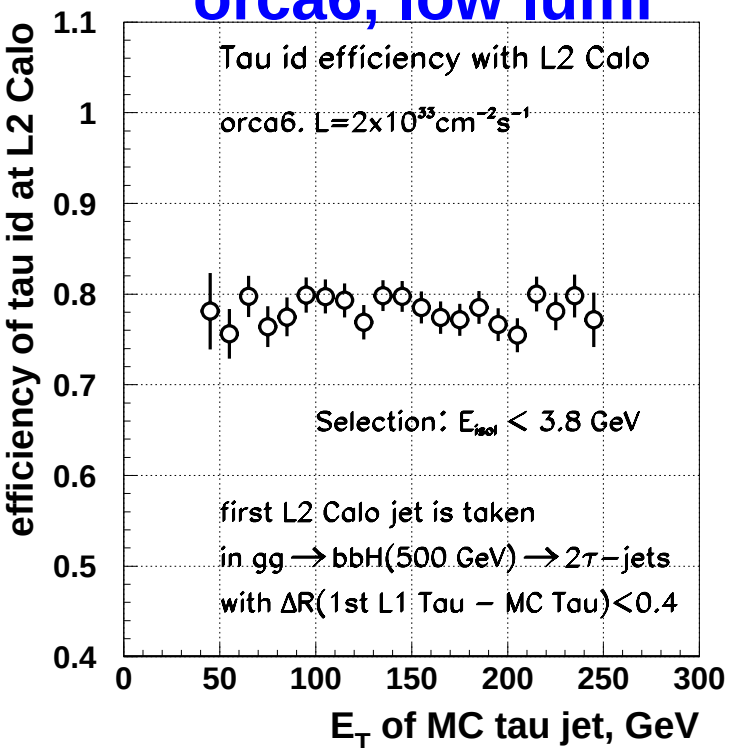
$\eta^{\tau\text{-jet}}$

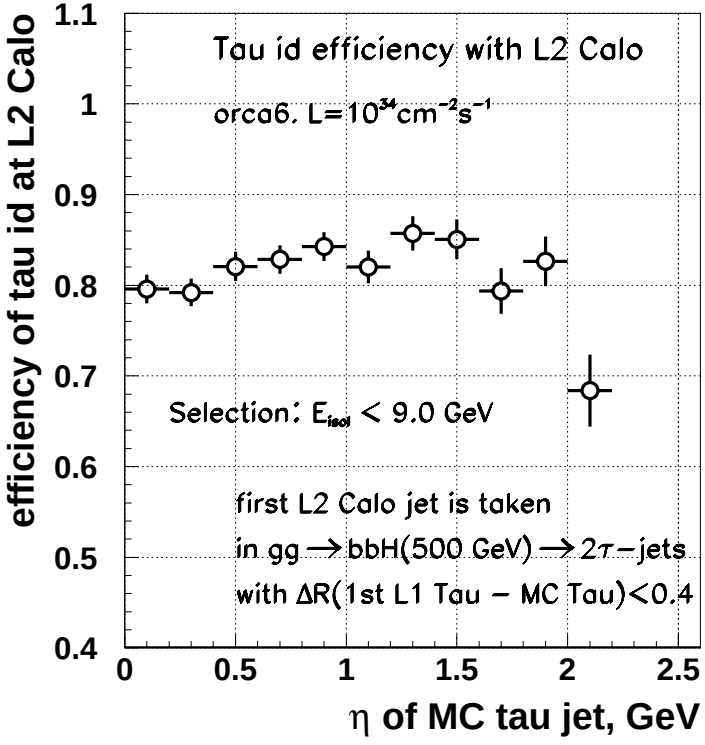
for first tau-jet in A->2τ->2j

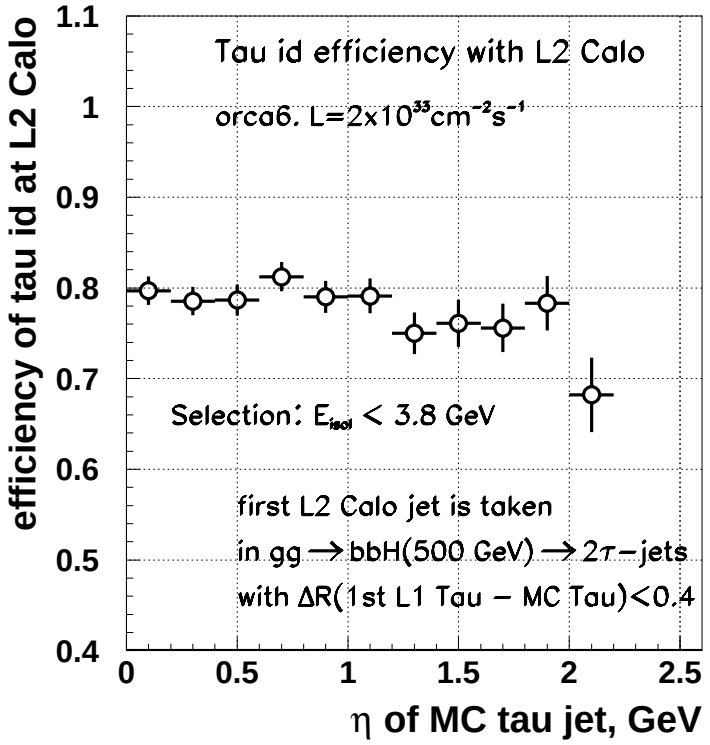
orca6, high lumi



orca6, low lumi

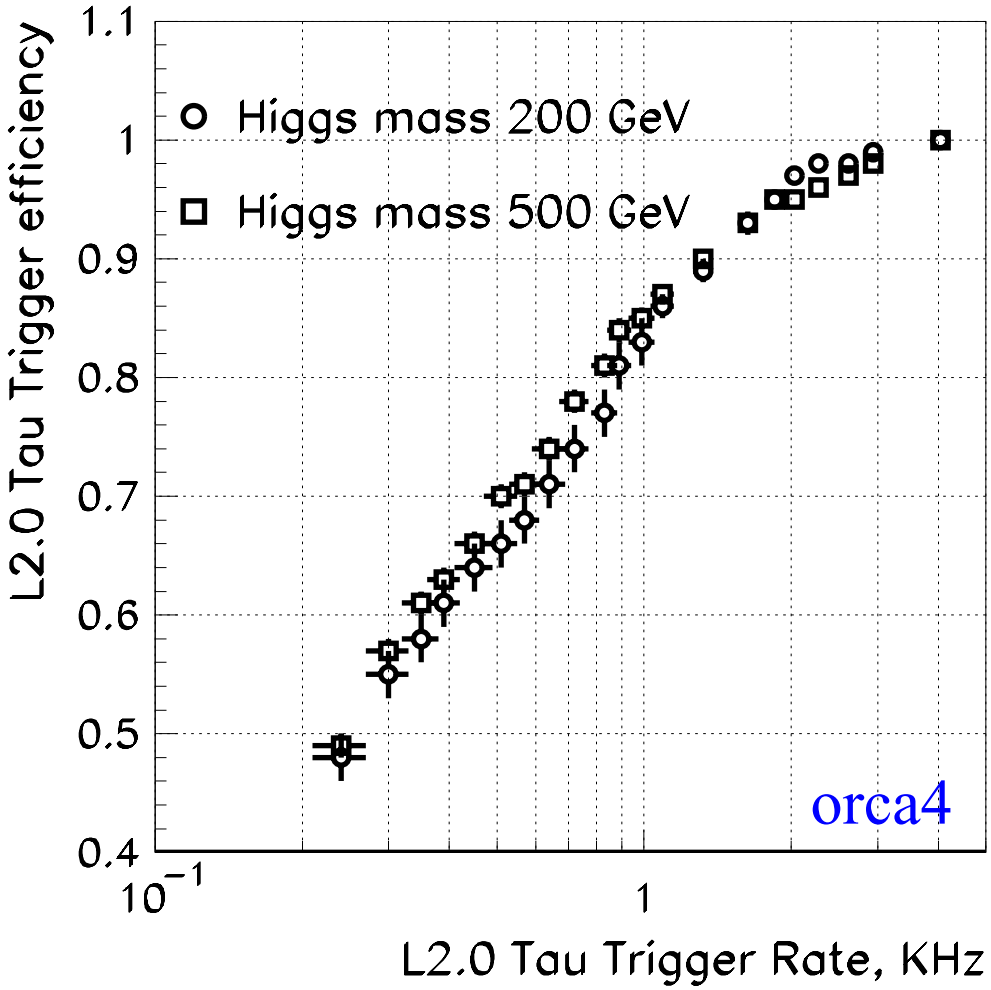




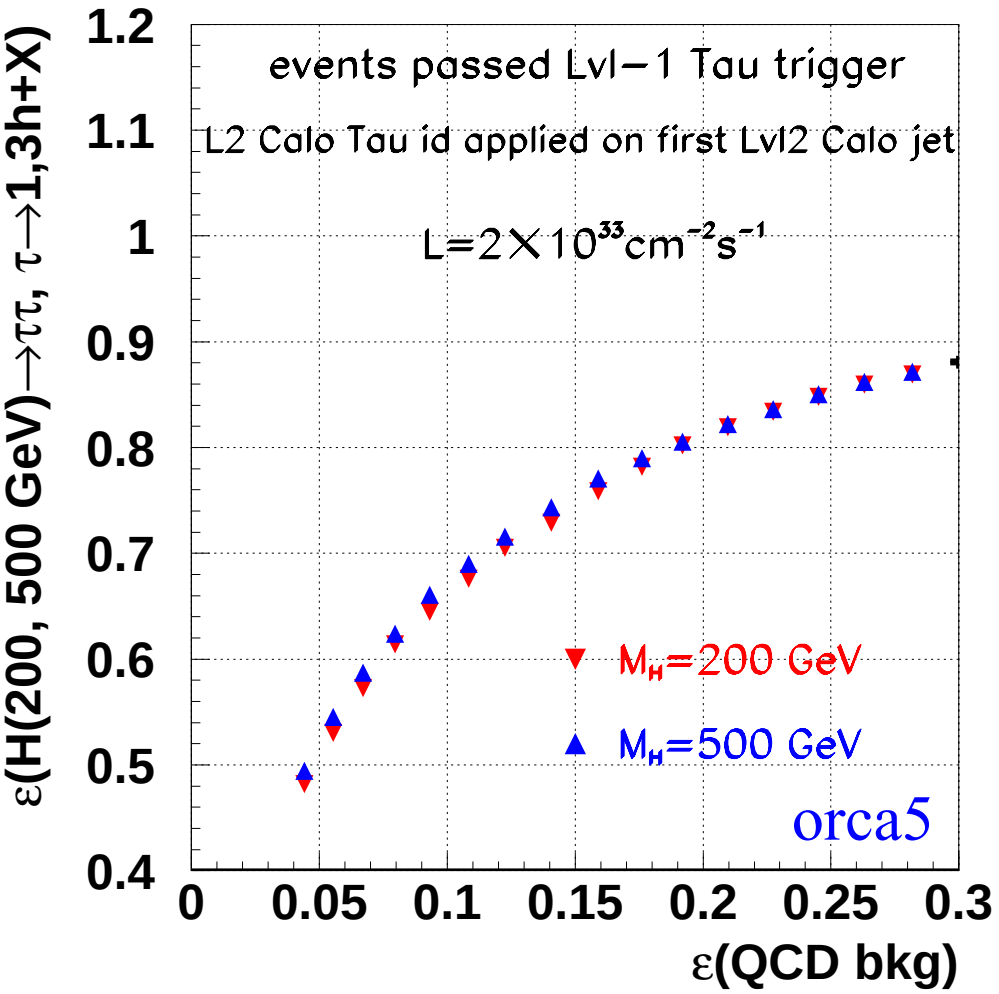


QCD rate supression v.s. A/H->2tau-jet efficiency with Lvl-2 Tau Calo trigger for events passed Lvl-1 1T or 2T trigger :

$L=10^{34}cm^{-2}s^{-1}$

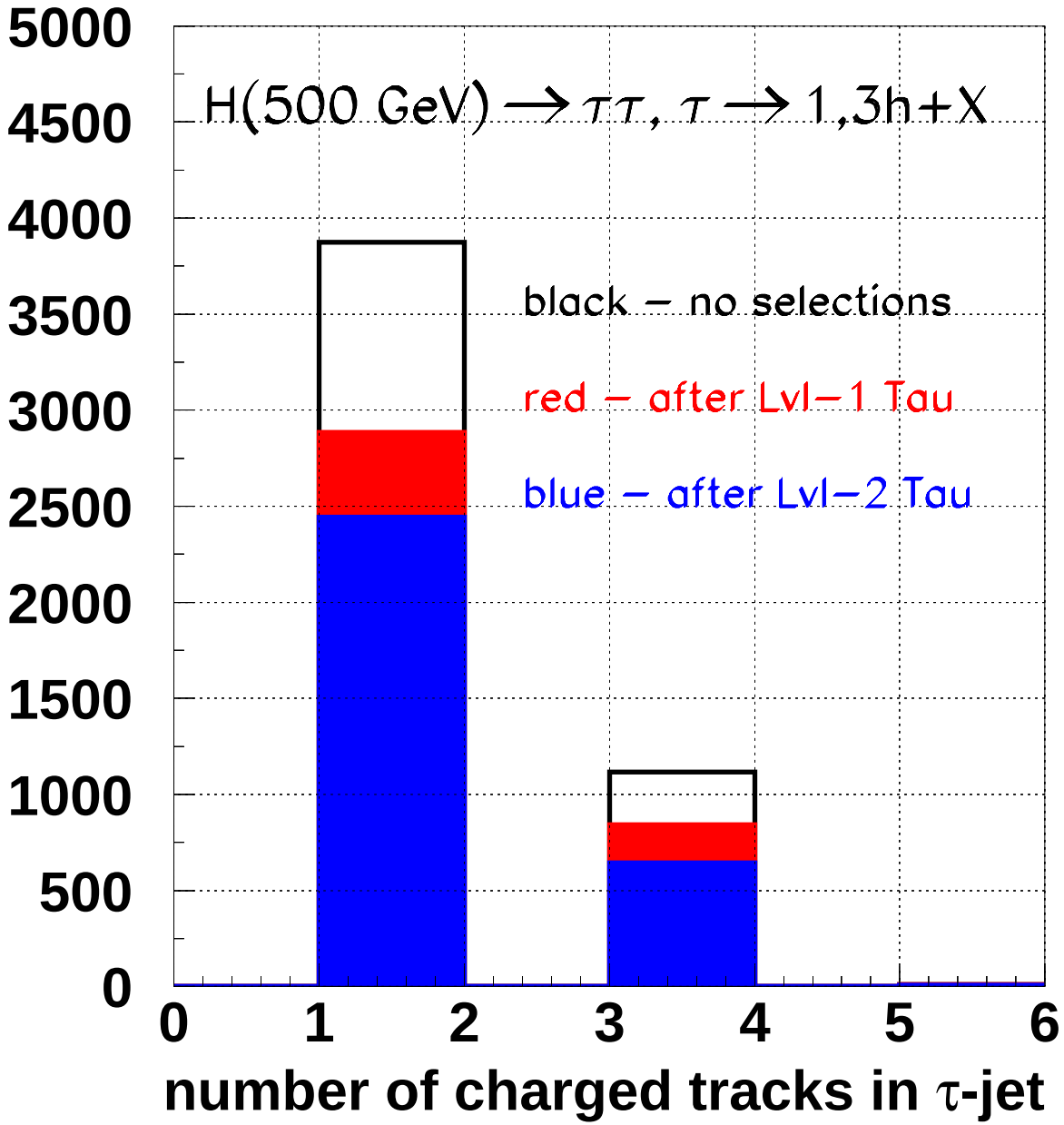


$L=2x10^{33}cm^{-2}s^{-1}$

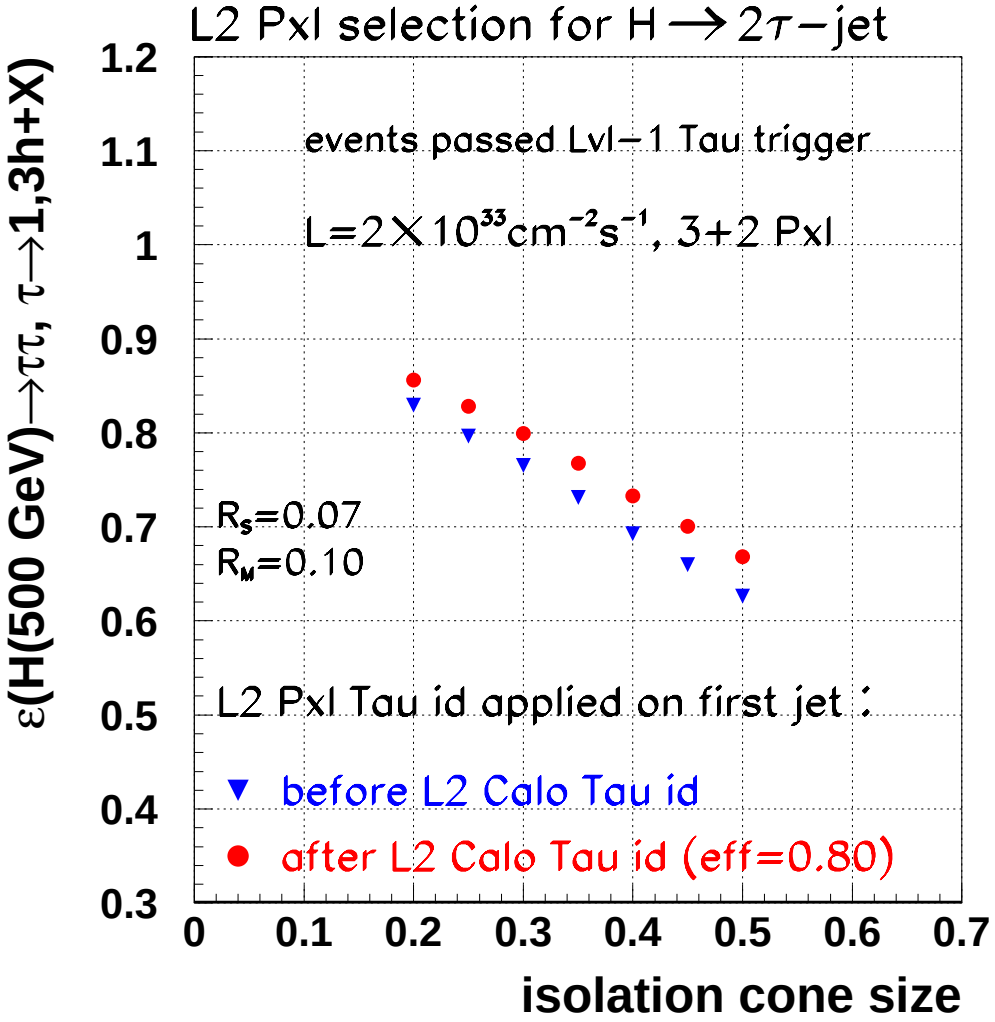


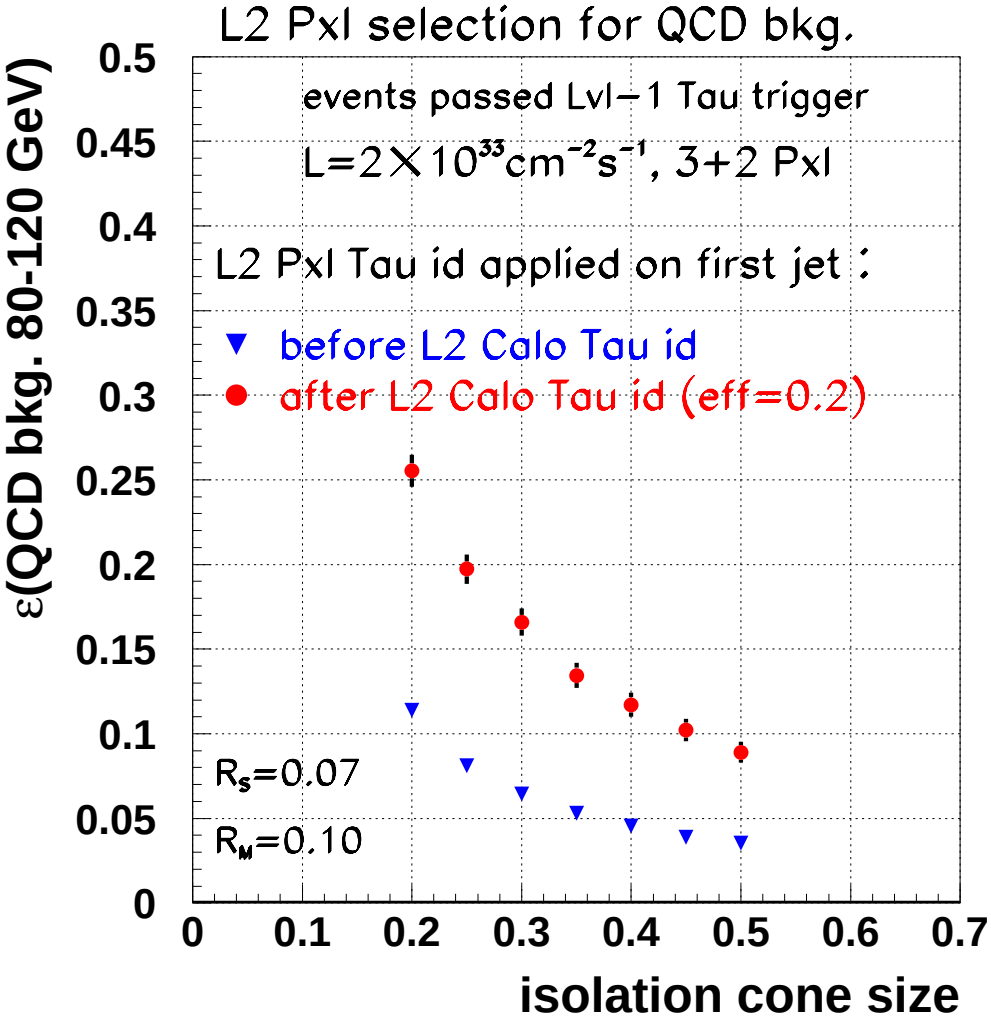
Present working point for $L=2x10^{33}cm^{-2}s^{-1}$ is $\varepsilon(qcd) = 0.2$, $\varepsilon(H) = 0.80$

Lvl-1 Tau and Lvl-2 Calo Tau triggers don't supress 3 prong taus (τ->3h+X) realtive to 1 prong taus (τ-> 1h +X)



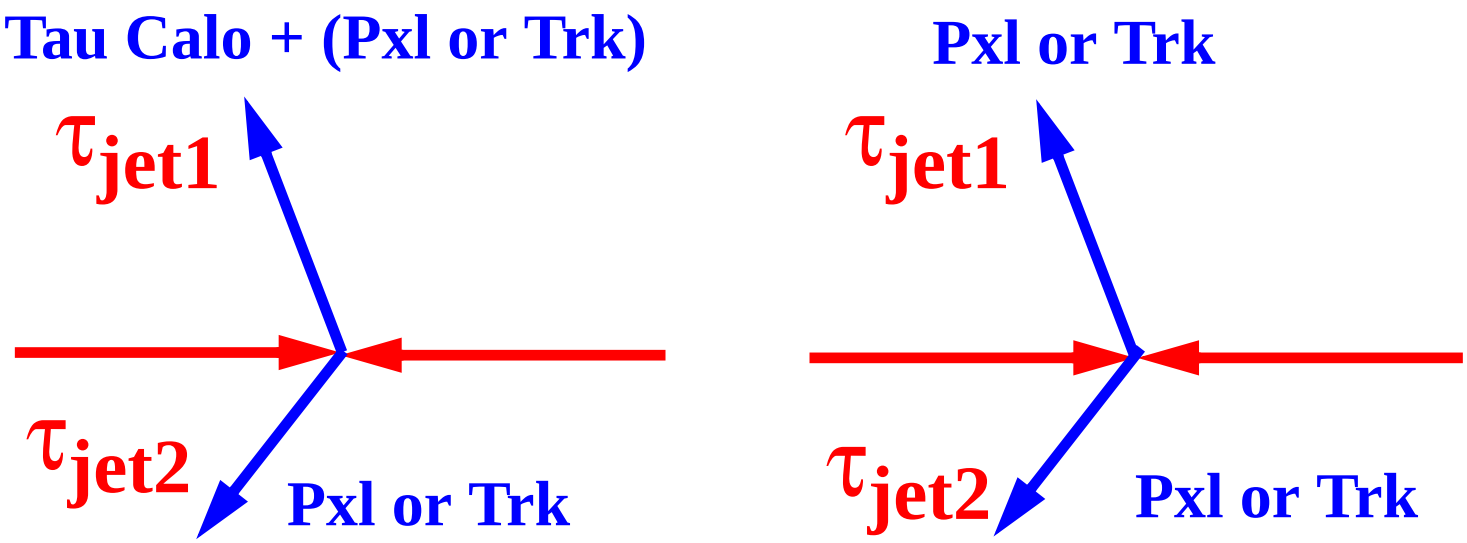
Effect of L2 Calo Tau preselection on efficiency of pixel isolation at HLT for QCD and A/H->2tau-jet :





L2 Calo Tau trigger affects qcd jet selections with Pxl (Trk) isolation

We consider possibility to use L2 Tau Calo trigger for $A^0/H^0 \rightarrow 2\tau$-jet channel. The following HLT paths are under study :



where Pxl - isolation with pixel lines, Trk - isolation with tracks

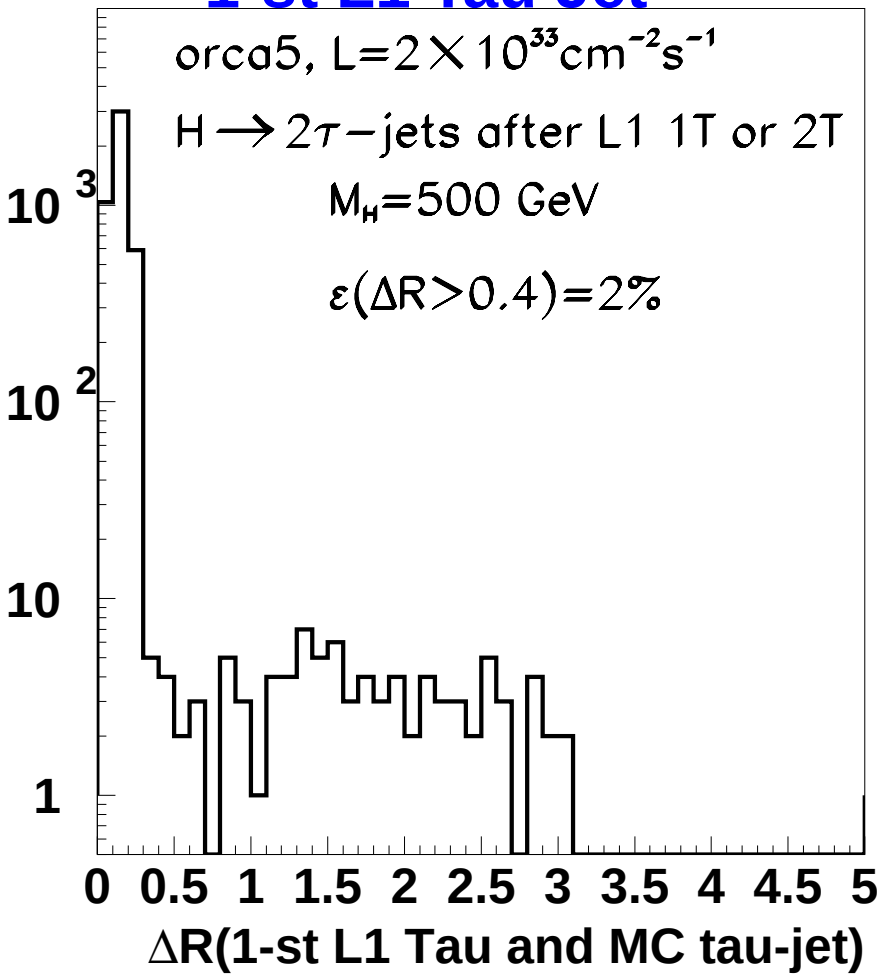
In these paths we use L1 Taus as a pointers for two L2 Calo Jets to be analysed at HLT .

What is “efficiency” and “purity” of L1 Tau Jets ?

....

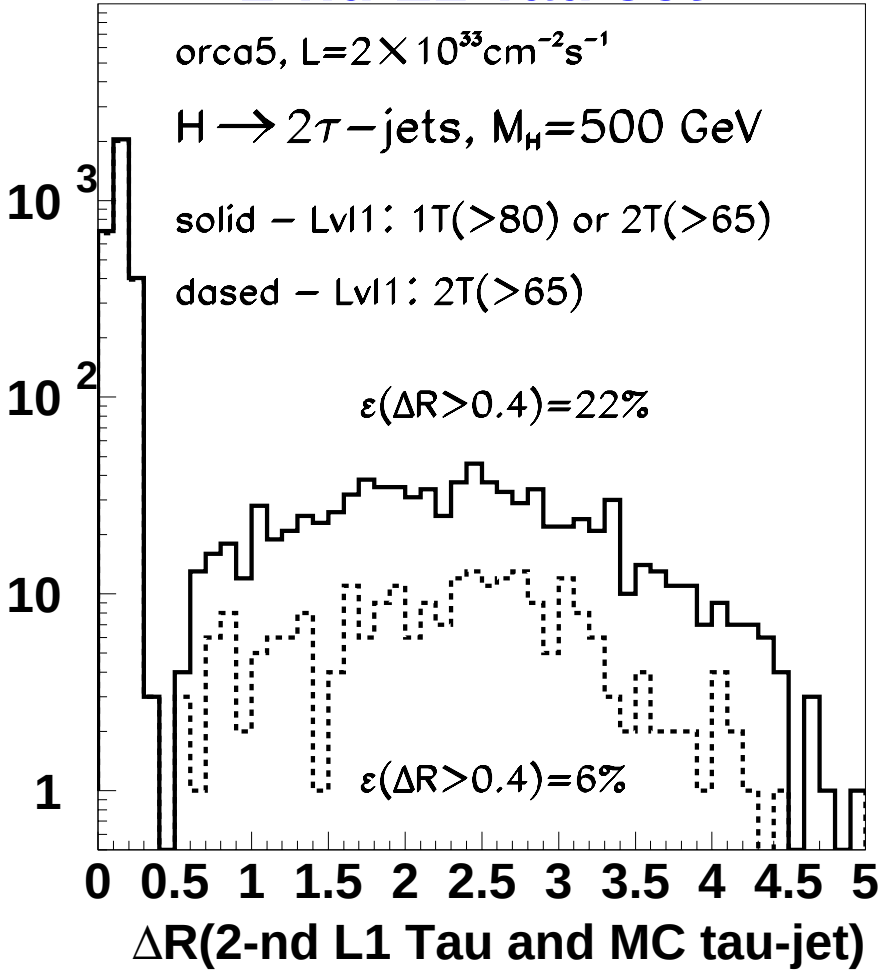
Problem with "purity" of 2-nd L2 Tau jet

matching of MC tau with 1-st L1 Tau Jet



good matching !

matching of MC tau with 2-nd L1 Tau Jet

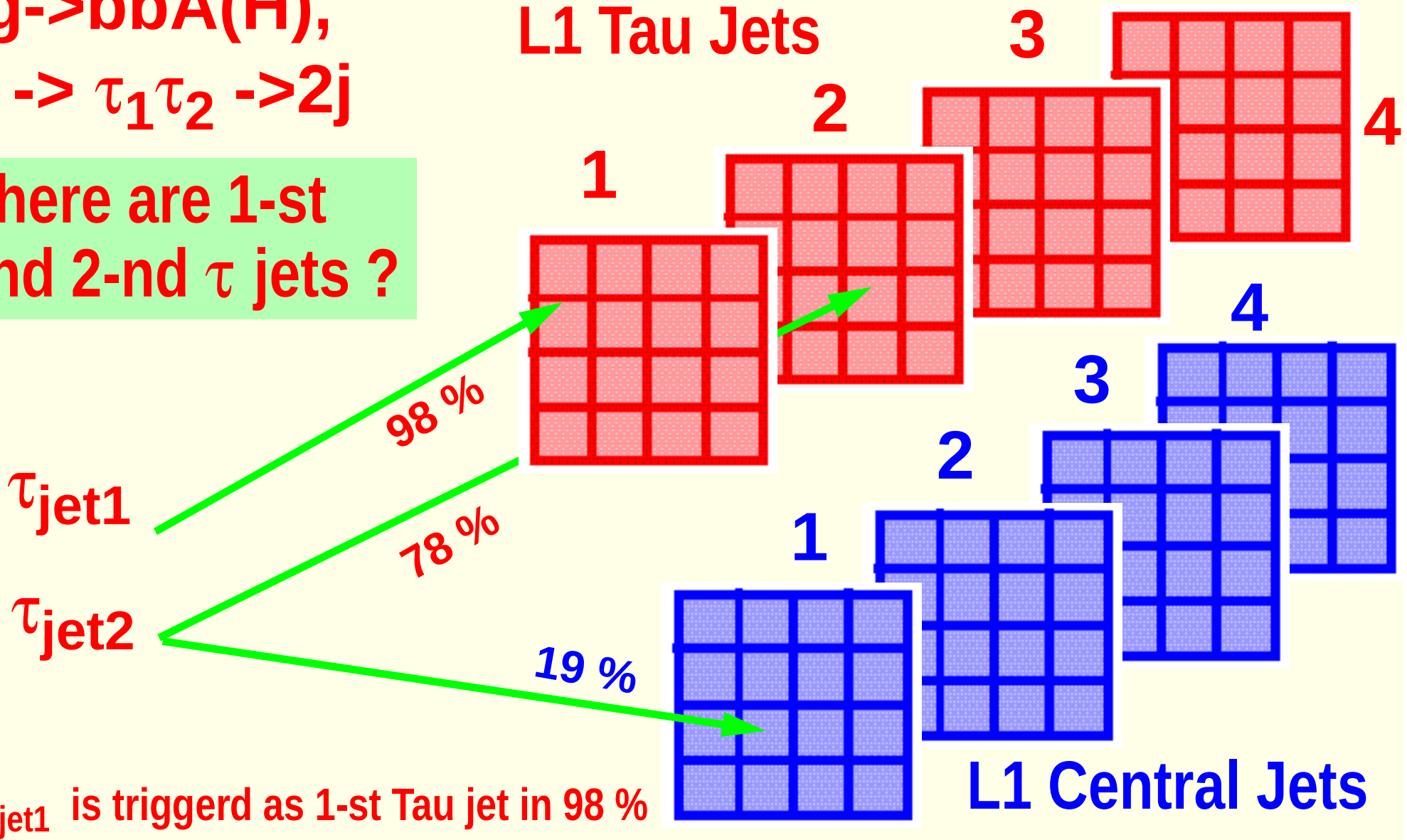


bad matching. it spoiles efficiency at Lvl-2 Pxl

How to search for 2-nd tau ?

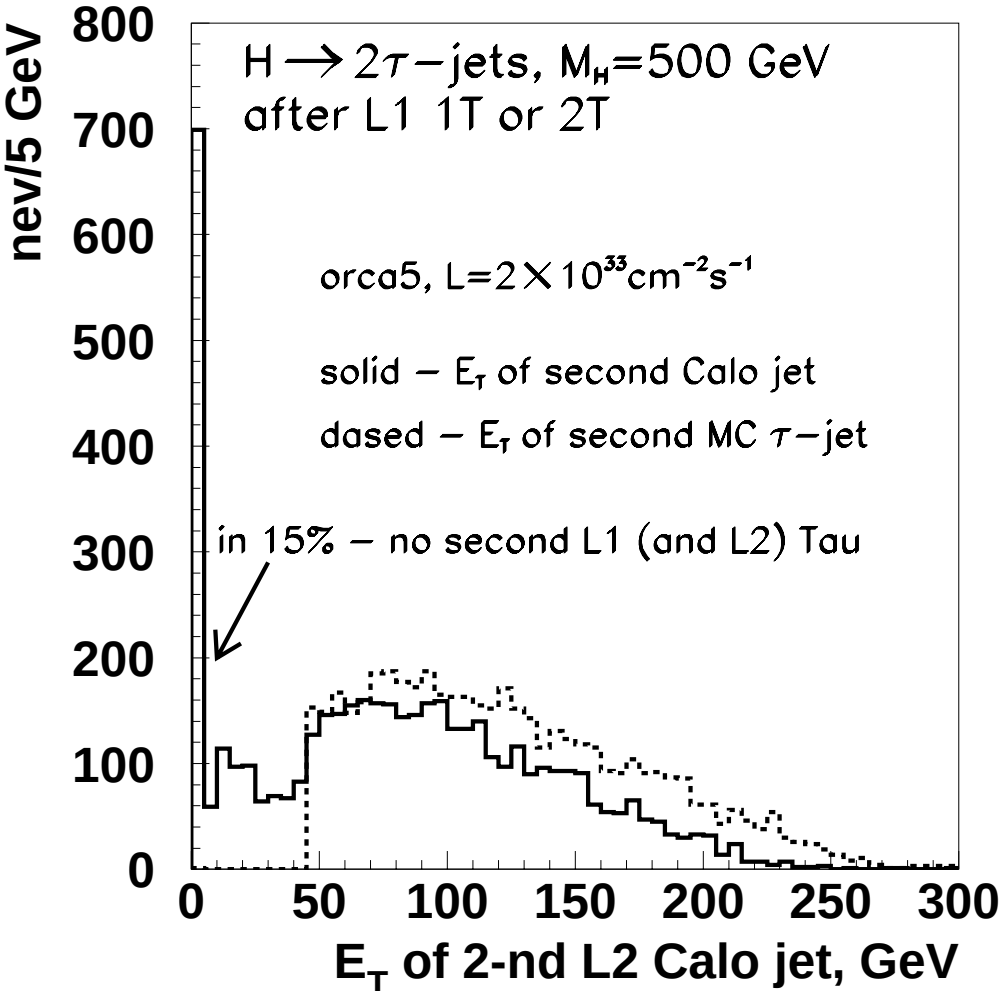
gg->bbA(H), H -> $\tau_1\tau_2$ ->2j

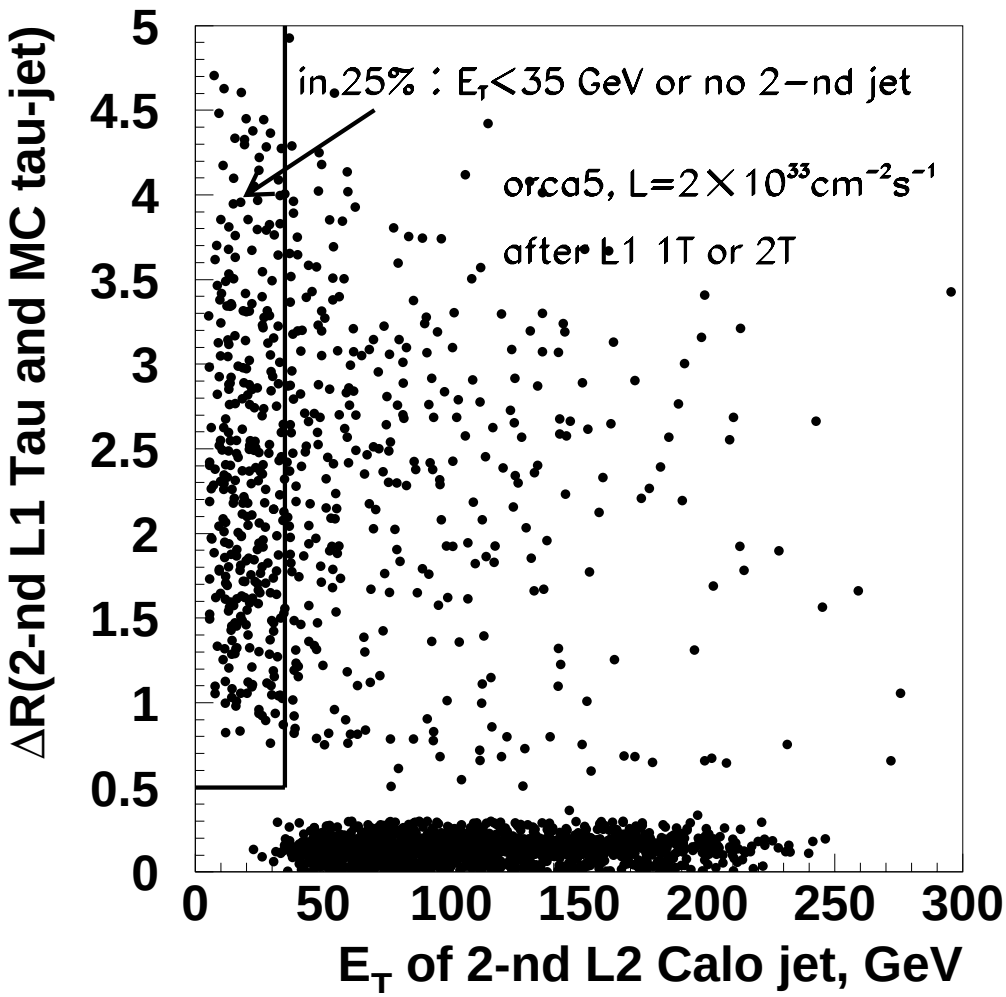
where are 1-st and 2-nd τ jets ?



- τ_{jet1} is triggerd as 1-st Tau jet in 98 %
- 2-nd L1 Tau exists in 85 %, τ_{jet2} is triggerd as 1-st L1 Tau Jet in 78 %
  τ_{jet2} is triggerd as 1-st L1 Central Jet in 19 %
- 2-nd L1 Tau doesn't exist in 15 %, τ_{jet2} is triggerd as 1-st Central Jet in 94 %

How it is solved





if E_T of 2-nd Lvl-2 Calo Jet is small or jet doesn't exist, take jet matched with 1-st L1 Central Jet.

Search for two Lvl-2 Tau Jet candidates with L1 output in gg->bbH, H->2τ-jet events passed Lvl-1 T or 2T trigger

search for Lvl-2 Tau jets with Lvl-1 output	M_H=500 GeV $L=2x10^{33}cm^{-2}s^{-1}$	M_H=200 GeV $L=2x10^{33}cm^{-2}s^{-1}$
matching with 1-st Lvl-1 Tau Jet	0.98	0.99
no 2-nd Tau Jet in the Lvl-1 Tau jet list	0.15	0.12
matching with 2-nd Lvl-1 Tau Jet	0.78	0.86
matching with 2-nd Lvl-1 Tau Candidate	0.90	0.92

How to find Lvl-2 Tau jet candidates :

1-st L2 Tau Jet Candidate - L2 jet matched with 1-st L1 Tau Jet

2-nd L2 Tau jet candidate -

a) if E_T of 2-nd L2 Calo Jet > E_T^{cut} - take this jet

b) if E_T of 2-nd L2 Calo Jet < E_T^{cut} - take L2 jet matched with 1-st L1 Central Jet

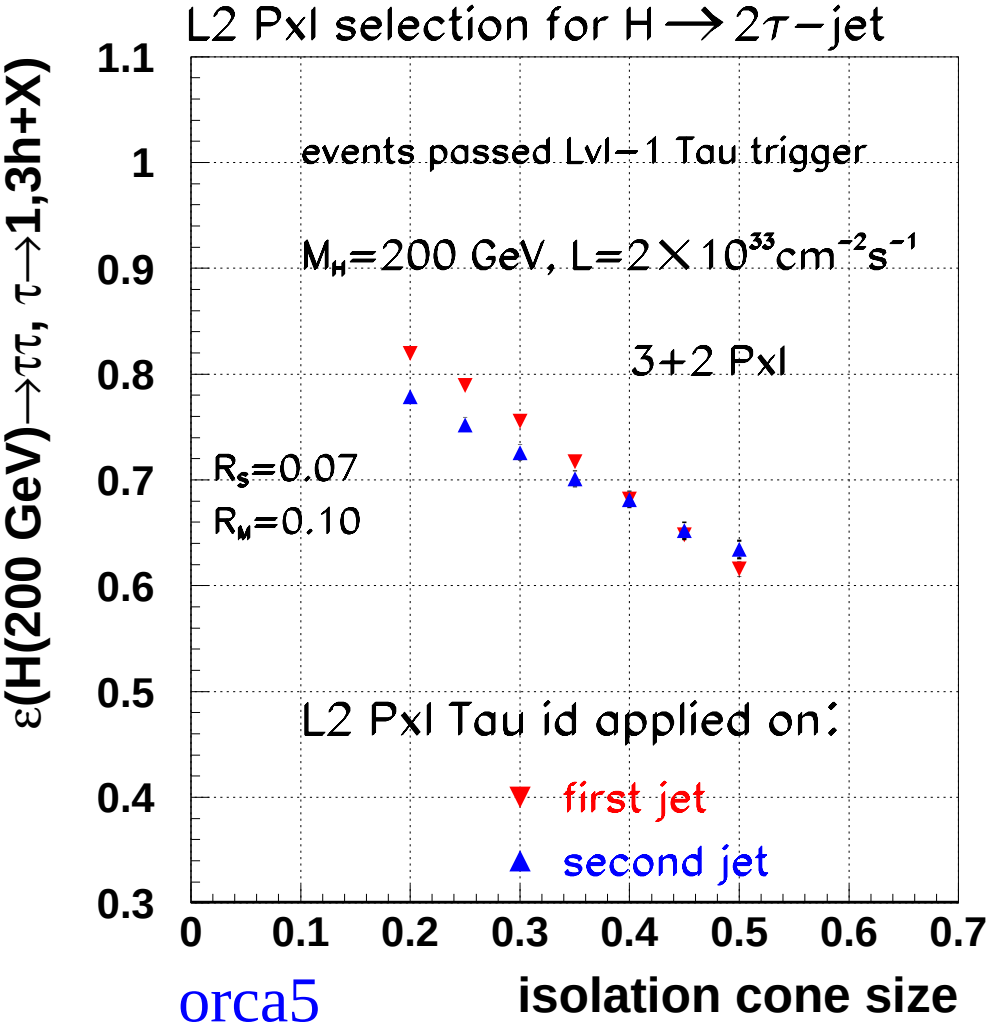
E_T^{cut} = 35 GeV used for orca5, $L=2x10^{33}cm^{-2}s^{-1}$

definition of L2 Calo Jet : 1-st / 2-nd L2 Calo Jet is L2 jet matched with 1-st / 2-nd L1 Tau Jet

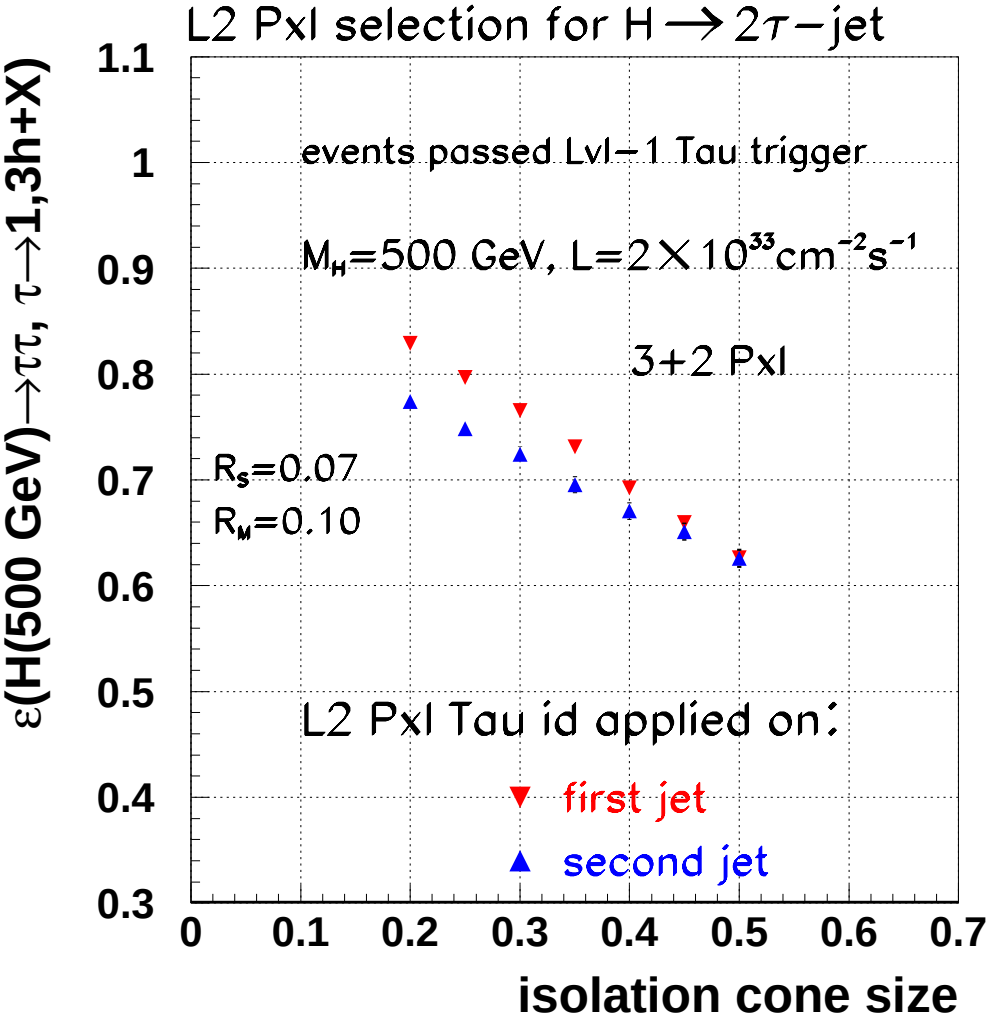
orca5

“Purity” of two Lvl-2 Calo Jets in A/H->2τ-jets is good enough to provide almost the same Pxl isolation efficiency for both jets

M_H = 200 GeV



M_H = 500 GeV



orca5

we don't plan to use L2 Calo Tau for H^+-> τ-jet

Strategy for charged Higgs at Lvl 2

off-line analysis uses cut on miss E_T > 100 GeV, so let's do it at Lvl 2

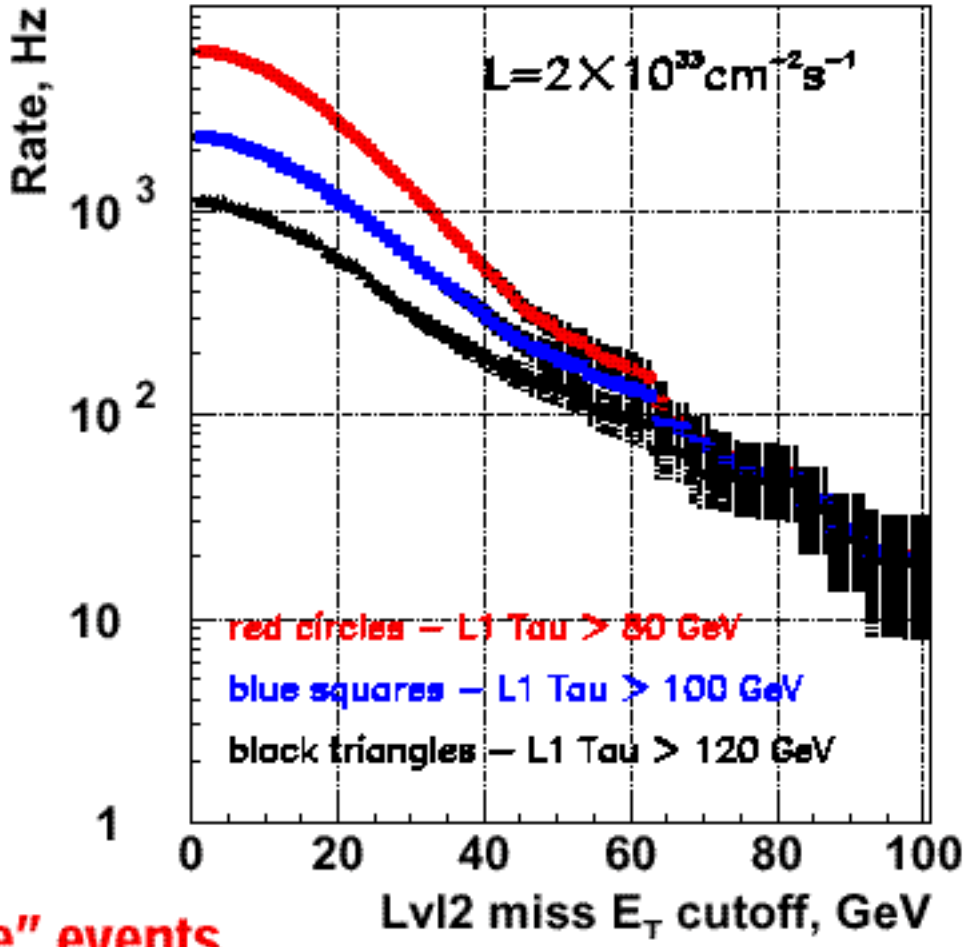
A. Nikitenko, R. Kinnunen

1. Use at Lvl 1 single Tau trigger

L1 cut-off	rate	eff.
80 GeV	~6 kHz	0.87
100 GeV	2.3 kHz	0.82
120 GeV	1.1 kHz	0.68

2. cut at Lvl 2 on MET:

MET > 90 GeV
rate ~ 30 Hz



no loss at Lvl-2 of "off-line" events

after MET trigger at L2 we plan to use for H^+-> τ-jet tracker isolation with regional tracking (see in talk of G. Bagliesi)

CPU performance for global and regional jet finding at High Level Trigger

Summary on JetMet HLT CPU

for Pentium III (Coppermine), cpu MHz : 600 MHz

JetMet HLT with L = 2 x 10 ^{33} cm^{-2}s^{-1} data

time to build towers ~ 200 ms / ev !!! **~ 30 ms now**

time for SUSY (global jet finding + MET) ~ 20 ms / ev

time for Taus from Higgs (regional jet finding) ~ 8 ms / ev

Conclusion

- Lvl-1 Tau trigger is a vital element of CMS Lvl-1 Jet trigger design in the search for $A^0/H^0 \rightarrow 2\tau$
- Lvl-2 Tau Calo trigger using ECAL data only can be used at an early stage of HLT for $A^0/H^0 \rightarrow 2\tau$
- optimization of the best trigger paths for SUSY A^0/H^0 and H^+ with tau jets are on the way.

Acknowlegments

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gg->bbA(H), H -> $\tau_1\tau_2$ -> e + j

Olivier van der Aa

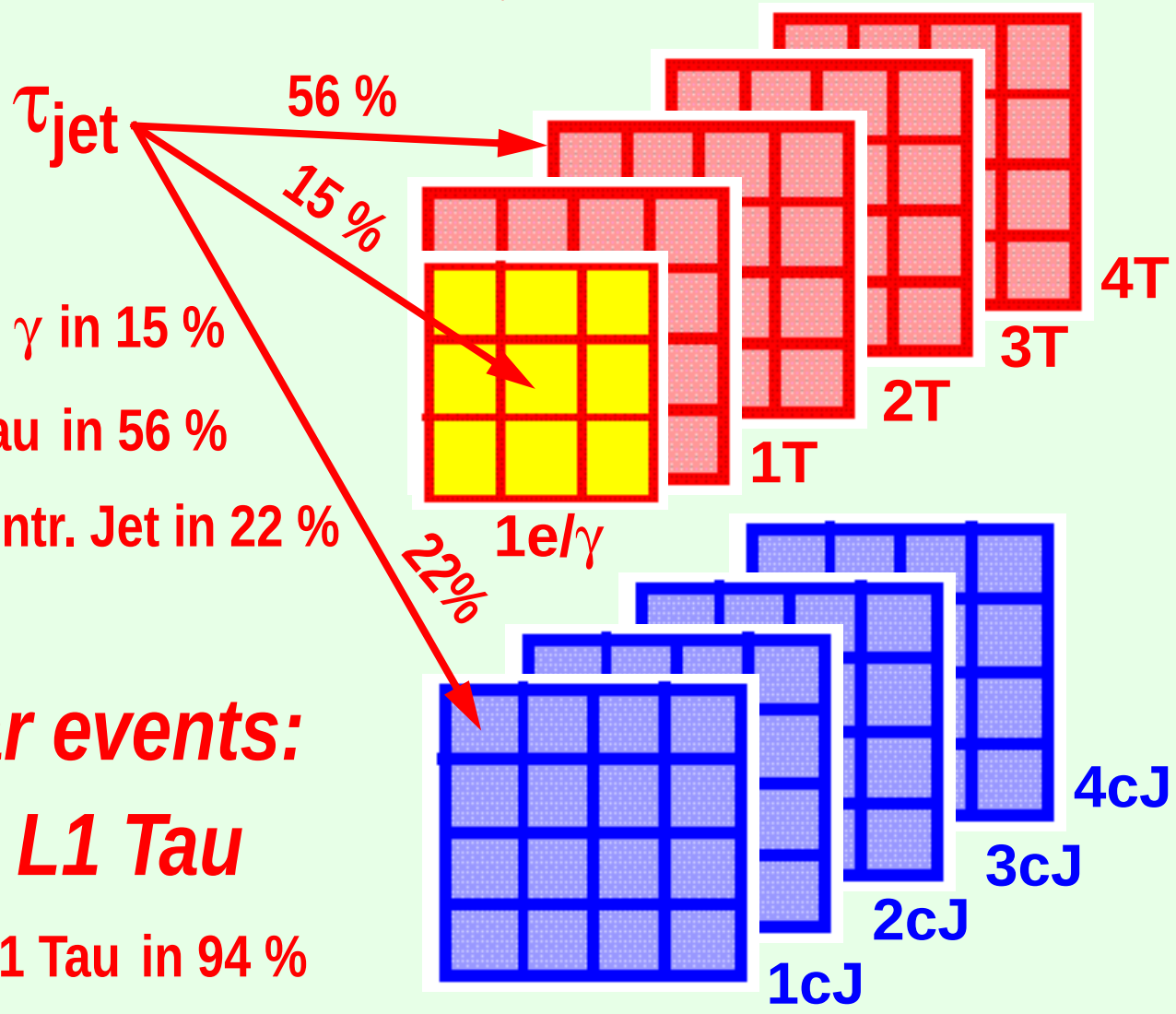
where is τ jet in events passed e&T trigger ?

a) 43 % collinear events: 1-st L1 e/γ = 1-st L1 Tau

τ_{jet} is triggered by 1-st L1 e / γ in 15 %

τ_{jet} is triggered by 2-nd L1 Tau in 56 %

τ_{jet} is triggered by 1-st L1 centr. Jet in 22 %



b) 56 % not collinear events:

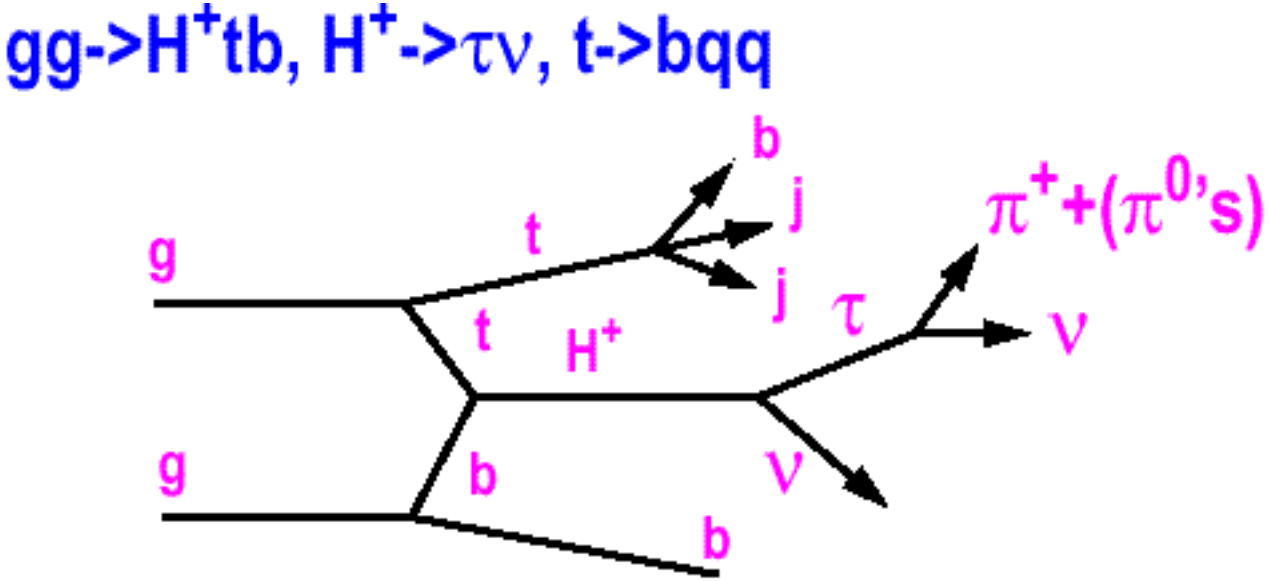
1-st L1 e/γ != 1-st L1 Tau

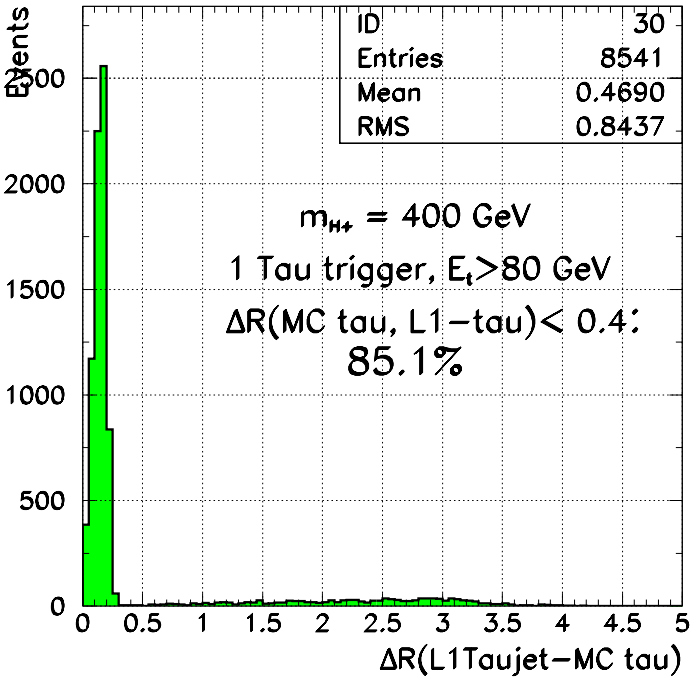
τ_{jet} is triggered by 1-st L1 Tau in 94 %

...

R. Kinnunen

in $H^+ \to \tau\nu$ τ-jet is triggered by 1-st L1 Tau in 85 %

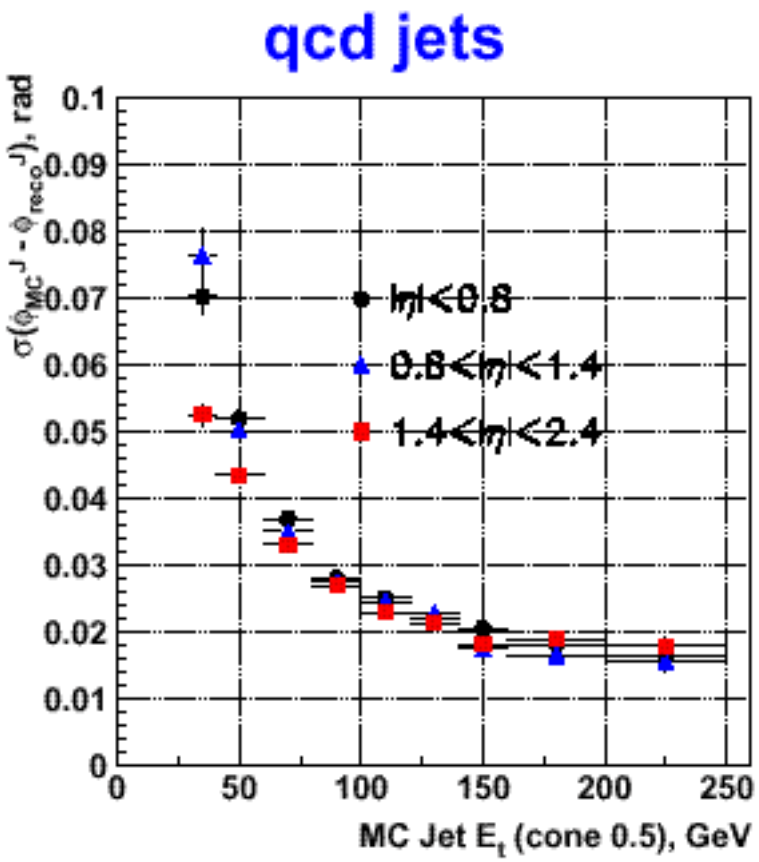




M. Konecki

in H->ττ-> μ+j, τ-jet is triggered by 1-st L1 Tau in 93 %

.....


qcd jets
$\sigma(\phi_{MC}^{J} - \phi_{reco}^{J})$, rad
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
50
100
150
200
250
MC Jet E_t (cone 0.5), GeV
|η|<0.8
0.8<|η|<1.4
1.4<|η|<2.4