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Physics

- brief look at software for physics simulation
- updates on selected Higgs physics channels

UK Physics Meeting. 14 Febr. 2003

❑ brief look at software for physics simulation

Generation	Detector Simulation		Digitization	Analysis
MC Physics generators (see next slide)	FAST	CMSJET* (fortran)		
		FAMOS** (c++)	ORCA	ORCA
	FULL	CMSIM* (G3, fortran)	ORCA6 (Obj. DB)	ORCA6 (Obj. DB)
		OSCAR** (G4, c++)	ORCA7 (root)	ORCA7(root)

* fast and full CMS fortran simulation packages are used since ~ 8 year in CMS

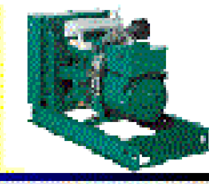
** under development, not ready yet. OSCAR2 should be ready by June.

It is supposed to be just one (c++) way in sometime :

Generation -> FAMOS / OSCAR -> ORCA

Tools used in CMS to generate physics at LHC

http://cmsdoc.cern.ch/cms/generators/

Event Generators for CMS 

Information and support for generators used in CMS

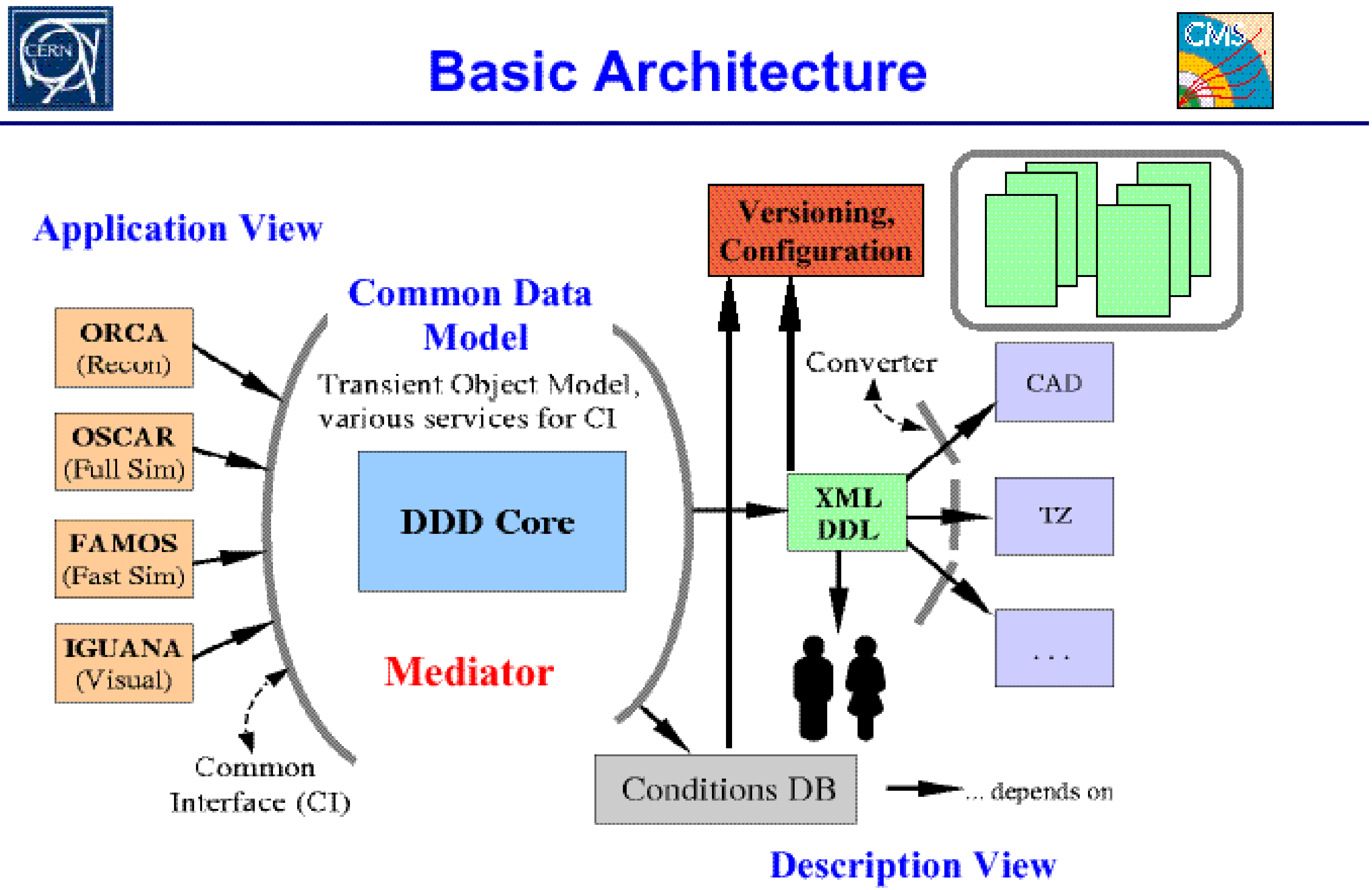
Coordinators: Albert de Roeck and Sergei Slabospitsky

general purposes generators	dedicated generator(s)/package(s)
• PYTHIA /Slabospitsky, Nikitenko/	• HDECAY, HQQ, VV2H, HIGLU, MadCUP
• HERWIG /Moortgat /	• TAUOLA
• ISAJET /Abdullin/	• Single Top
• CompHEP /Ilyin/	• TopReX
• diffraction /de Roeck/	• generators for soft hadronic events
• heavy ions /Kodolova/	• SIMUB
• MC Events Data Base /Doudko /	• ALPGEN

- Workshop on MCs for the LHC, July 7 - Aug 2 2003, at CERN

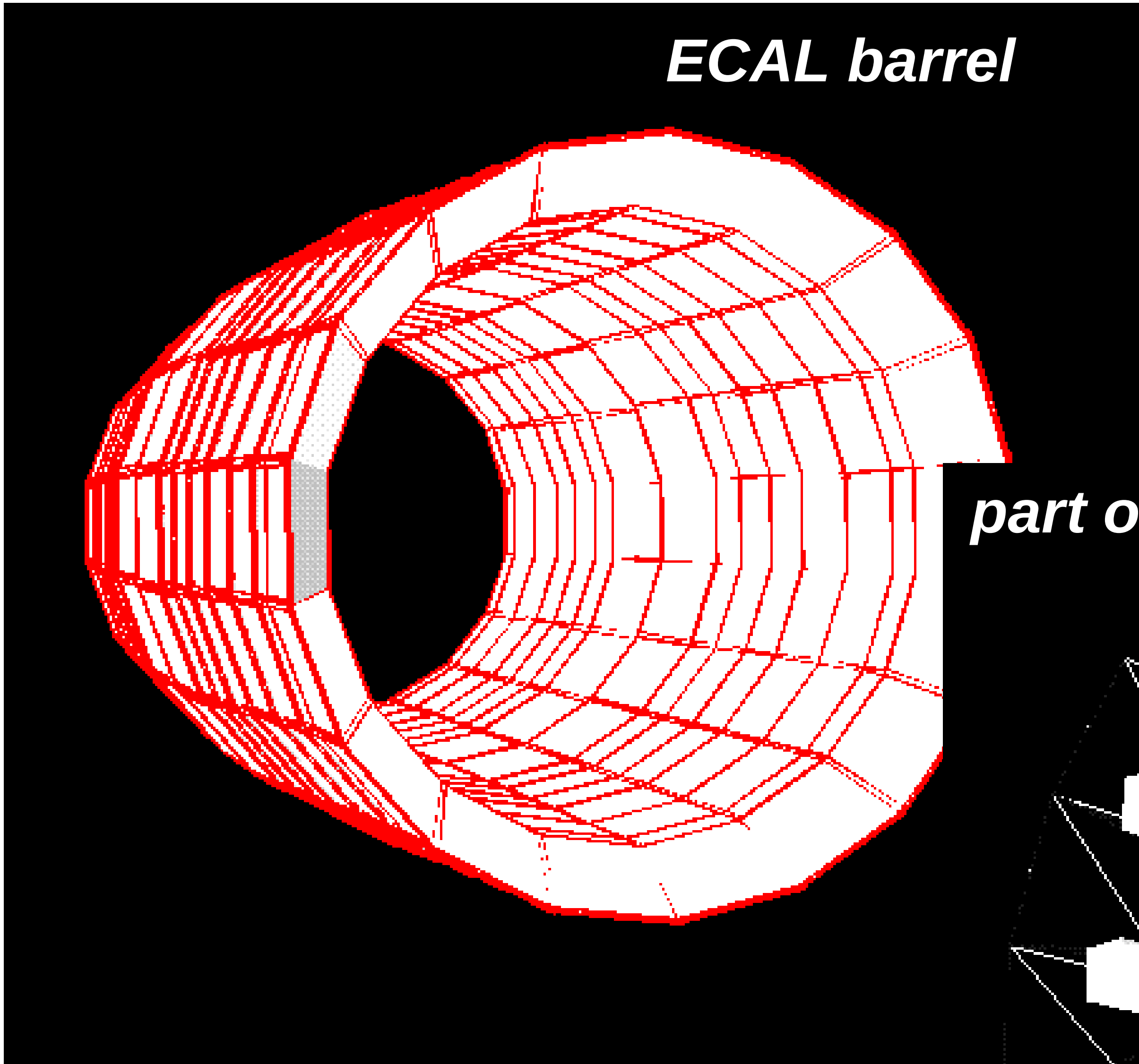
Full detector simulation : from CMSIM (G3) to OSCAR (G4)

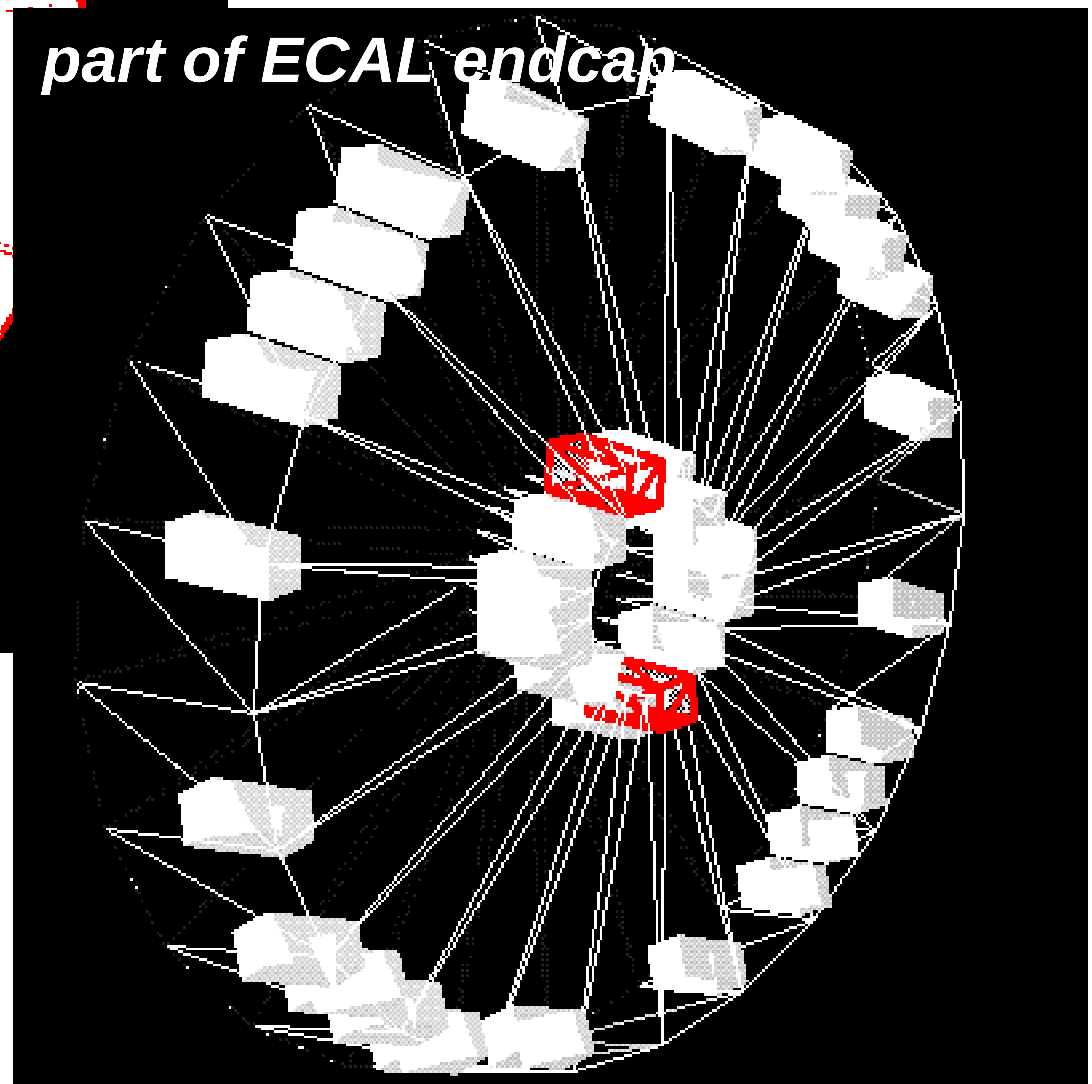
Detector Description Database written in XML will serve requests from simulation (OSCAR/FAMOS), reconstruction (ORCA) and visualization (IGUANA)



CMS ECAL in OSCAR (IGUANA visualization)

many thanks to general SW experts helping to move cmsim ecal to oscar :
M.Stavrianakou, P. Arce, M. Liendl





<u>ECAL simulation geometry responsibles :</u>

ECAL geometry : A. Nikitenko

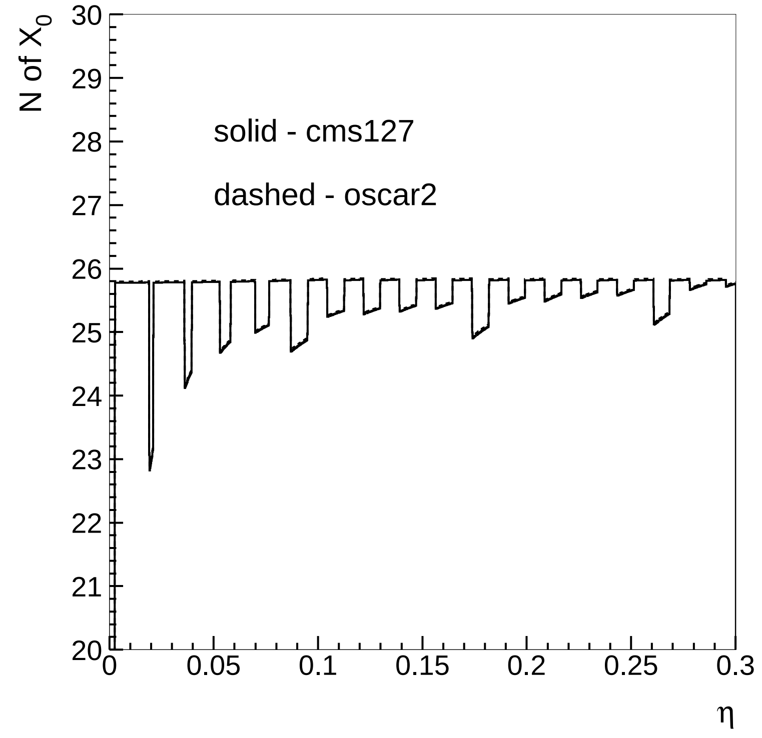
EB - M.Lethuillier, J. Donini

EE - B. Kennedy

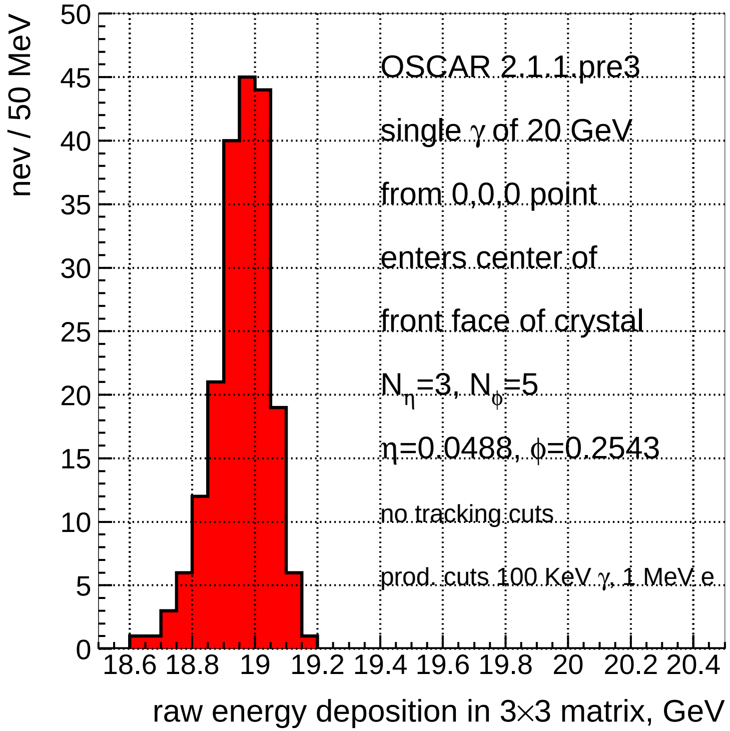
Preshower - D. Barney

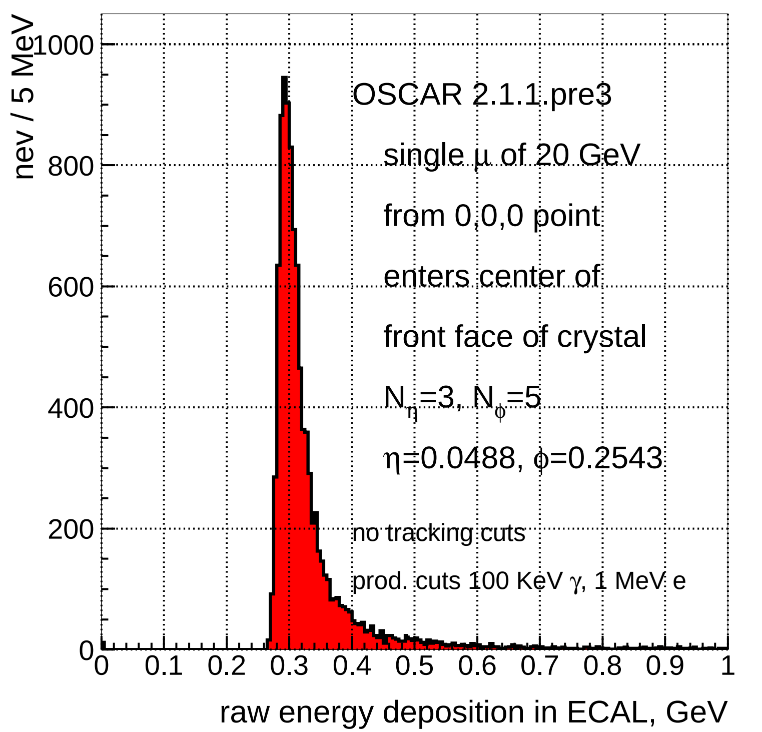
Work is going on verification of ecal geometry and e.m. physics within OSCAR_2

A.Nikitenko, K. Lassila, D. Holmes



OSCAR_2 is planned to be ready for mass production for DC04 by June. We will use OSCAR_2 to simulate physics for Physics TDR

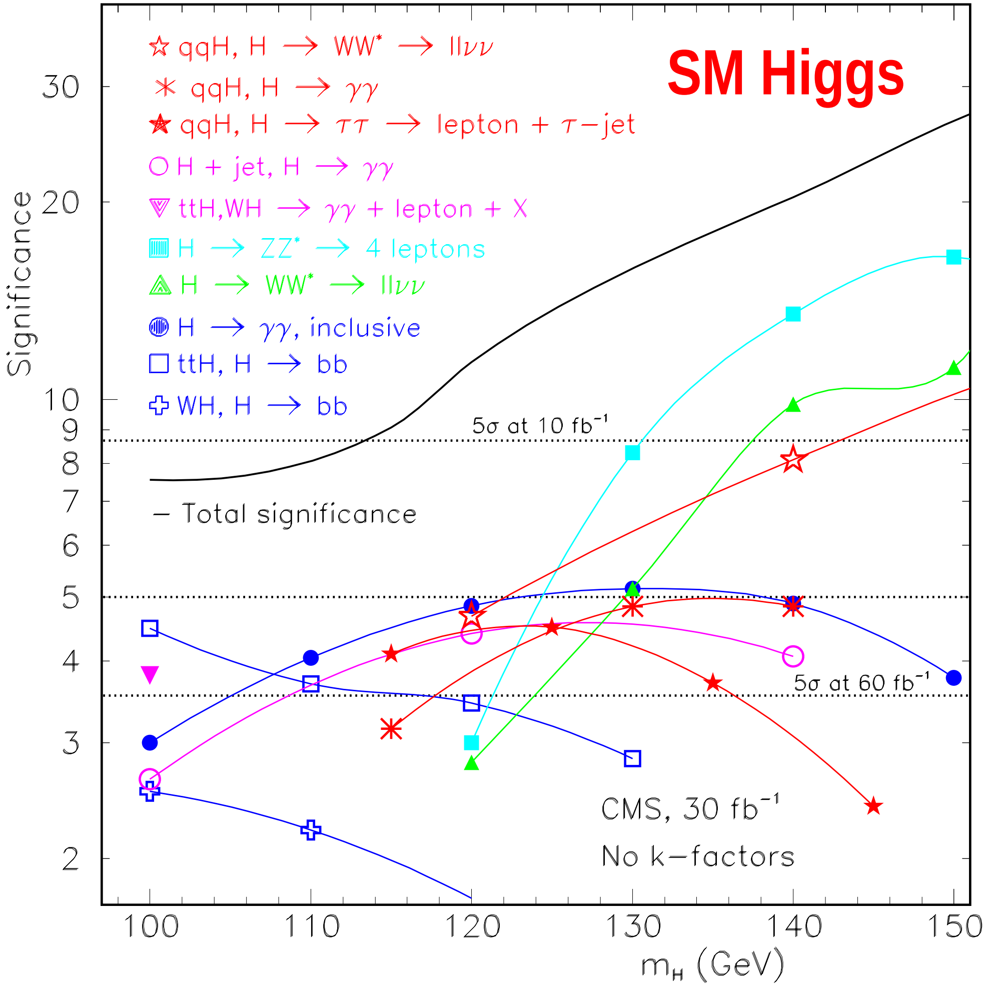




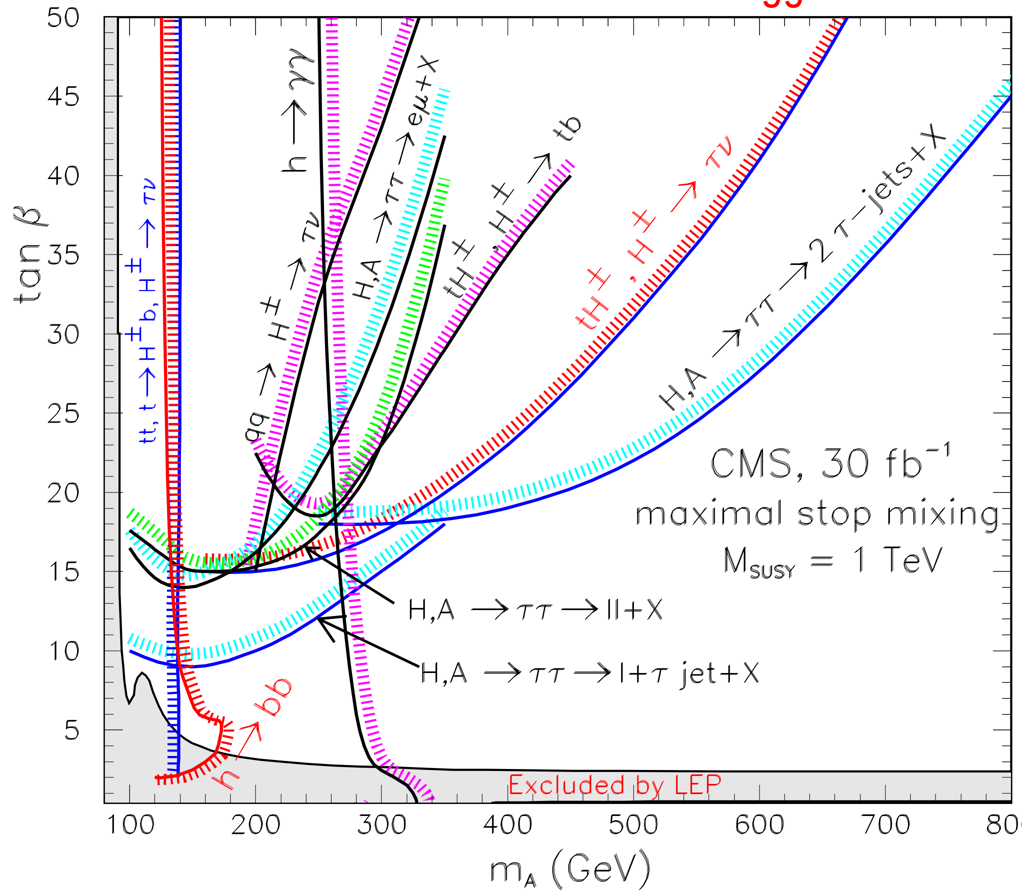
. . . start to talk about "Physics". I will talk about some Higgs physics in CMS . . .

Current CMS plots for SM and MSSM Higgs discovery

produced by R. Kinnunen on the basis of old and current CMS studies. Some of curves will be updated as result of dedicated full simulation studies on the way towards CMS Physics TDR as well as result of more theoretical development in the Higgs sector.



some MSSM Higgs channels



I will show recent (last year) results/updates/problems on detection of :

MSSM gg->bbA^0/H^0, A^0/H^0->2τ->2jet

SM / MSSM qq->qqH, H-> 2τ -> lepton + jet

qq->qqH, H->invisible mode

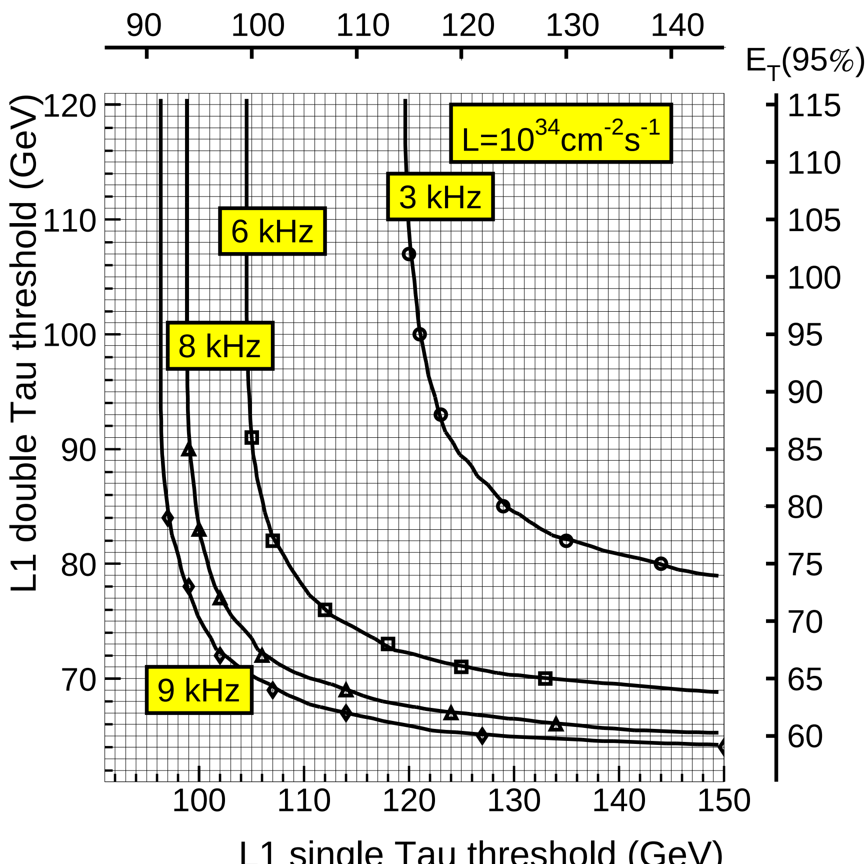
High tan(β) channels: $gg \to bbA^0/H^0$, $A^0/H^0 \to 2\tau \to 2$ jet, $gb \to tH^+$, $H^+ \to \tau\nu$, $\tau \to$ jet, $t \to bjj$

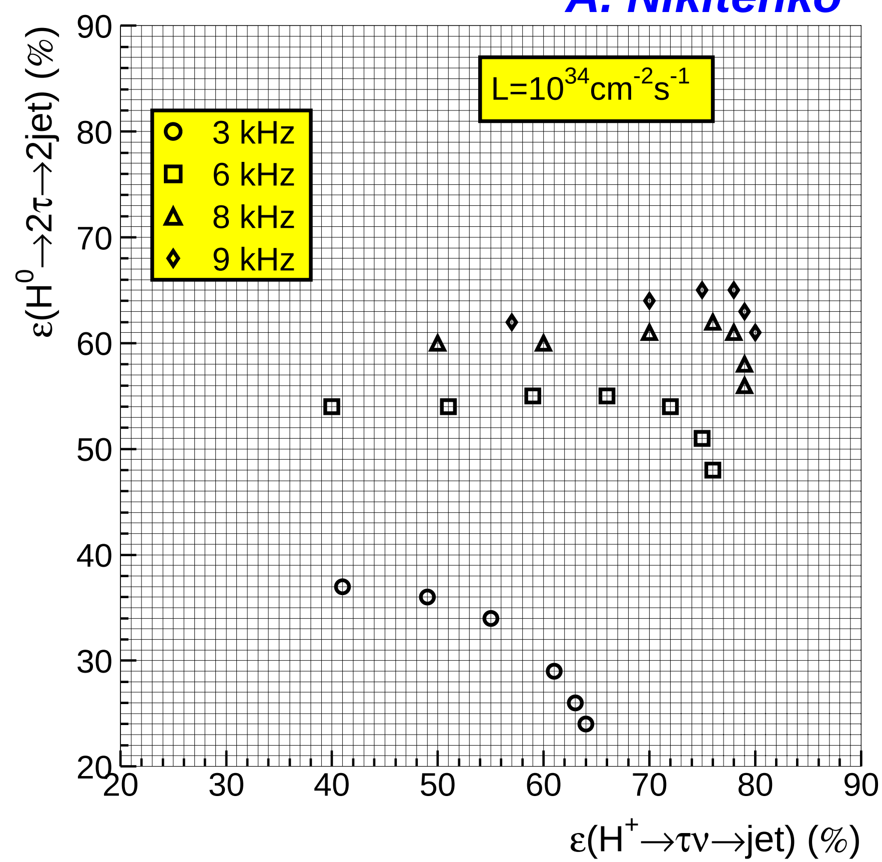
τ lepton decays hadronicaly 65 % of time, producing a "τ-jet".

For DAQ TDR Level-1 Tau trigger has been optimized and High Level Trigger has been developed to select tau jets using ECAL and Pixel Detector only or regional tracking with the full Tracker.

optimization of Level-1 1T vs 2T trigger thresholds at $L=10^{34}cm^{-2}s^{-1}$

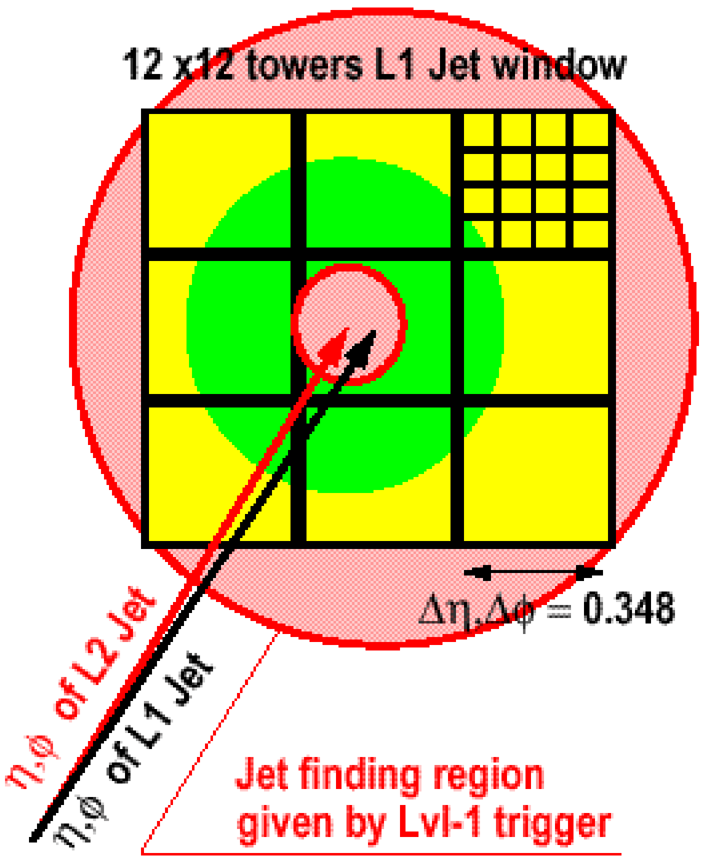
A. Nikitenko





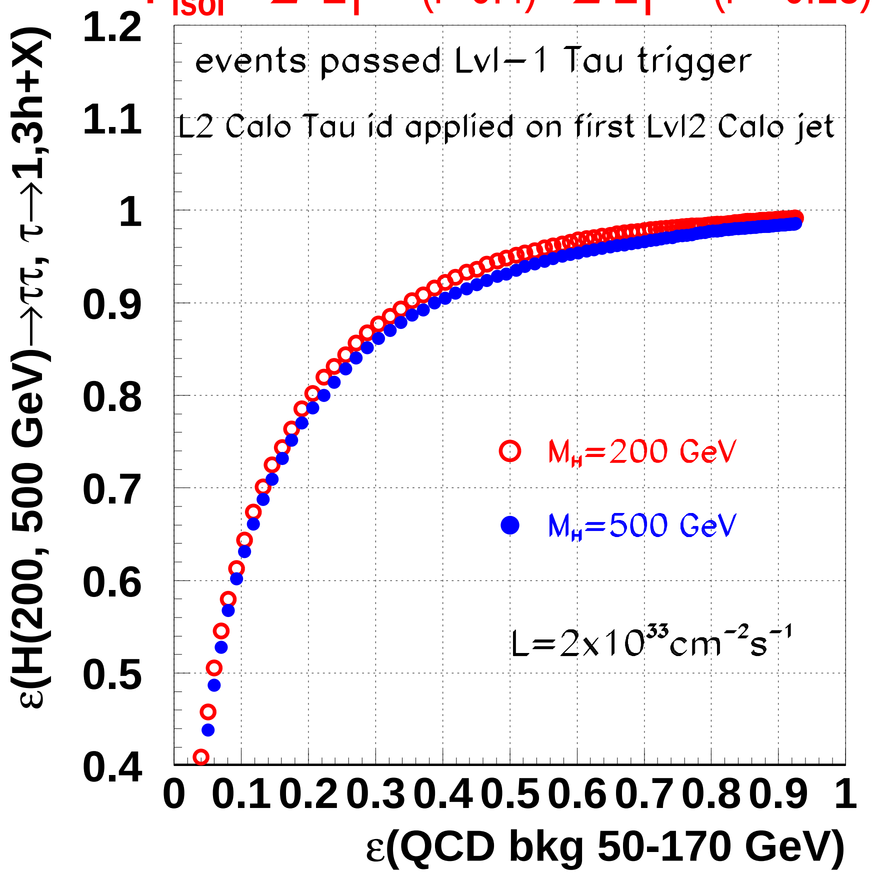
Level-2 calo jet as input for τ id with tracker : calo-based τ -jet id.

A. Nikitenko, S. Eno



cut on e.m. isolation parameter :

$P_{isol} = \Sigma\ E_T^{em}\ (r<0.4) - \Sigma\ E_T^{em}\ (r < 0.13)$



Time at 1 GHz CPU for Calorimeter Tau identification		
time per step, ms / luminosity	$L = 2x10^{33}cm^{-2}s^{-1}$	$L = 10^{34}cm^{-2}s^{-1}$
Calo Tower building	24 ms	39 ms
Regional jet finding + shape analysis	9 ms	15 ms
Total time	33 ms	54 ms

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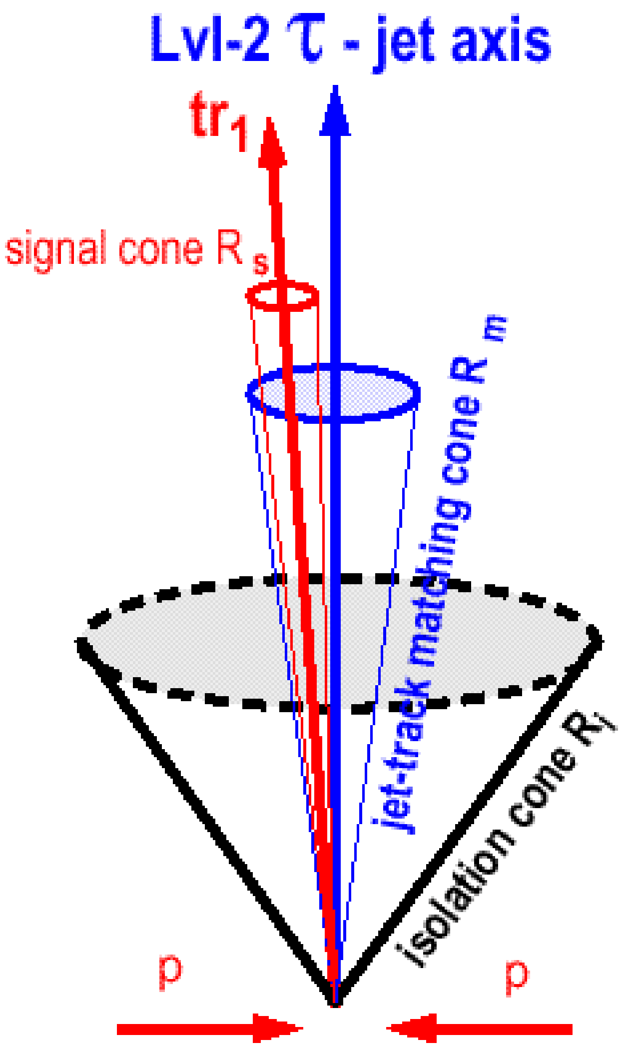
D. Kotlinski, A. Nikitenko, R. Kinnunen

Tau identification at Lvl-3 with Pixels

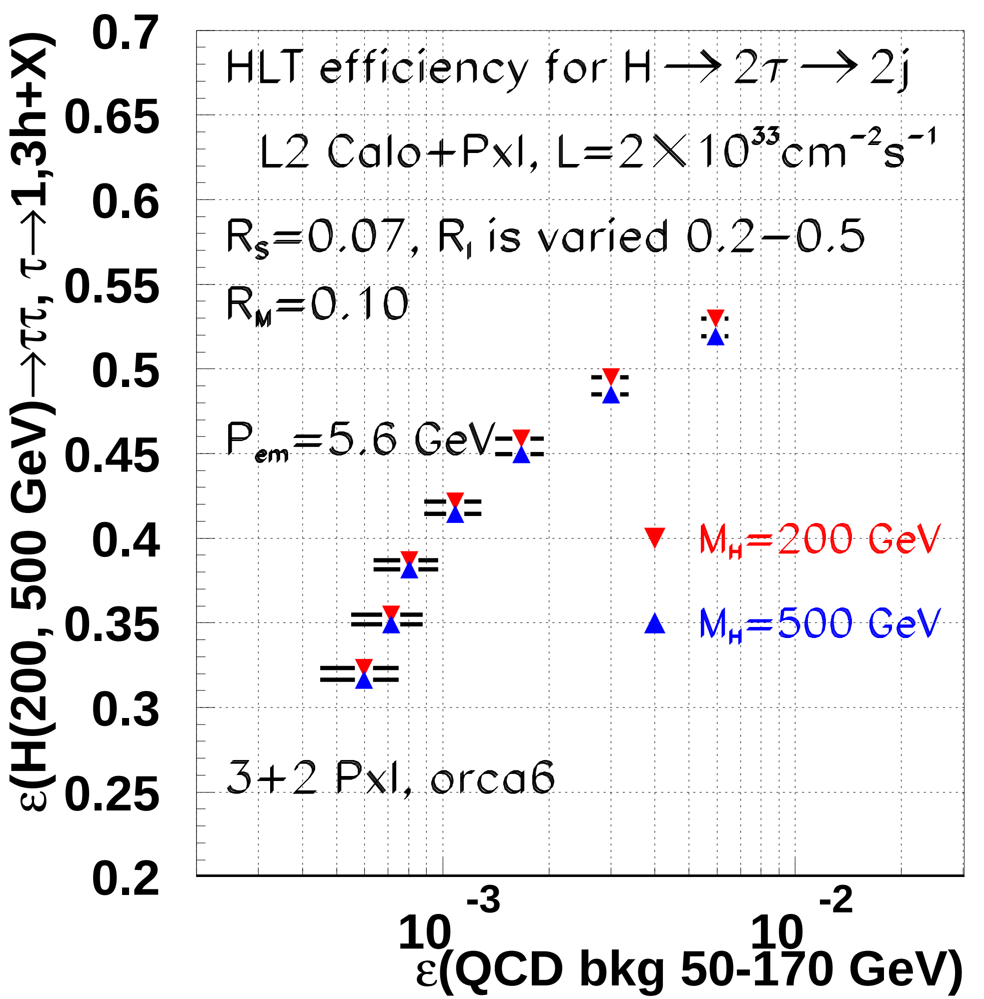


Algorithm steps

- reconstruct tracks $p_t > 1$ GeV with pixels only
  resolution : $\sigma(p_t)/p_t = [3.6 + 1.7 p_t(\text{GeV})]\%$
- find primary vertices (histogramming method)
- find highest p_t track with good Lvl-2 jet matching
  $\Delta R(j - tr_1) < R_m$ (~0.1) , $p_t^{tr1} > p_t^m$ (~3 GeV),
  tr_1 defines signal primary vertex (PV)
- count number of tracks from PV in the isolation cone and signal cone :
  N_i tracks with $\Delta R(j - tr) < R_i$ (~0.3) ,
  N_s tracks with $\Delta R(tr_1 - tr) < R_s$ (~0.05) ,
  $p_t^{tr} > p_t^i$ (~1 GeV)
- accepts as τ if tracks found only in signal cone
  $N_s = N_i$

Calo + Pxl HLT path for $A^0/H^0 \rightarrow 2\tau$-jet at $L=2x10^{33}cm^{-2}s^{-1}$

optimization of L2 Calo Tau supression factor for HLT Calo+Pxl supression factor 1000									
L2 Calo Tau suppression factor S_{calo}	1	1.5	2.0	3.0	4.0	5.0	6.2	7.5	10
Cut off on em. isol., GeV	no cut	10.4	7.6	5.6	4.6	4.0	3.4	3.2	2.6
CPU (1 GHz) $T_{calo}+T_{Pxl}$ / S_{calo}, ms	110	85	72	59	52	50	45	43	41
Calo+Pxl Tau id efficiency	0.35	0.37	0.40	0.41	0.40	0.39	0.37	0.36	0.35

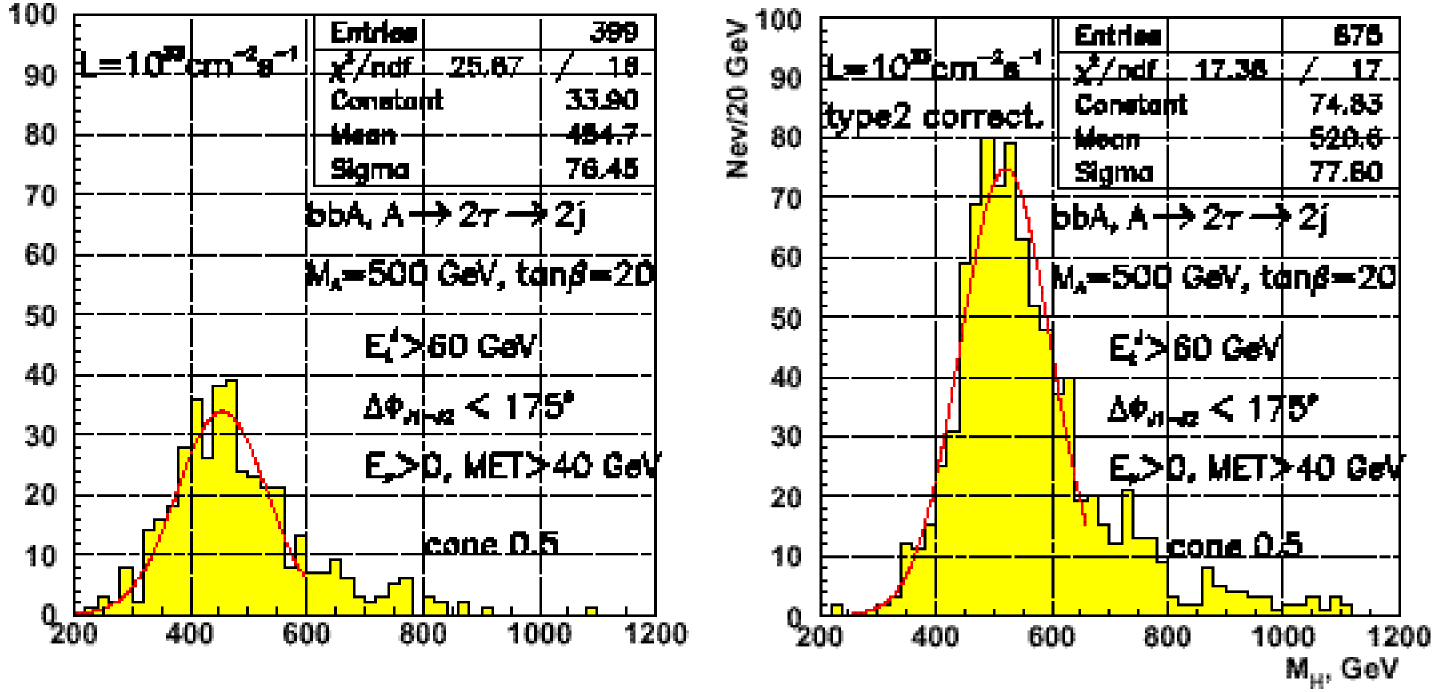


Some points of the off-line analysis . . .

Efficiency of mass reconstruction was suffering from the bad calorimeter missing E_T measuremet. The method was developped to measure MET with calo jet energy corrections which increases efficiency by factor 2 !

A. Nikitenko, S. Kunori

Higgs mass in bbA, A->2τ ->2j with corrected MET



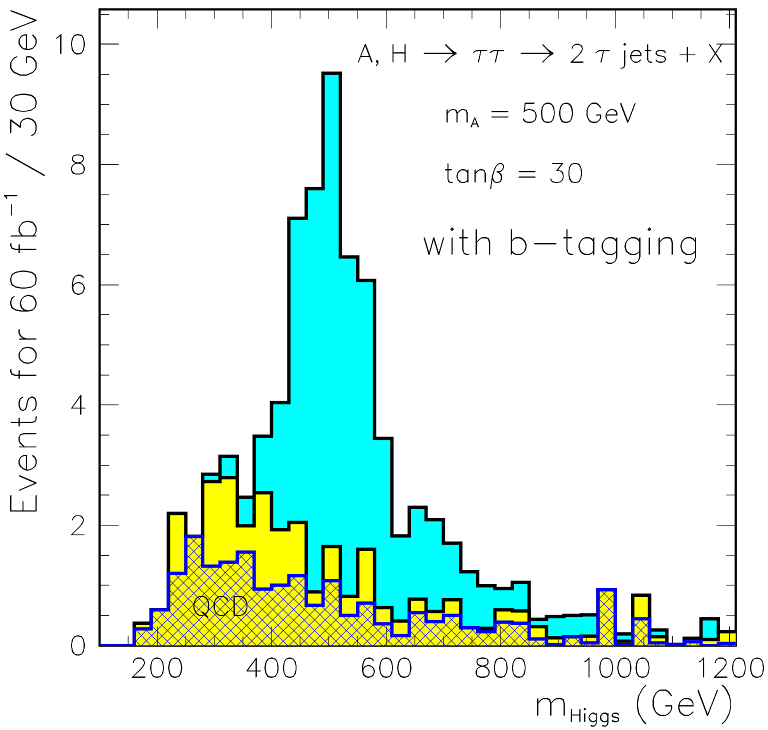
bbA, A->2τ->2j	no corrections	type1 corrections	type2 corrections	CMSJET
$<M_H>$	455.0 GeV	510.0 GeV	521.0 GeV	500.0 GeV
$\sigma / <M_H>$	16.8 %	16.4 %	14.9 %	13.8 %
ε_{reco}	0.17	0.31	0.36	0.34

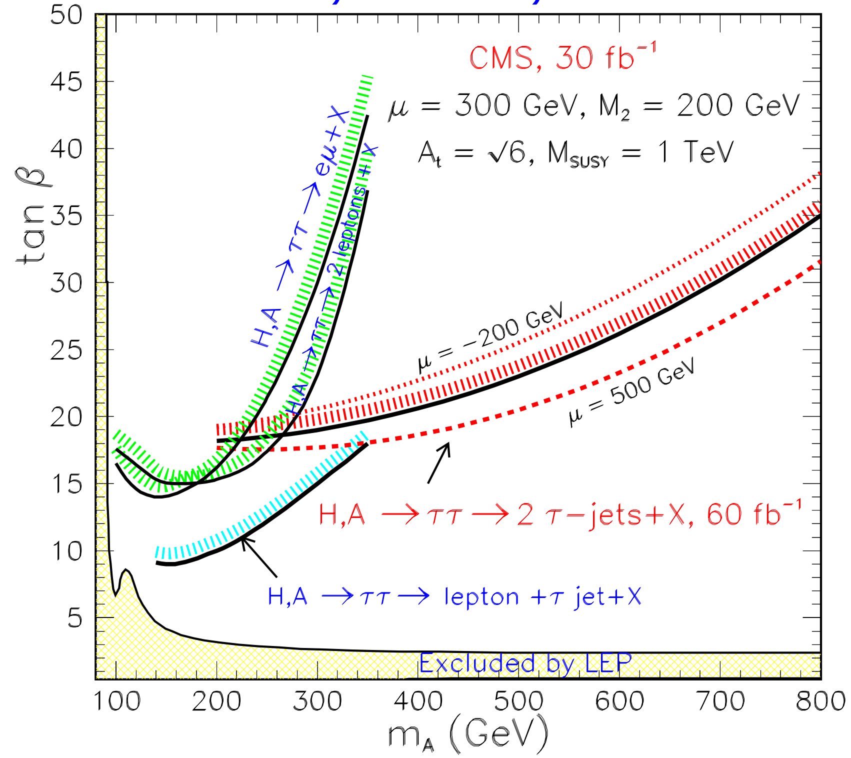
Some points of the off-line analysis . . .

off-line analysis uses b-tagging and τ tagging with impact parameter
it is done with cmsjet where ip resolution is taken from "full simulation".

current plots of discovery with MSSM A^o/H^o -> 2 τ

R. Kinnunen, S. Lehti, A. Nikitenko



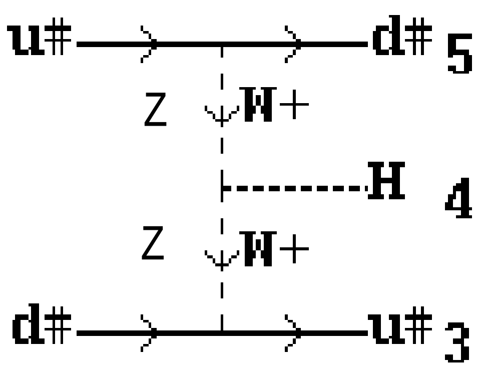


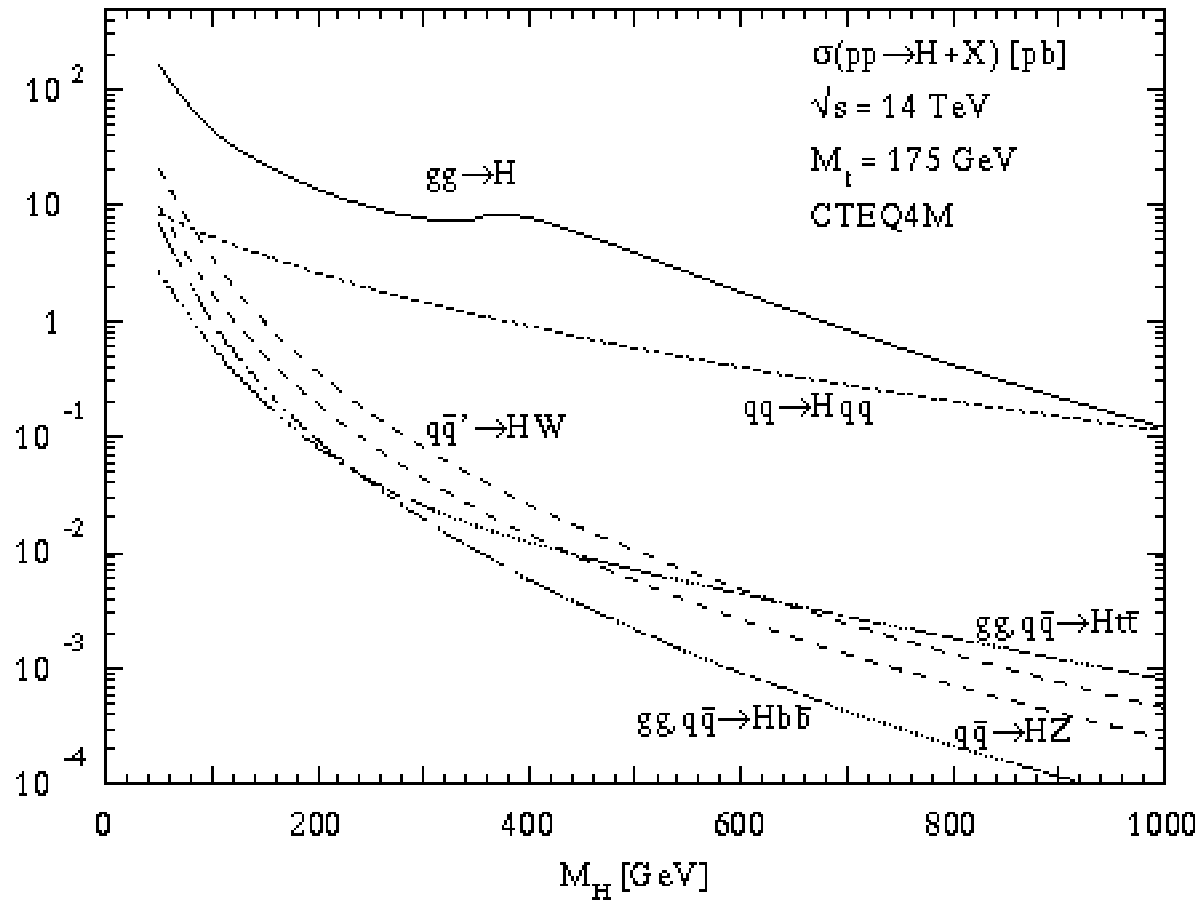
we will exploit τ polarization to reduce tt and QCD bkg (S. Moretti & D.P.Roy 2002)

MSSM A^o/H^o -> 2 τ channels are included as responsibility of Detector PRS b/tau group for Physics TDR analysis.

We will do with full simulation another H->2τ channel : qq->qqH, H->2τ, M_H < 150 GeV. next slides . . .

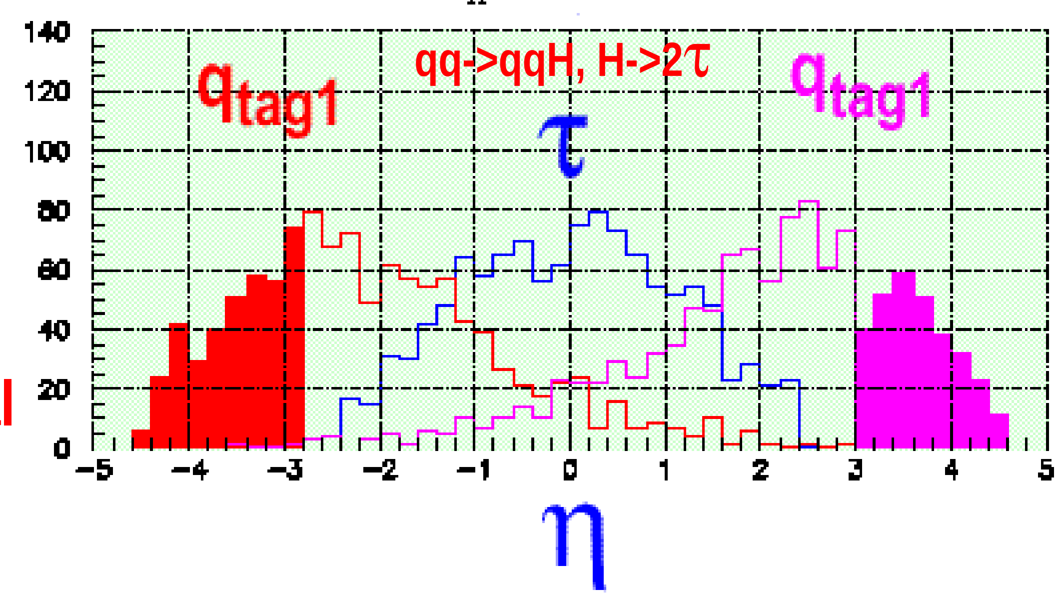
qq->qqH becomes the most "experimentally" studied channel.





- large enough rates
- forward jet tagging and mini-jet veto for low L
- central Higgs decay products to trigger
- not too big bkg, S/B ~ 1

D. Zeppenfeld and collaborators are discussing it since ~ 10 years



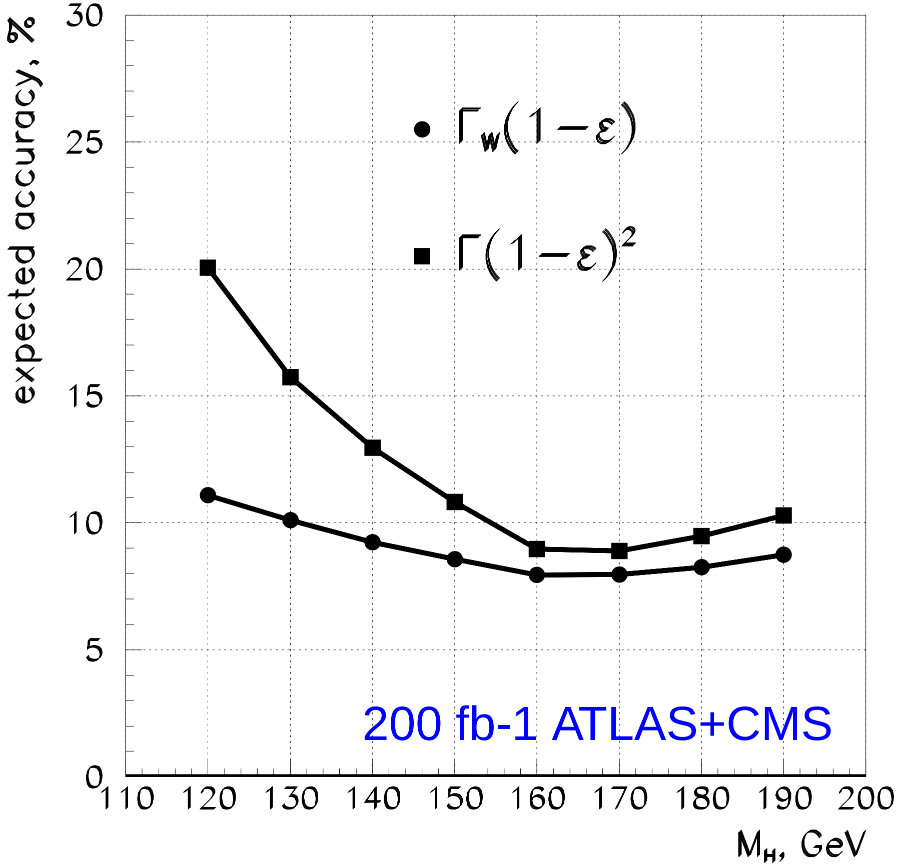
BUT detailed simulations/experimental analysis is needed !

Observation of SM WBF Higgs channels :

- $qq \to qqH, H \to 2\tau$, $M_H < 150$ GeV
- $qq \to qqH, H \to 2\gamma$, $M_H < 150$ GeV
- $qq \to qqH, H \to WW^* \to 2l\,2\nu$, $M_H > 120$ GeV

together with $gg \to WW^* \to 2l\,2\nu$, allows underect measurement of Higgs width :

D.Zeppenfeld, R. Kinnunen, A.Nikitenko, E.Richter-Was . Phys.Rev.,D62(2000)



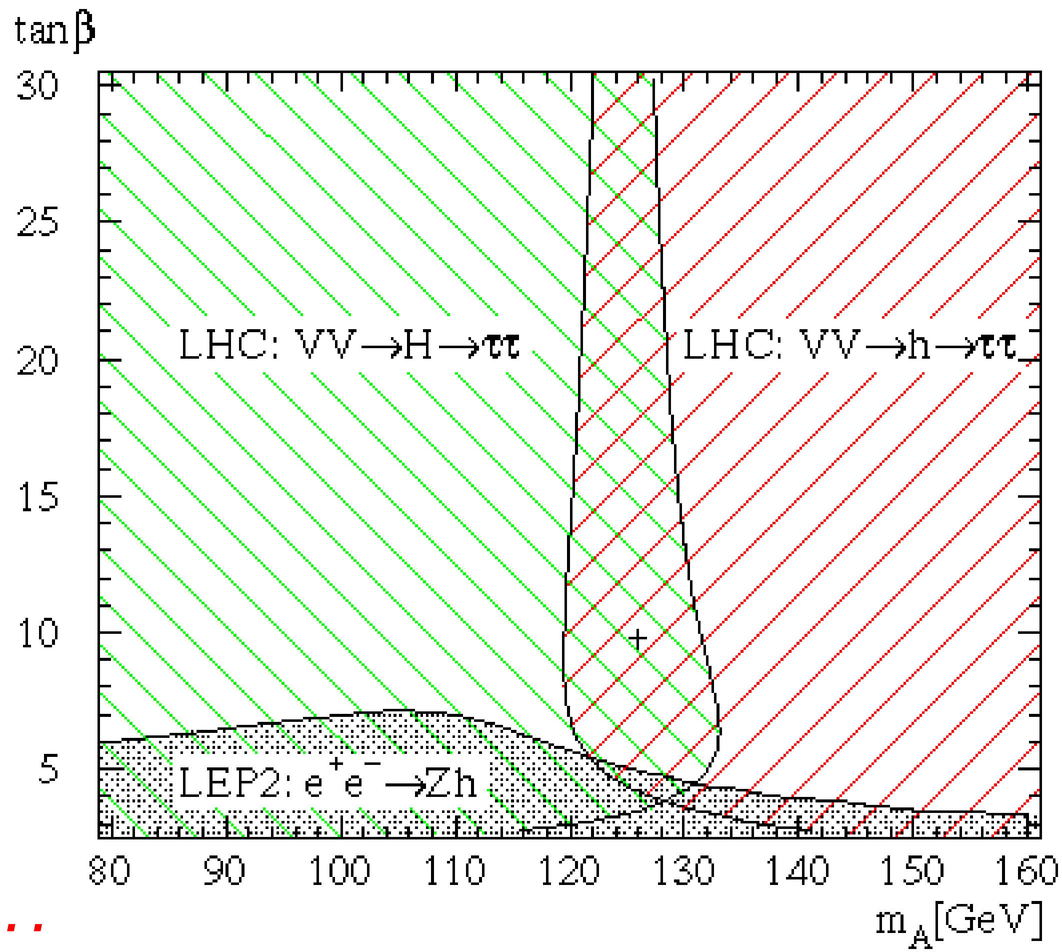
. . .also Higgs couplings together with ttH . . .

$qq \to qqH, H \to 2\tau$

implication for MSSM may be very promising if it is confirmed by CMS/ATLAS simulations !

T. Plehn, D. Rainwater, D. Zeppenfeld Phys. Rev., D61(2000)

parton level analysis of l+jet & 2l final states; 100 fb^{-1}, maximal mixing



S. Ilyin, A. Nikitenko, D. Zeppenfeld

SM qq->qqH, H -> 2τ -> *l* + j

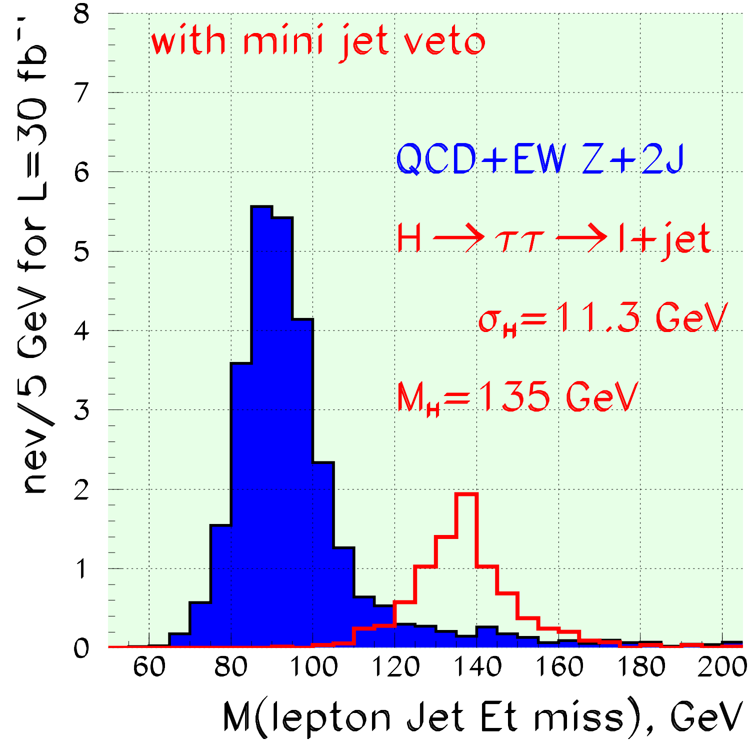
Preliminary results for low luminosirty

fast cmsjet simulation. tau-id from full simulation

(Les Houches Higgs Working Group summary report hep-ph/0203056)

Data for 30 fb^{-1} at low luminosity running

Mass, GeV	115	125	135	145
σ, pb	4.49	4.15	3.81	3.57
Br, %	7.2	6.1	4.5	2.6
S	12.6	9.9	6.7(6.2)	3.6
B	5.5	2.3	1.5(1.1)	1.1

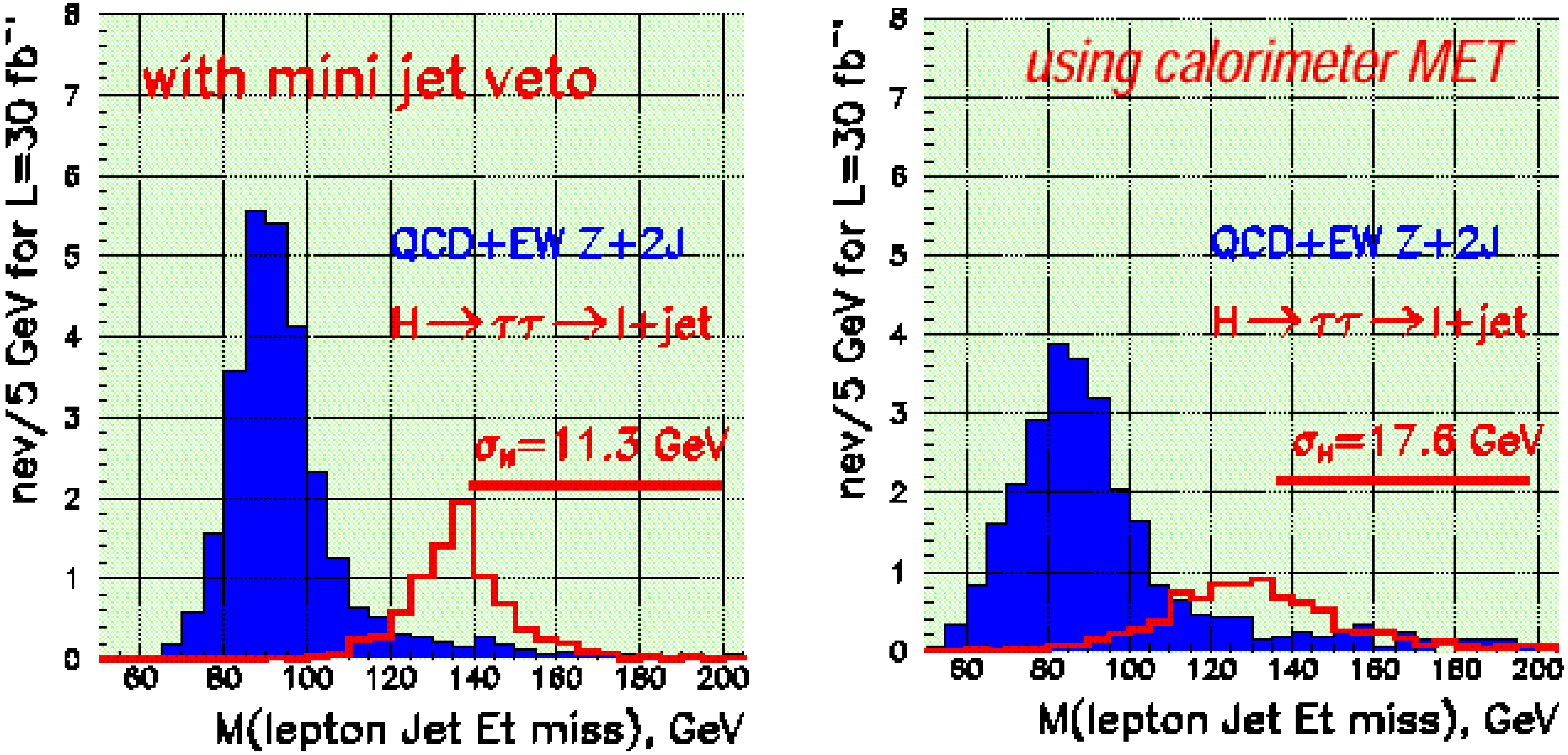


confirm parton level estimates, but full simulations show problems which hopefuly will be solved (next slides).

improve calo missing E_T: one of the most suffering Higgs channels is light Higgs in qq->qqH, H->2τ->lepton + jet

CMSJET fast simulation	full simulation and OO/c++ reco

qq->qqH, M_H = 135 GeV *A. Nikitenko*



calorimeter missing E_T hopefuly will be improved with energy flow method (under initial development in CMS)

Mini-jet veto for WBF Higgs selection: no central jets $E_T > 20$ GeV.

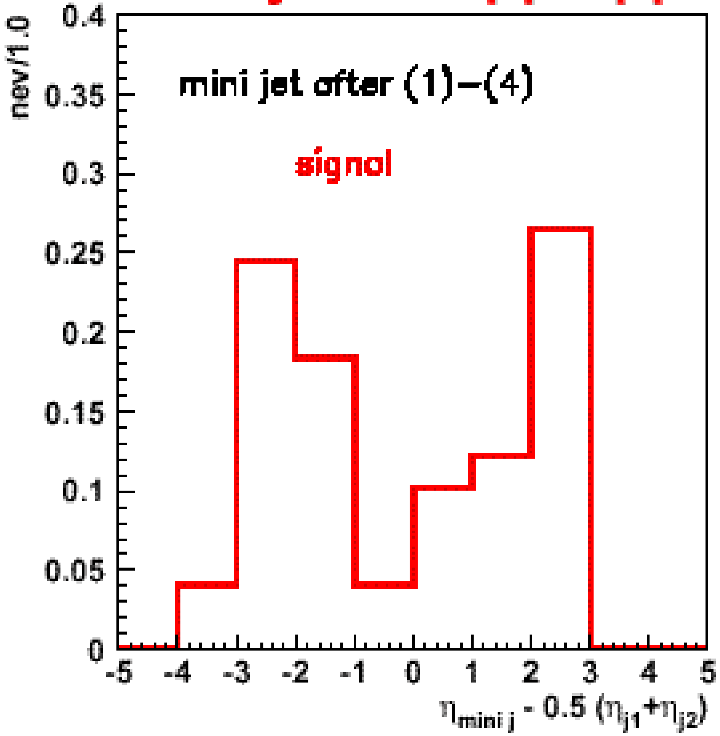
idealy, should reduce bkg by factor of 3

with ~ 90 % efficiency for the signal

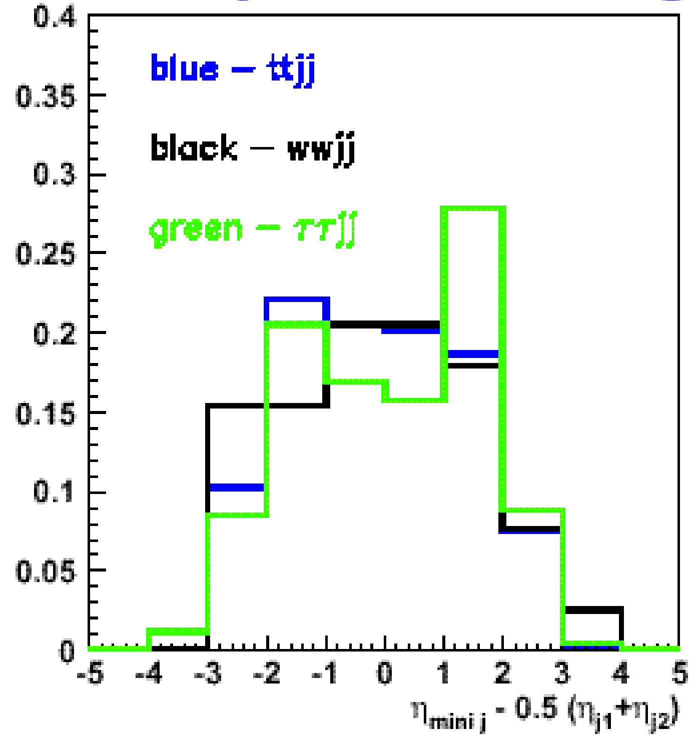
η of mini jet with $E_T > 30$ GeV between tag. jets

$$\eta_0 = \eta_J - 0.5\,(\eta_{J1} + \eta_{J2})^*$$

mini jets in qq->qqH



mini jets in QCD bkg



no color exchange between q's :
no central mini jets

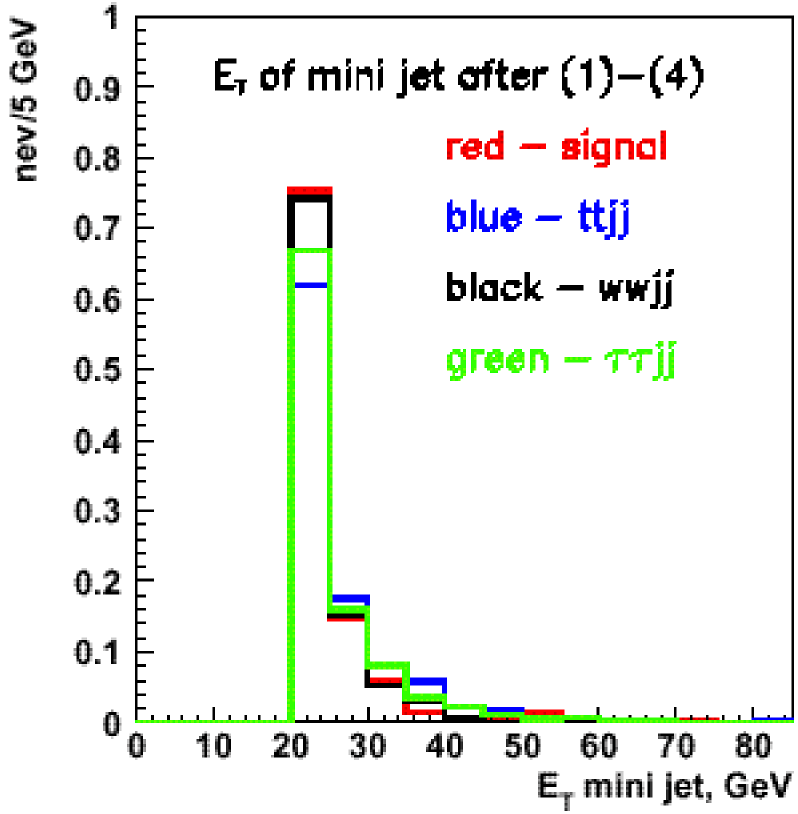
radiation in the central rapidity
region for QCD backgrounds

* D. Rainwater, R. Szalapski, D. Zeppenfeld MADPH-96-943

mini-jet veto : problem with “false” soft calo jets E_T ~ 20 GeV . . .

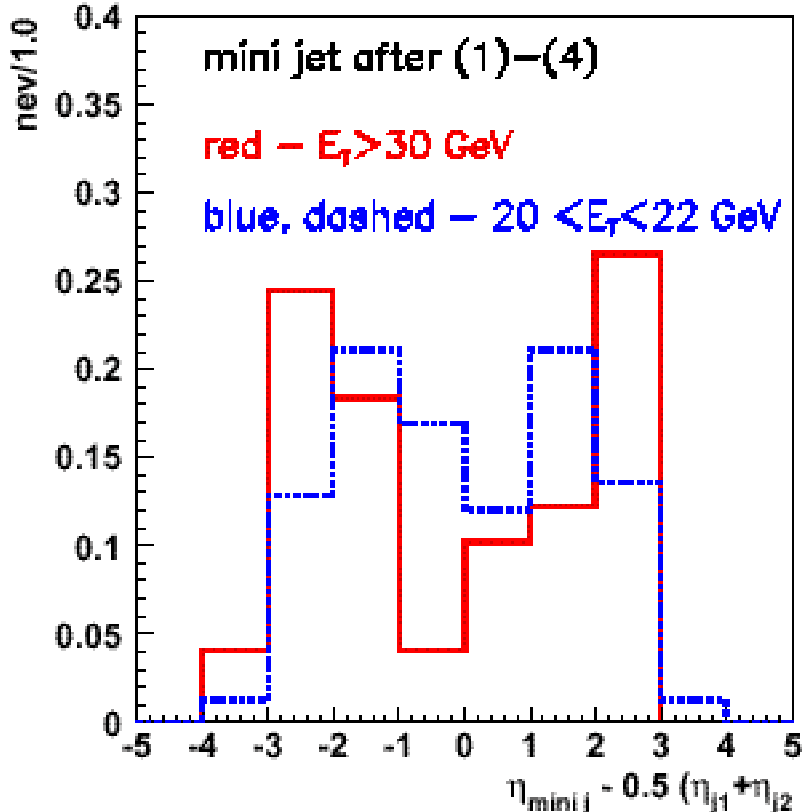
however “false” soft jets may spoil mini jet veto performance . . .

jets between tag.jets



they are very soft

Higgs



very soft jets in Higgs ev. look like in bkg . . .

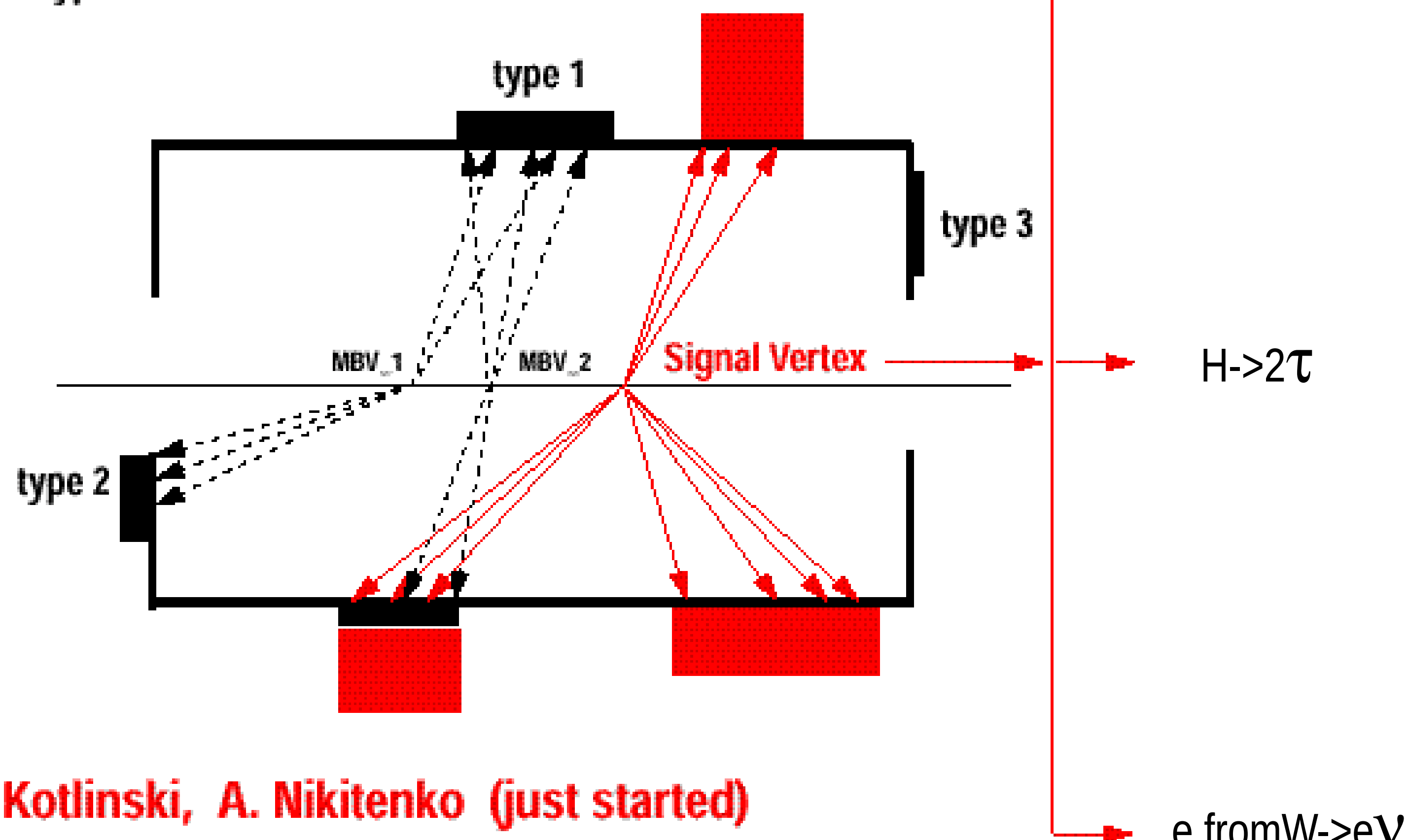
hopefuly tracker will help to recognize false jets . . .

Calo false jets due to :

type 1 - overlap from different min.bias vertices

type 2 - mini jet from min. bias vertex

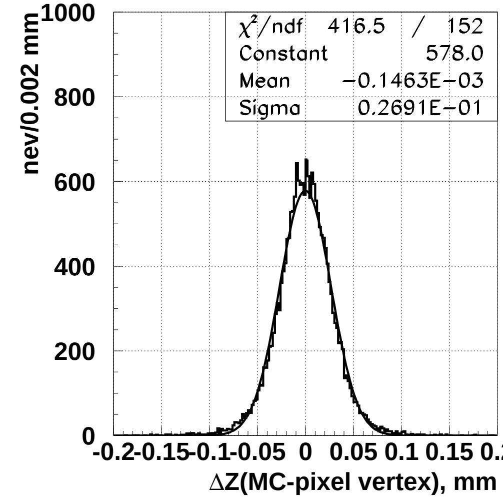
type 3 - electronic noise

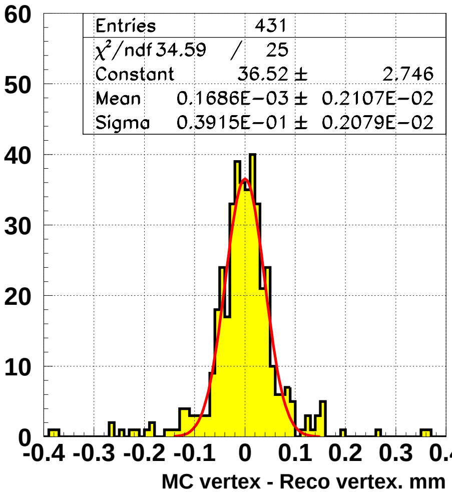


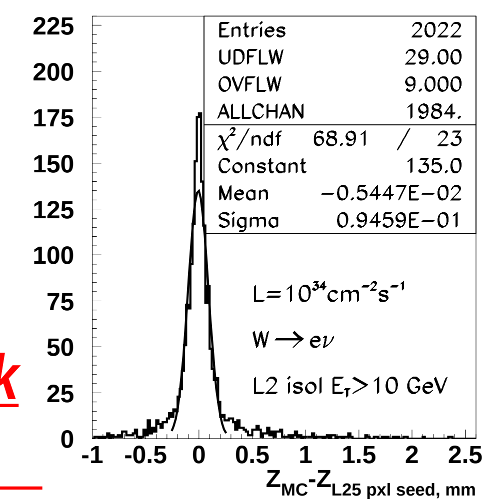
D. Kotlinski, A. Nikitenko (just started)

Is it possible to remove false jets with tracker ? False calo jets should not match with pxl (trk) jets from the signal vertex.

qq->qqH, H->2tau -> l+jet & 2 leptons will require a lot of work with full simulation/analysis to prove that it can be observed

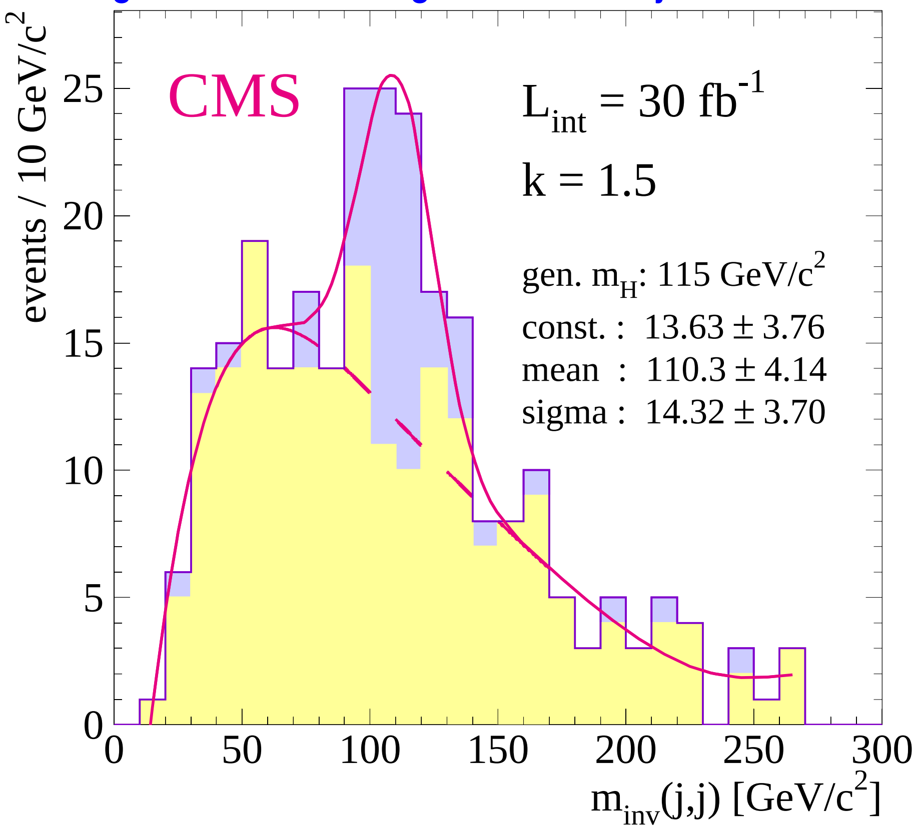


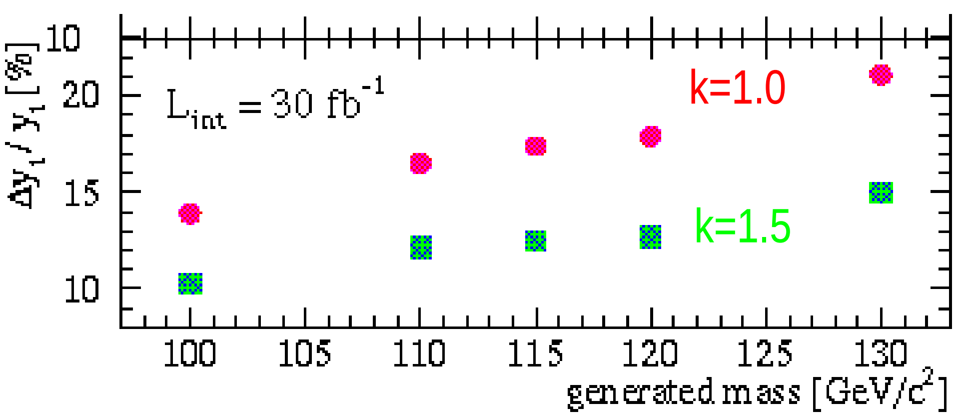




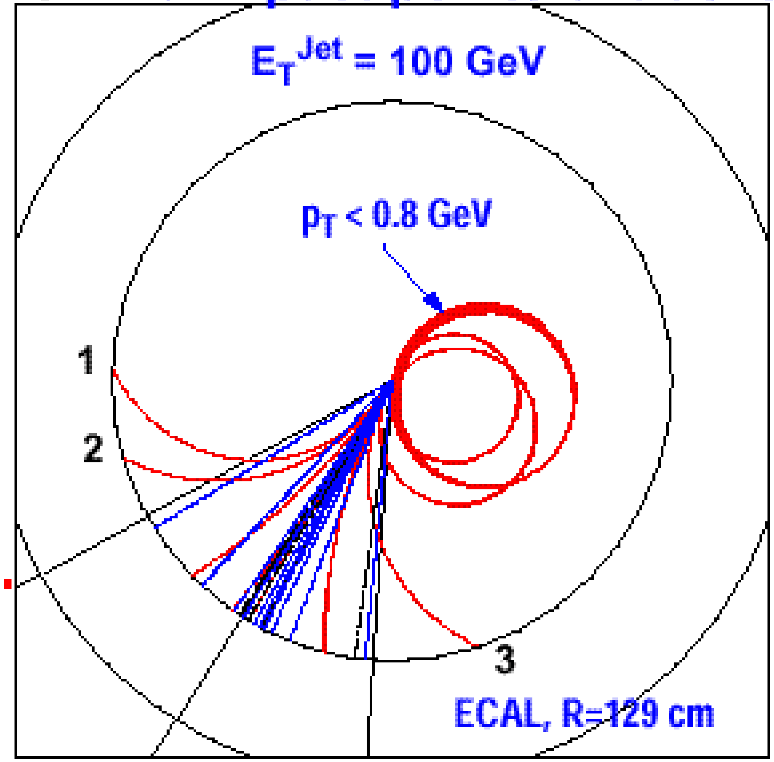
Htt Yukawa coupling measurement in gg->ttH, H->bb (if Br(H->bb) is known)

Drollinger, Muller, Denegri 2001. cmsjet simulation

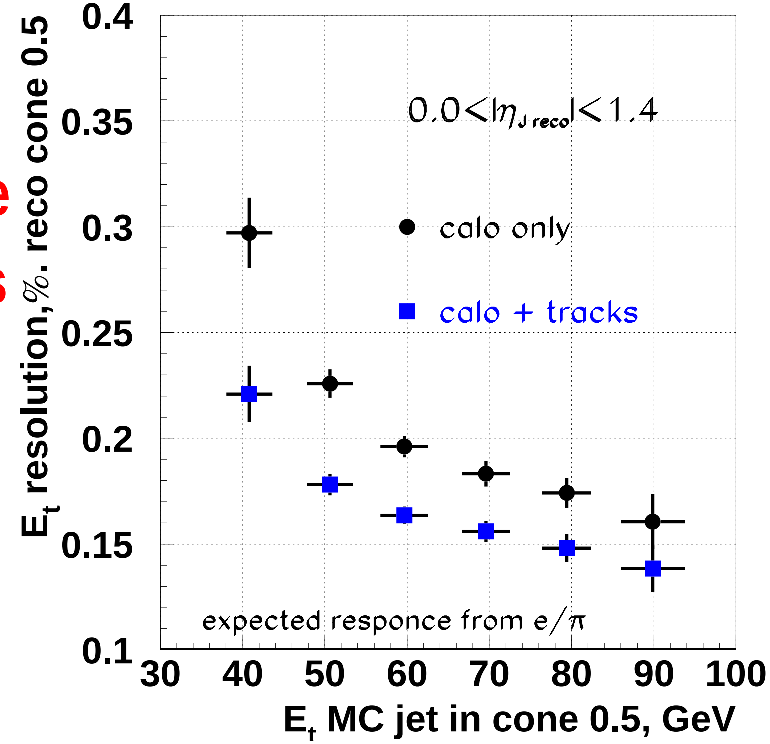




We start to use tracks to improve calo jet energy resolution.



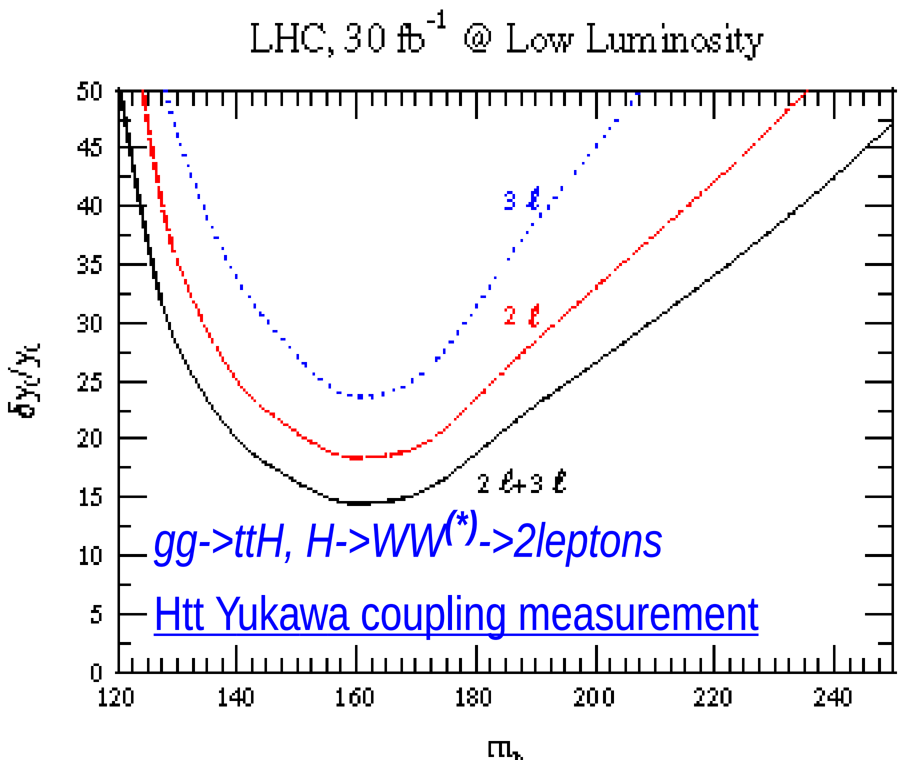
h->bb is the first candidate to try this and improve $\sigma(M_{bb})$



(2002)

O. Kodolova, I. Vardanyan, A. Nikitenko, G. Bruno, L. Fano

Important parton level simulation studies on Higgs coupling measurements which we should check with CMS detector simulation



gg->ttH, H->WW$^{(*)}$->2leptons

Htt Yukawa coupling measurement

F.Maltoni, D.Rainwater, S.Willenbrock 2002

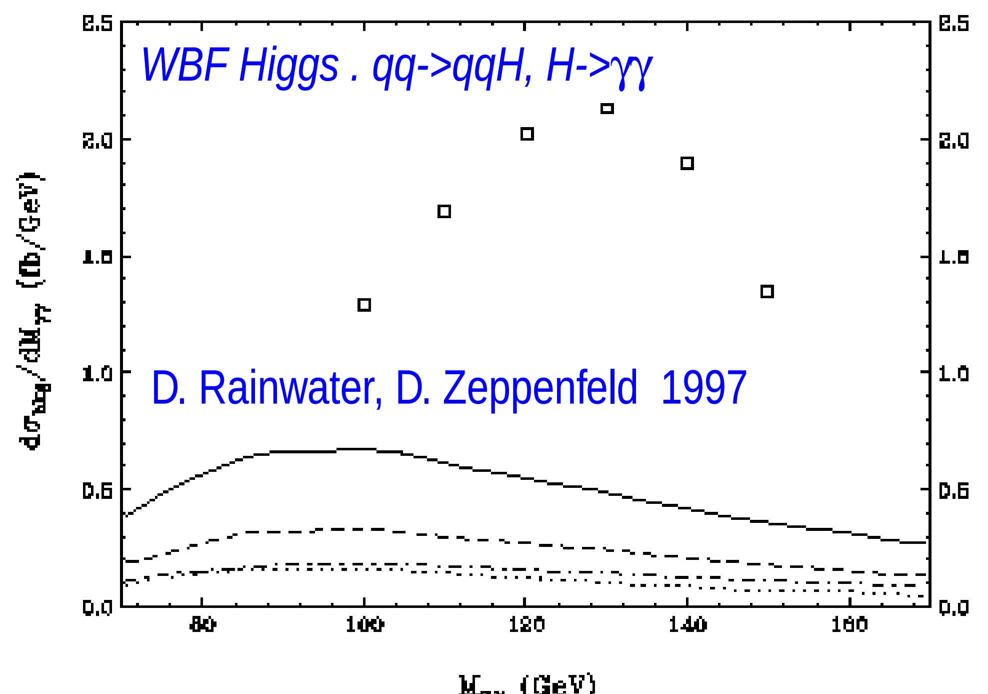
WBF Higgs. qq->qqH, H->bb.

De Roeck, Khoze, Martin, Orava, Ryskin IPPP/02/29.

M.L. Mangano, M> Moretti, F. Piccinini, R. Pittau and A.D. Polosa 2002. for 60 & 600 fb^{-1}

Hbb Yukawa coupling measurement

m_H	115 GeV	120 GeV	140 GeV
(a) $\delta y_{Hbb}/y_{Hbb}$	0.48	0.51	1
	0.16	0.17	0.37
(b) $\delta y_{Hbb}/y_{Hbb}$	0.30	0.30	0.57
	0.10	0.10	0.19



WBF Higgs . qq->qqH, H->γγ

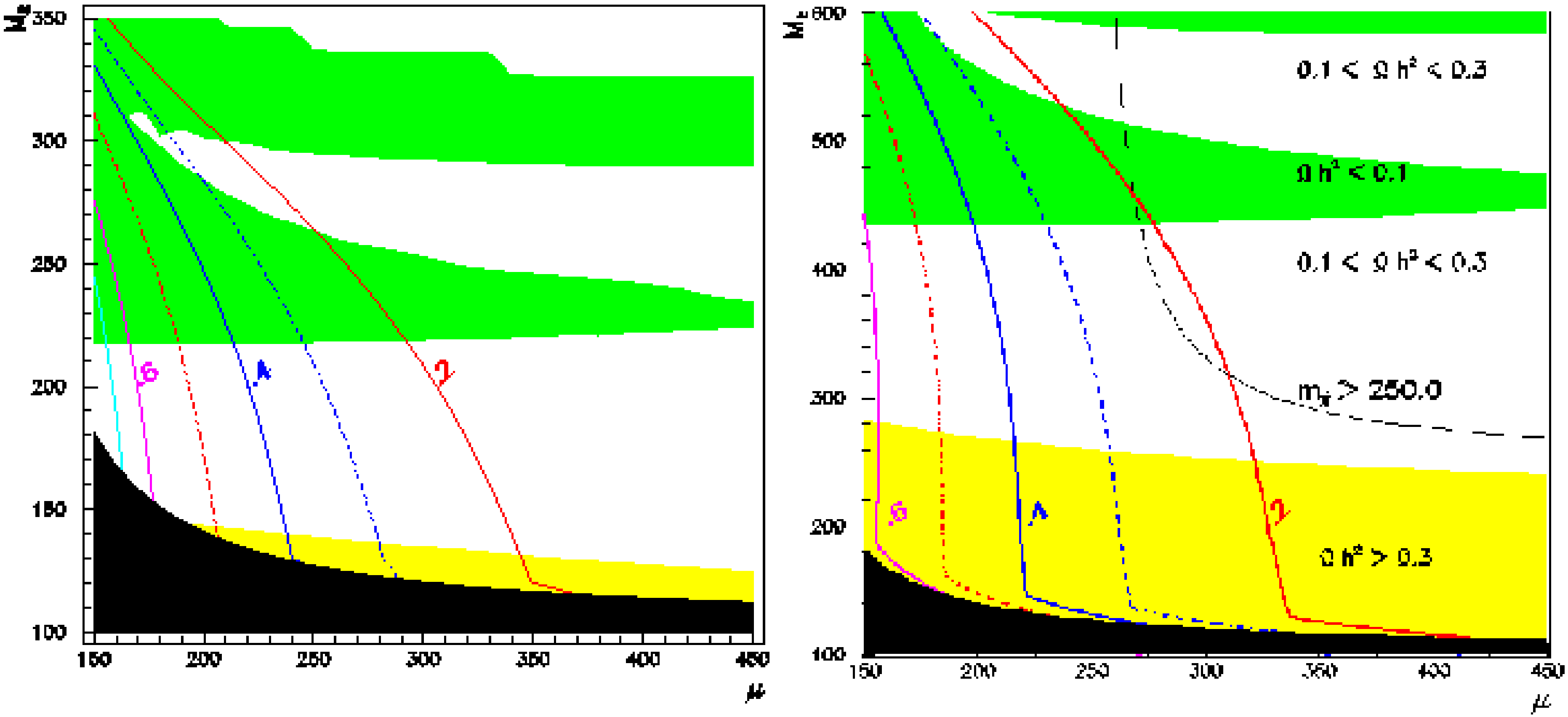
D. Rainwater, D. Zeppenfeld 1997

WBF production of Higgs is important in some "patalogical" cases when branching ratio of Higgs to invisible final states is large (next slides) . . .

Invisible Higgs in qq->qqH, H->$\chi_1^0\chi_1^0$ (O.J.P.Eboli & D.Zeppenfeld 2000)

invisible branching ratio can be large in no-universal models

(Belanger, Boudjema, Cottrant, Godbole, Semenov)



$M_1 / M_2 = 0.1$ $M_1 / M_2 = 0.2$

Figure 10: *Contours of constant B.R.*$(h \to \tilde{\chi}_1^0\tilde{\chi}_1^0) = .2, .3, .4, .5, .6, (.65)$ *for* $r = .1(.2)$ *in the right (left) panel, along with the DM as well as LEP constraints on the* $M_2 - \mu$ *parameter space. The white region is the cosmologically preferred area with* $.1 < \Omega h^2 < 0.3$, *for* $m_0 = 94(100)$ *GeV. This corresponds to* $\tan\beta = 5$ *and* $m_h = 125$ *GeV. The black region corresponds to the area excluded by the chargino searches at LEP. The lightly (heavily) shaded region corresponds to* $\Omega h^2 > 0.3 (< 0.1)$.

For DAQ TDR the effective Level-1 and High Level Trigger has been developed to trigger on invisible Higgs in qq->qqH

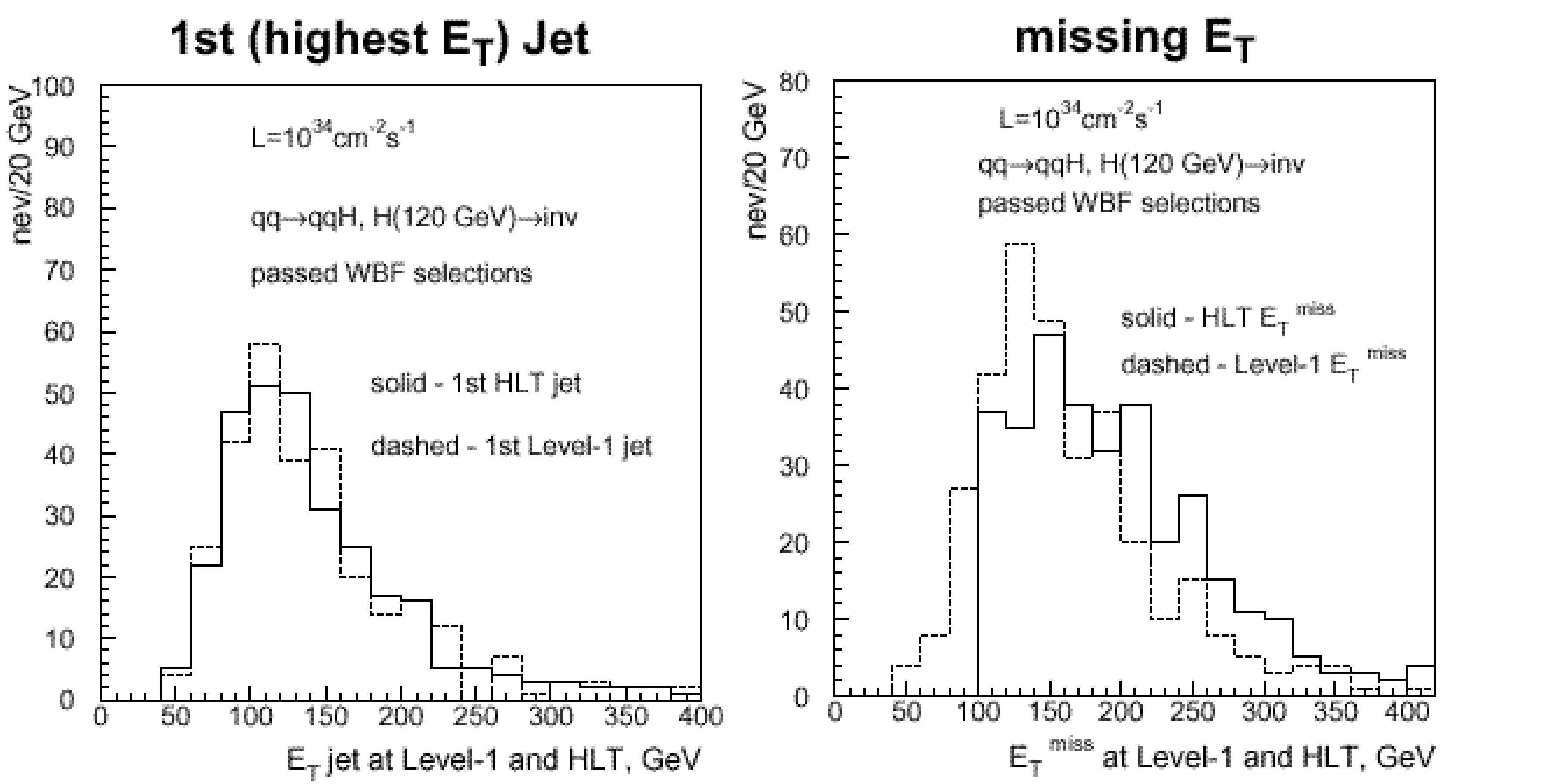
A. Nikitenko

qq->qqH, H->invisible : possible strategy at Level-1 (I)

Level-1 Jet + E_T^{miss}

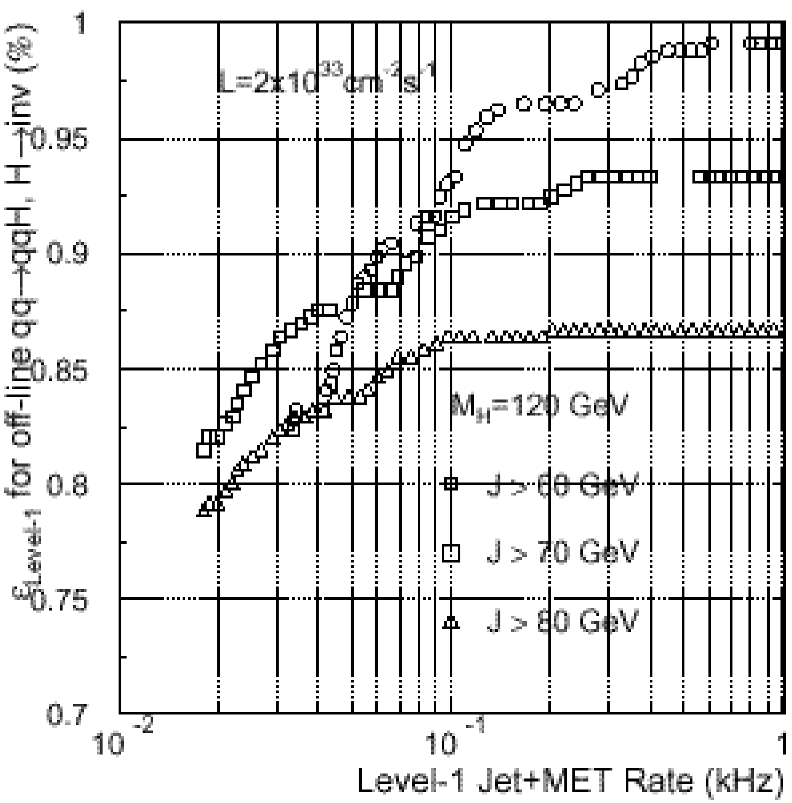
efficiency is defined for Higgs events passed off-line WBF cuts :

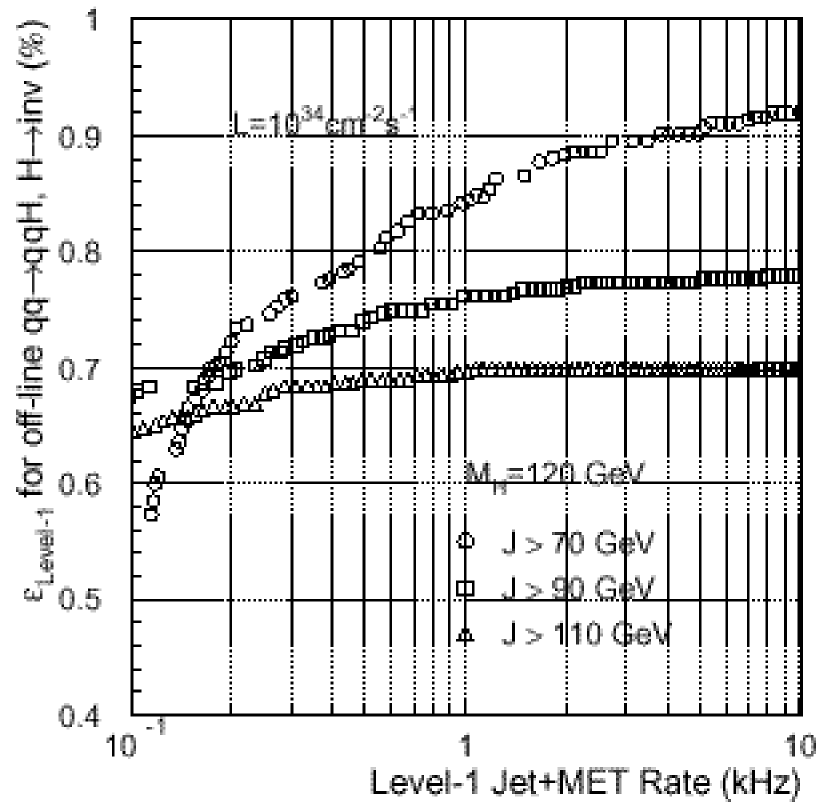
$E_T^J > 40$ GeV, $|\eta_{j1} - \eta_{j2}| > 4.4$, $\eta_{j1}\eta_{j2} < 0$, $M_{j1j2} > 1200$ GeV, $\phi_{j1j2} < 1$, $E_T^{miss} > 100$ GeV



qq->qqH, H->invisible : possible strategy at Level-1 (III)

Level-1 Jet + E_T^{miss} optimization: efficiency vs rate

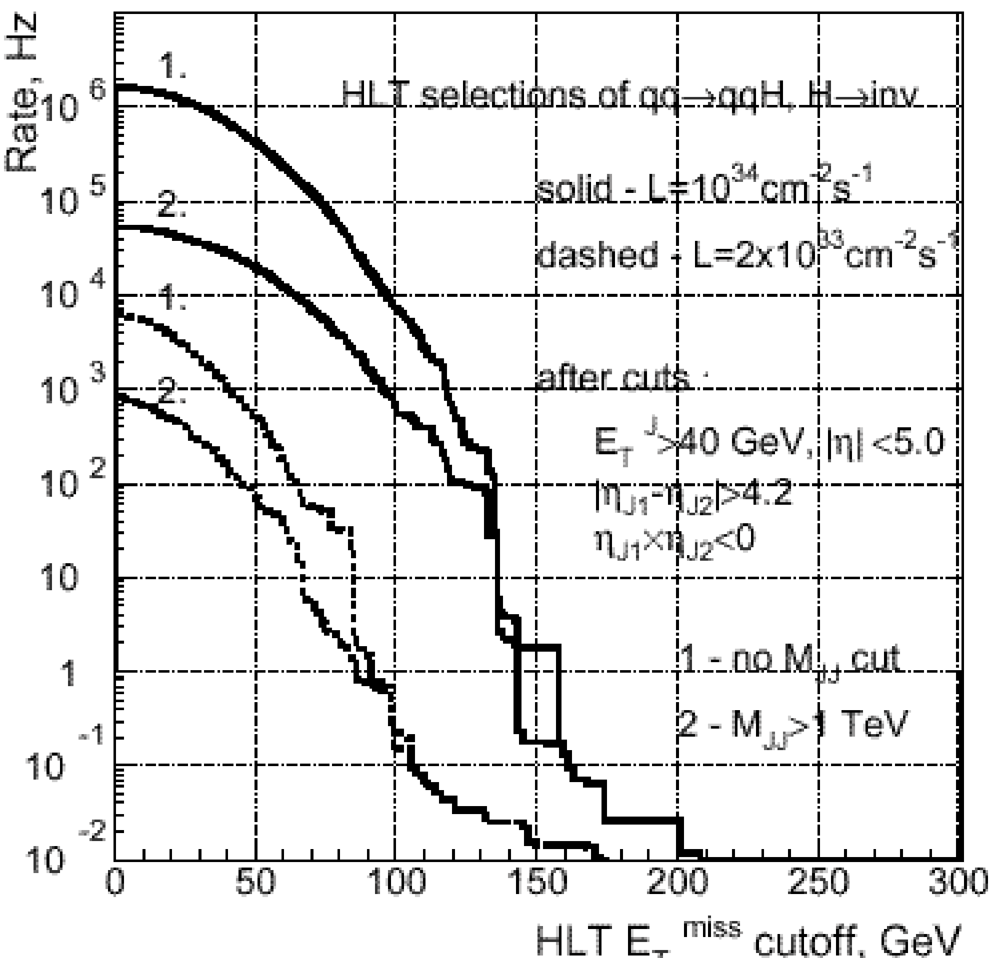


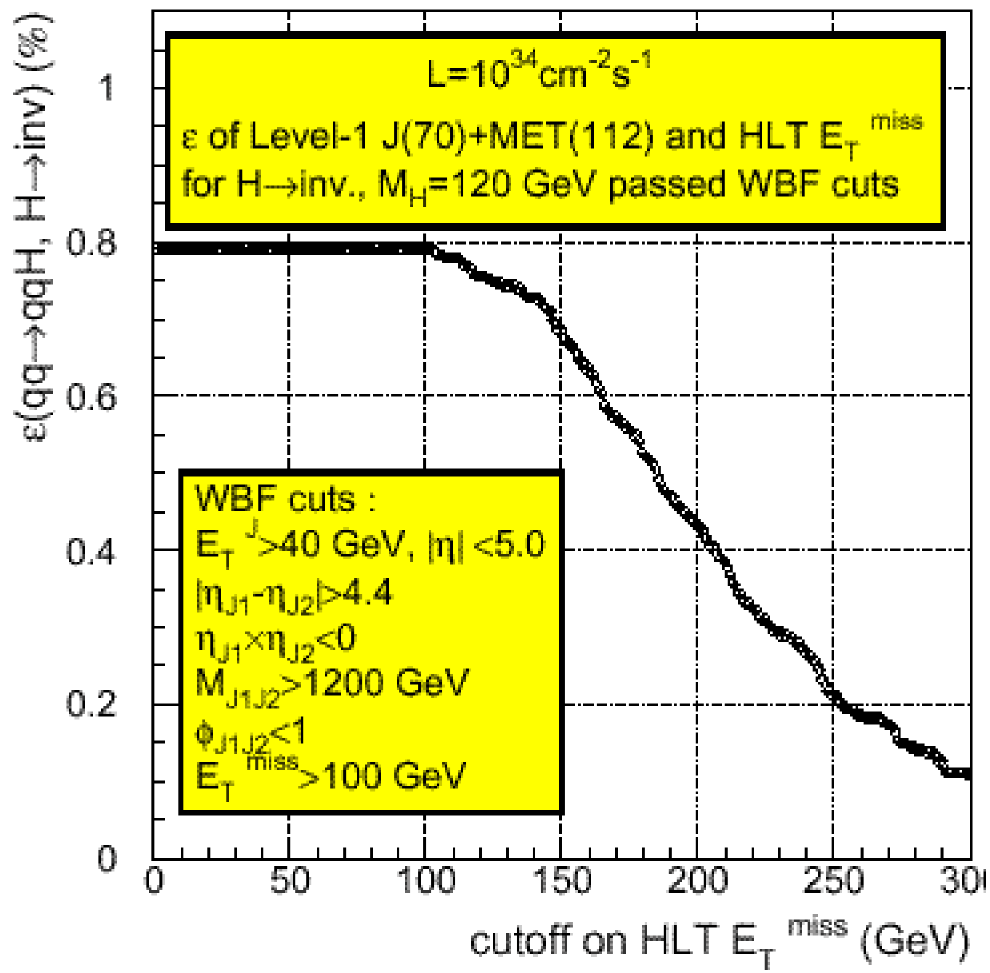


Level-1 Rate of J1+MET, kHz		0.2	0.5	1.0
$L=2x10^{33}cm^{-2}s^{-1}$	L1 J1, MET thresholds, GeV	60, 73	60, 64	60, 56
	L1 efficiency	0.96	0.98	0.99
$L=10^{34}cm^{-2}s^{-1}$	L1 J1, MET thresholds, GeV	70, 122	70, 112	70, 103
	L1 efficiency	0.72	0.79	0.84

qq->qqH, H->invisible : possible strategy at HLT (I)

HLT with loose WBF cuts; optimization of E_T^{miss} cutoff





- ϕ_{j1j2} cut is not desirable for H->inv, since prevents physics background estimates from the data (QCD/EW W/Z bkg)

.....

off-line analysis of qq->qqH, H->inv with full and fast simulation data

(Les Houches Higgs Working Group summary report hep-ph/0203056)

qq -> qqH, H-> invisible ($\chi_0^1 \chi_0^1$)

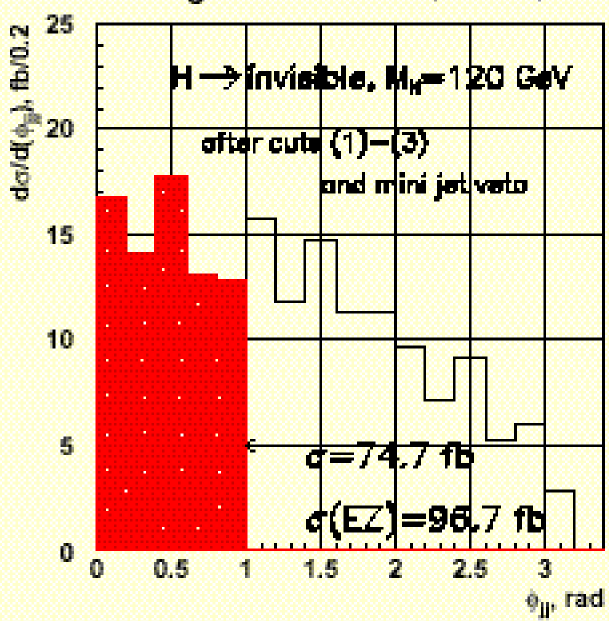
K. Mazumdar, A. Nikitenko

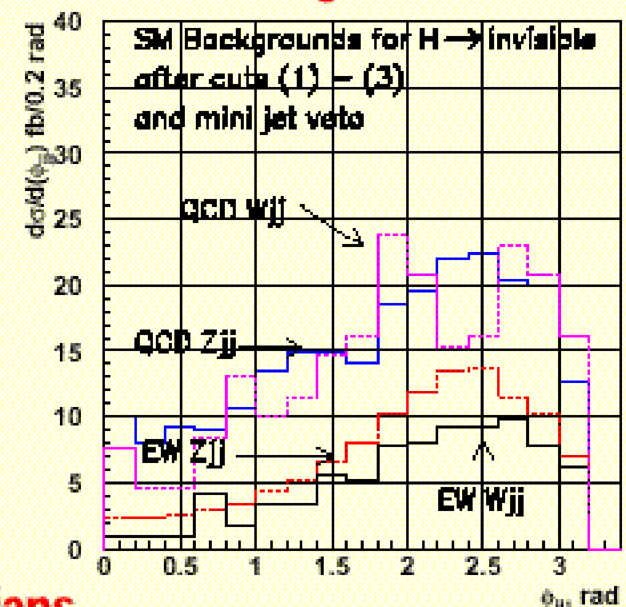
WBF selections :
(1) $E_{Tj1,j2} > 40$ GeV, $|\eta_{j1,j2}| < 5.0$, $|\Delta\eta_{j1,j2}| > 4.4$, $\eta_{j1}\eta_{j2} < 0$
(2) $M_{JJ} > 1200$ GeV
(3) missing $E_T > 100$ GeV
(4) central jet veto & lepton veto

Search for event excess in $\Delta\phi_{JJ} < 1$ rad.

assuming SM σ and Br(H->inv) = 100 %

Background will be known from data; syst. error on bkg. is still under study

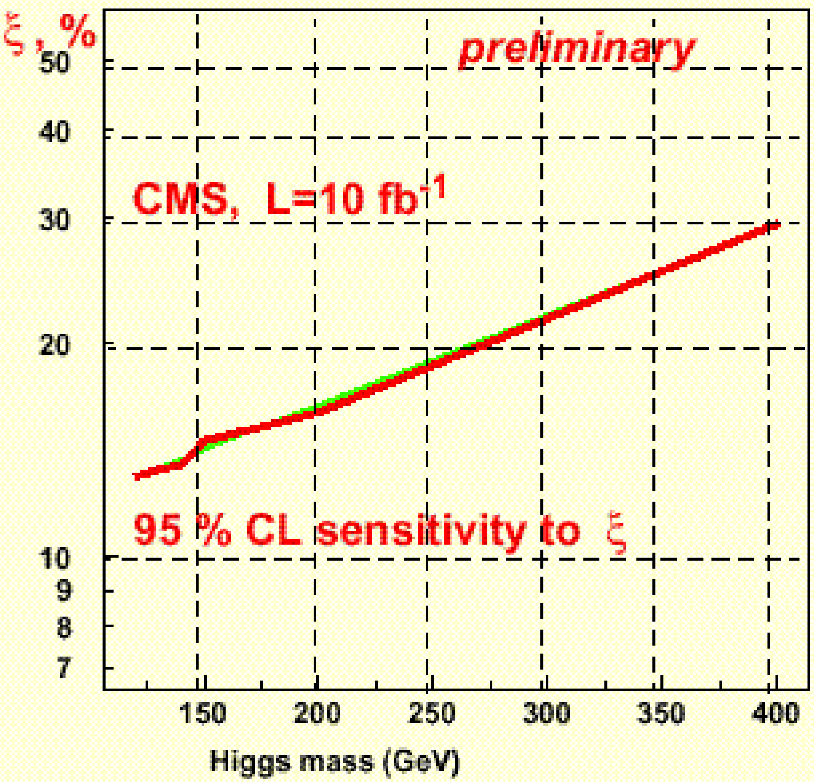




$\Delta\phi_{JJ}$, radians

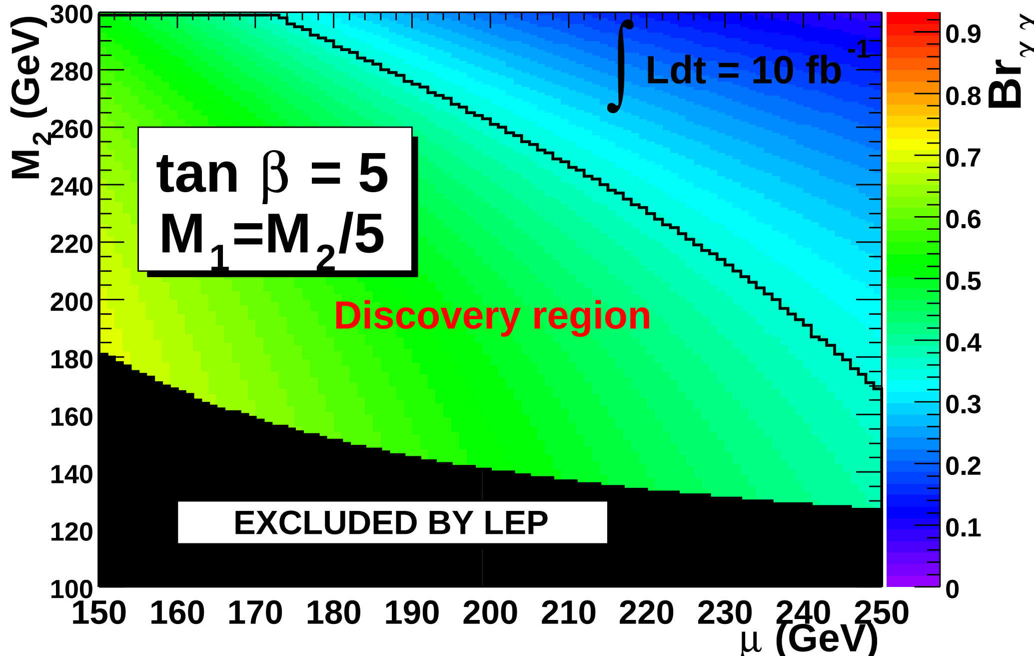
qq -> qqH, H-> invisible ($\chi_0^1 \chi_0^1$) K. Mazumdar, A. Nikitenko

ξ = Br(H->invisible) x σ(qq->qqH) / $\sigma(qq\text{->}qqH)_{SM}$



ATLAS : m_h=120 GeV

in decoupling limit : M_A=1 TeV, M_{stop}=1 TeV, A_t=2.4 TeV



I did not say

I did not say about interesting Higgs studies going on in CMS now :

MSSM A^0/H^0, H^+-> sparticles and Higgs from SUSY cascades

F. Moortgat with Djouadi, Datta, Guchait, Mambrini, S, Moretti

new updates with full simulations on

MSSM A/H-> $\mu\mu$ L. Bellucci

gg->ZZ^*-> 4μ V. Ciulli, M. Sani

current studies on :

HW-> lept + bb S. Gennai

update on WH, ttH-> lept + 2 γ O. Ravat, S. Gascon

H-> hh -> 4b L. Fano

radion -> hh -> 2γ + 2b G. Dewhirst , A. Nikitenko

THE END

“External” conditions for taus at High Level Trigger

Working points of Level-1 1T or 2T trigger

rate, kHz	luminosity	1T threshold (95 %), GeV	2T threshold (95%), GeV	$\varepsilon(H^0\to 2\tau)$ M_H=200 GeV	$\varepsilon(H^+\to \tau\nu)$ M_H=200 GeV
3	low	93 (86)	66 (59)	0.78	0.81
	high	129(124)	85(80)	0.34	0.55
6	low	82(75)	60(53)	0.87	0.84
	high	112(107)	76(71)	0.54	0.72
8	low	78(71)	57(50)	0.90	0.85
	high	106(101)	72(67)	0.62	0.76
9	low	76(69)	56(49)	0.91	0.86
	high	102(97)	72(67)	0.65	0.78

- **Level-1 output rate of 1T and 2T triggers : 3 kHz at low lumi**
  8 kHz at high lumi
- **HLT output rate on tape for taus : 4 (10) Hz at low (high) lumi**
- **accepted time at HLT per Level-1 event ~ 500 ms at 1 GHz PIII**

analysis of qq->qqH, H->2 τ -> lepton + τ-jet (may skip this slide)

fast cmsjet simulation. tau-id from full simulation

y

cmsjet simulation

data for M_H=135 GeV	H->ττ->lj	QCD Z+2j*	EW Z+2j**	W+3j	bb+2j
cross-sect x Br(Z->2τ/W->lν)	0.1715	1.044	0.314/0.036	5180	
p_t^j>14 GeV, |η|<2.4. MC $p_t^{\tau-j}$>20 GeV, |η|<2.4 MC	0.364	0.314	0.283/0.343	0.616	
tracker lep isol + p_t^l > 15 GeV	0.873	0.906	0.939/0.930	0.88	
calo lepton isolation	0.915	0.954	0.939/0.967	0.91	
>=3 jets, E_t>30 GeV, |η|<4.5	0.451	0.363	0.665/0.601	0.04	
τ-jet association(MC)	0.886	0.867	0.769/0.866	0.0019	
$\eta_{j\,min}+0.7<\eta_{l,\tau-j}<\eta_{j\,max}-0.7$ $\eta_{j\,min}\,\eta_{j\,max} < 0$	0.587	0.757	0.527/0.559	0.20	
$\|\eta_{j\,max}-\eta_{j\,max}\| > 4.4$	0.718	0.867	0.521/0.647	0.48	
M_{JJ} > 1 TeV	0.635	0.455	0.708/0.690	0.34	
$m_t(l,p_t^{miss})$ < 30 GeV	0.764	0.794	0.852/0.759	0.16	
$0<x_{\tau l}<0.75$, $0<x_{\tau h}<1$	0.666	0.623	0.639/0.680	0.37	
M_H window 30 GeV	0.770	0.047	0.026/0.228	0.05	
P_{surv} mini jet veto from D.Z.	0.87	0.28	0.80	0.28	0.28
N event for 30 fb^{-1}	6.7 +-0.3	0.63+-0.10	0.29 / 0.45 0.74+-0.08	0.14+-0.05	-
D.Z. estimates	6.2	1.1			

*D.Zeppenfeld ME element +pythia , E_t^j > 20 GeV, \|η\| < 5.35, M_Z > 70 GeV, M_{JJ} > 700 GeV, $|\Delta\eta_{JJ}|$ > 4.2, p_t^{τ} > 20 GeV

** EW Z+2J - generated by S.Ilyin with comhep, cteq4m, E_t^J>20 GeV, \|η\| < 5, 80<M_Z<100 GeV / M_Z>100 GeV, M_{JJ}>500 GeV

eff. of tau-id = 0.32, tau/jet missidentification = 0.0019 , eff lepton reco = 0.90

off-line analysis of qq->qqH, H->inv with full and fast simulation data

kinematics generation

- QCD and EW production of W jj + Z jj with COMPHEP and ME input from D. Zeppenfeld with loose cuts :

  $p_{Tj1,j2} > 20$ GeV, $|\eta_{j1,j2}| < 5.0$, $|\Delta\eta_{j1,j2}| > 4.2$, $\eta_{j1}\eta_{j2} < 0$

QCD W+jj	QCD Z+jj	EW W+jj	EW Z+jj
76.0 pb	15.7 pb	4.7 pb	0.64 pb

Br(Z -> $\nu\nu$) and Br (W->l ν) is included

processed with fast detector simulation

- QCD bkg for missing E_T study. ~ 1M of events in p_T bins from:

  10-15 GeV (σ = 8.87e+12 fb) to
  2600-3000 GeV (σ=11.25 fb)

  fully simulated (cmsim) and reconstructed (orca) events

- Higgs of 120 GeV. (σ_{prod}=4.3 pb) *fully simulated events*