SELECTED SIGNALS : THE JORNEY FROM INTERACTION POINT TO THE TAPE ...

Progress on Studies of Signals Containing Jets and Missing ET

Salavat Abdullin (UMD) for HCAL/Jets/MET group

- **Invisible Higgs**

  Jim Brooke (Bristol Univ.)

- **qqH→ qqWW→ 2 l + MET + 2 tagging jets**

  Mehmet Zeyrek (Texas Tech Univ.)

  Sasha Nikitenko (Imperial College)

- **mSUGRA @ M_{SUSY} ~ 0.5 and 1.0 TeV**

  Salavat Abdullin (Univ. of Maryland)

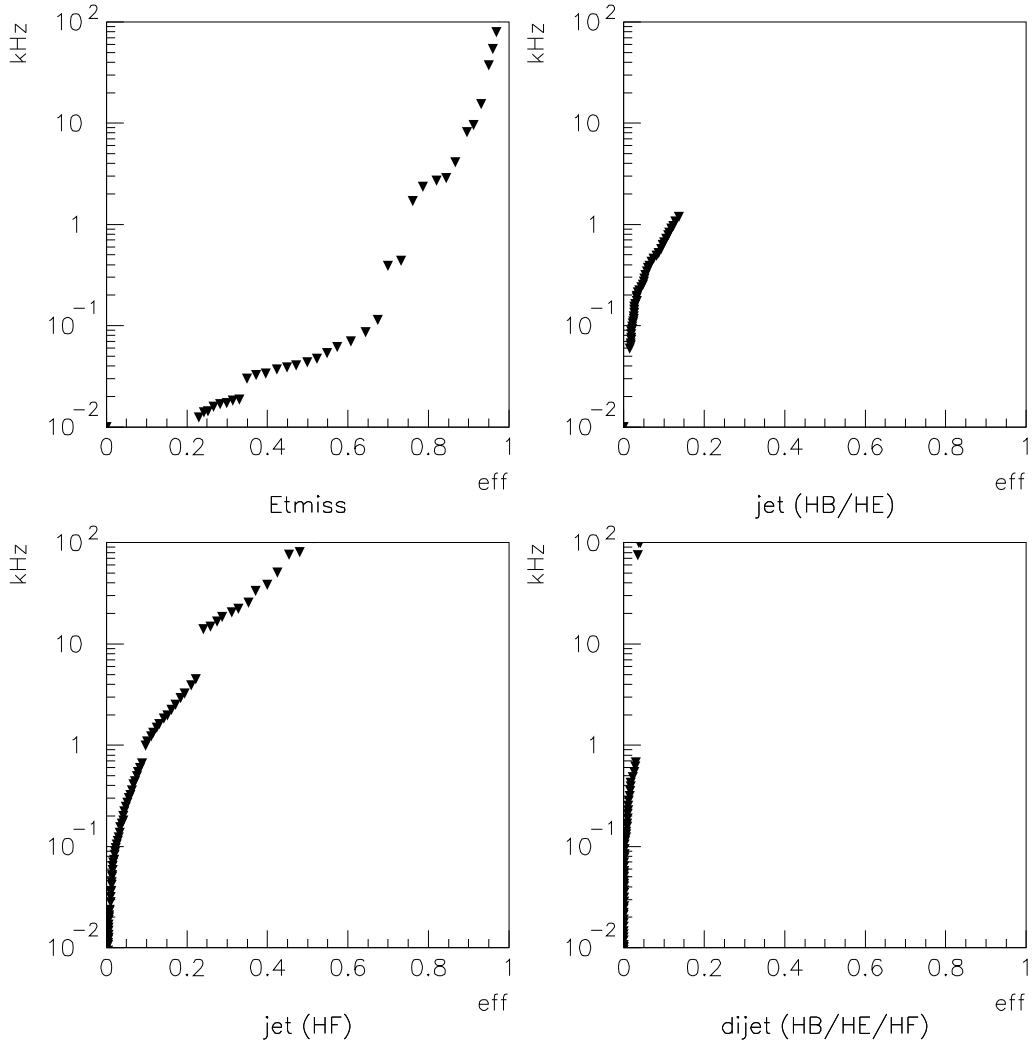
INVISIBLE HIGGS (I)

Jim Brooke (Bristol Univ.)

- **Accodring to some models, Higgs may decay to invisible (undetectable) particles with significant branching ratio ...**
  - O.Eboli and D.Zeppenfeld, Phys.Lett., B495 (2000) 147
  - SM WBF production cross section ~ 5 pb for $m_H = 120$ GeV
  - Br ~ 13 % (~ 5 %) is required 10 fb^{-1} (100 fb^{-1}) to observe the signal at the 95 % CL, according to the paper ...

INVISIBLE HIGGS (II)

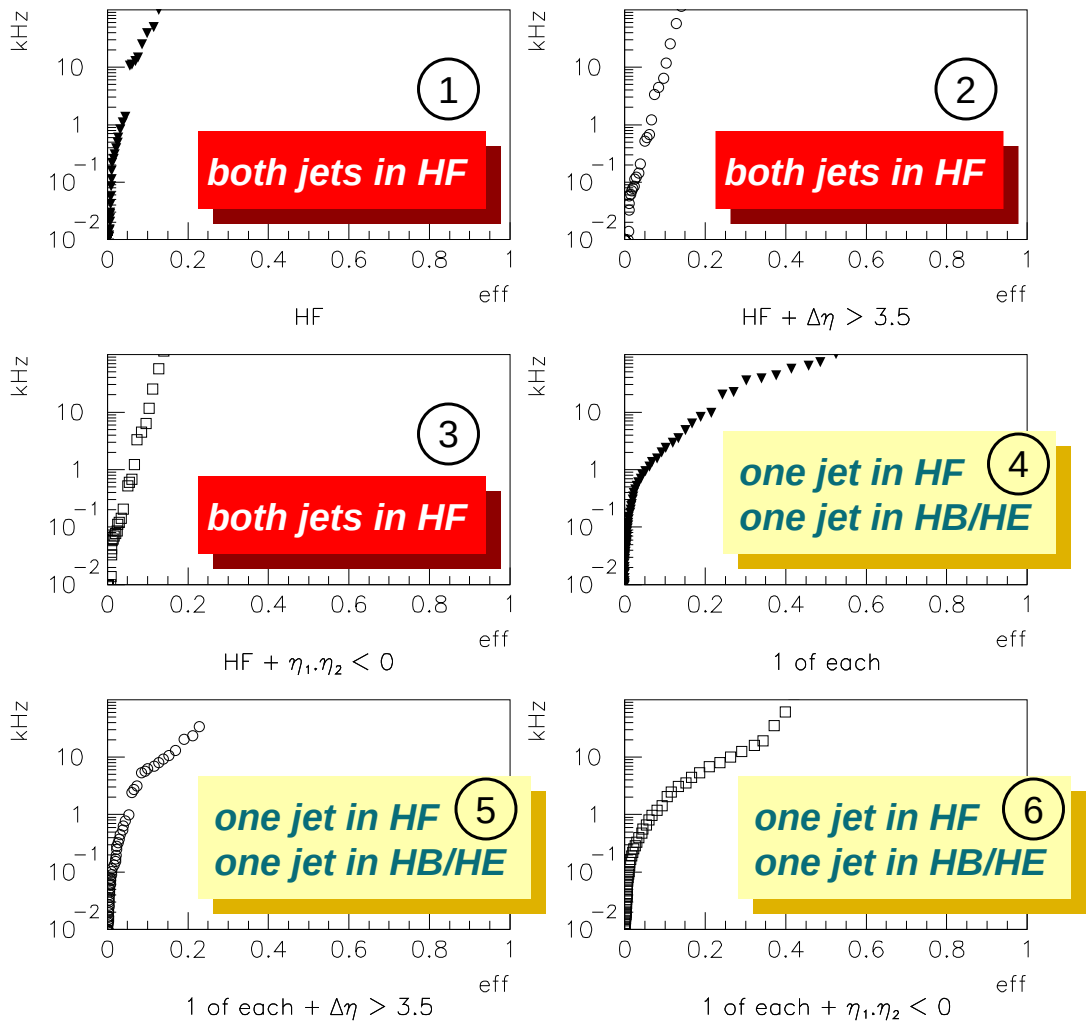
L1 QCD rate vs signal efficiency



- **Efficiencies quoted wrt cuts on generated quantities :**
  - $E_T^{miss} > 100$ GeV
  - 2 tag.quarks with $E_T > 40$ GeV, $\eta < 5$
  - $\Delta\eta_{qq} > 4.4$, $\eta_{q1} \cdot \eta_{q2} < 0$
- **Jet energy corrections :**
  - Andrei Krokhotine (ITEP) for low luminosity

INVISIBLE HIGGS (III)

L1 QCD rate vs signal efficiency



- **Efficiency vs MET is MET-sensitive ...**
- **So attempt to trigger on tag jets ...**
- **Simple dijet trigger is ineffective ...**
- **Use of available topological cuts ...**
- **Plans :**
  - to combine 3,4,5,6 with missing ET
  - to try "HT" (total hdronic trigger)

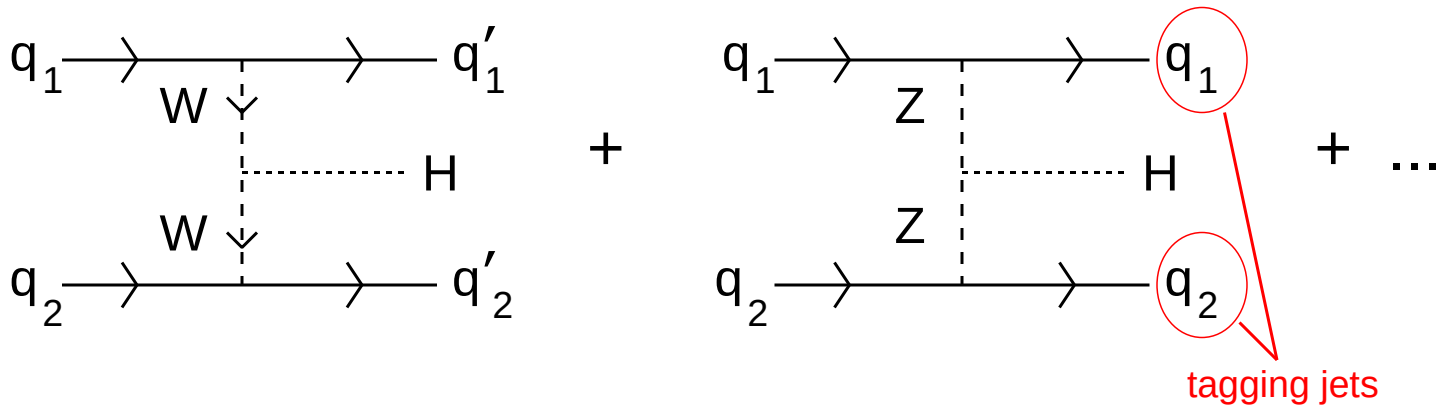
PREVIOUS STUDIES : THERE IS A HOPE ...

	Lumi.	Jet / MET cuts (GeV)	Signal eff. (%)
1 Sasha Nikitenko, talk at the special joint L1 meeting, November 9, 2000 (included in Trigger TDR)	10^{33}	50 / 50	96 wrt off-line preselection
	10^{34}	80 / 100	58 wtr off-line preselection
2 Salavat Abdullin, Sarah Eno p.13 of the talk mentioned above; CMS IN 2000/060	10^{34}	80 / 100	58 wrt off-line preselection
3 Pamela Chumney et al., CMS IN 2001/042	$2 \cdot 10^{33}$	120 / 100	49 no preselection

qqH -> qqWW -> 2l + MET + 2 TAGGING JETS

Sasha Nikitenko (Imperial College)

- **Production mechanism is the same as for "invisible" Higgs, but now 2 leptons appear to trigger on ...**



- **Could be a discovery channel at the very beginning of the LHC running**

☞ D.Zeppenfeld et al., Phys.Lett., B503 (2001) 113 : optimized cuts with ME + (smeared) ATLAS

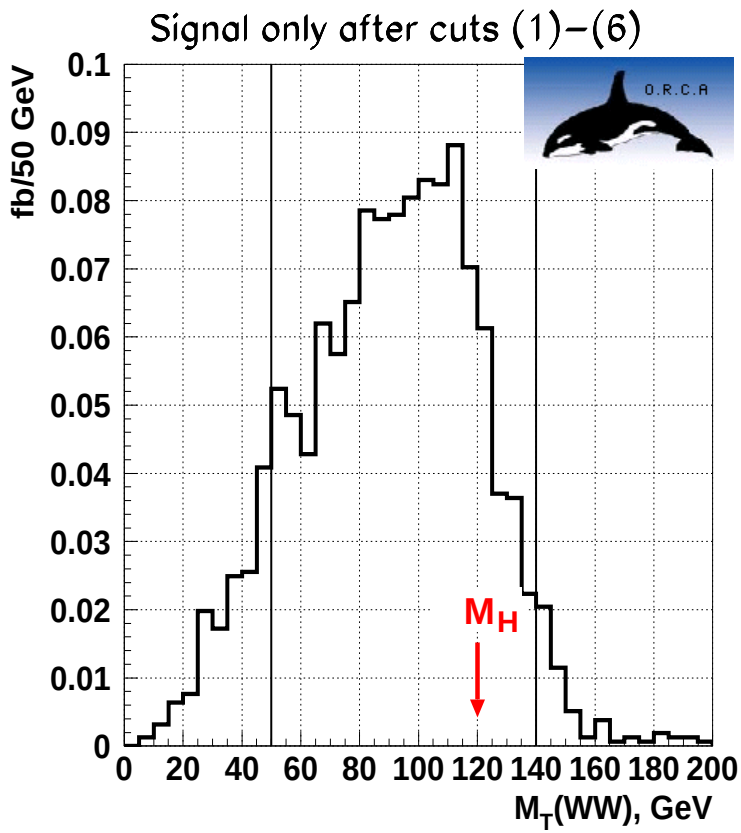
comphep+pythia+orca analysis by A. N. v.s. ME+smeared detector by D. Zeppenfeld et ll

cuts are as in the paper D.Z. et al PL B 503 (2001) 113-120	σ, f b (A.N.)	σ, f b (D.Z)
cross-section qq->qqH, H->WW*-> e μ + P_T^{miss}	6.38	
(1) > 1 jet E_T^J>30 GeV, P_T^l>20,10 GeV, $\|\eta^l\|$ < 2.4, ΔR_{lJ} > 0.7	2.25	D.Z. E_T^J > 20 GeV
(2) $\eta_J^{min} - 0.6 < \eta_{lept} < \eta_J^{max} - 0.6$, $\eta_{J1} \times \eta_{J2} < 0$	1.96	
(3) M_{JJ} > 600 GeV, $\|\eta_{J1} - \eta_{J2}\|$ > 4.2	1.66	
(4) no jets E_T > 30 GeV with $\eta_J^{min} - 0.6 < \eta_J < \eta_J^{max} - 0.6$	1.64	D.Z. E_T^J > 20 GeV
(5) m_{ll} < 60 GeV, ϕ_{ll} < 140 ^{0}	1.49	
(6) veto on $X_{\tau 1}$ > 0, $X_{\tau 2}$ > 0, $\|M_{\tau\tau} - M_Z\|$ < 25 GeV	1.32	
(7-8) 50 GeV < M_T (WW) < M_H + 20 GeV (140 GeV)	1.12	1.65
(9) $\Delta\phi(l\ l, P_T^{miss}) + 1.5\ P_T^H > 180^0$ and $12\ \Delta\phi(l\ l, P_T^{miss}) + P_T^H > 360^0$	0.96	1.48
(10) P_T^{miss} > 20 GeV if P_T^H < 50 GeV (against bb)	0.95	1.46 x 0.89 = 1.30
(11) m_{ll} > 10 GeV, P_T^{miss} > 30 GeV for ee, μμ analysis	0.81	0.92

not too much different !

M_T (WW) RECONSTRUCTION

$$M_T^2(WW) = (E_T^{miss} + E_T^{ll})^2 - (\vec{P}_T^{miss} + \vec{P}_T^{ll})^2$$

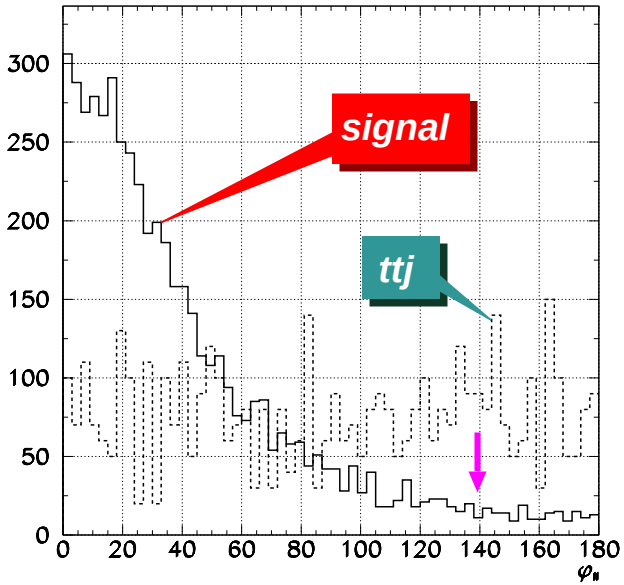


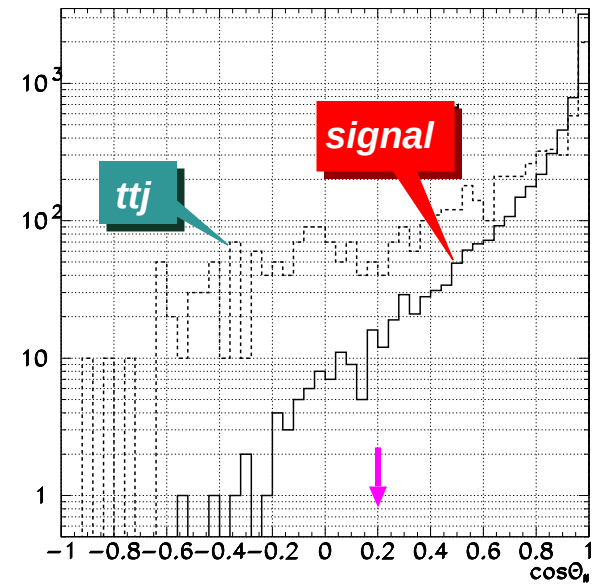
BACKGROUND VS SIGNAL

Mehmet Zeyrek (Texas Tech University)

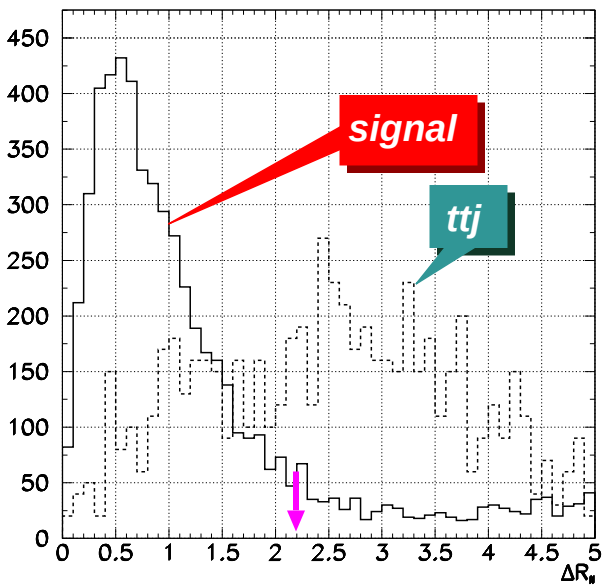
- **ORCA-processed samples**
  - 20 k signal ($\sigma \cdot$ Br = 12.7 fb $\rightarrow$ 127 ev / 10 fb^{-1})
  - 20 k $t\bar{t}j$ ($\sigma \cdot$Br = 36.8 pb $\rightarrow$ 3.68 $\cdot 10^5$ ev / 10 fb^{-1})
- **Forward jet tagging + lepton selection (basic cuts)**
  - $E_T^j > 20$ GeV, $|\eta_j| < 5$, $\Delta R_{jj} > 0.7$
  - $E_T^l > 20$ GeV, $|\eta_l| < 2.4$, $\Delta R_{lj} > 0.7$
  - $\eta_{min} + 0.7 < \eta_l < \eta_{max} - 0.7$
- **Jet veto (extra jets)**
  - jet with $E_T^j > 20$ GeV, $\eta_{min} < \eta_j < \eta_{max}$
- **Additional cuts (deduced from distributions after basic cuts)**
  - $M_{jj} > 650$ GeV
  - $M_{ll} < 60$ GeV
  - $\phi_{ll} < 140^o$
  - $\cos\theta_{ll} > 0.2$

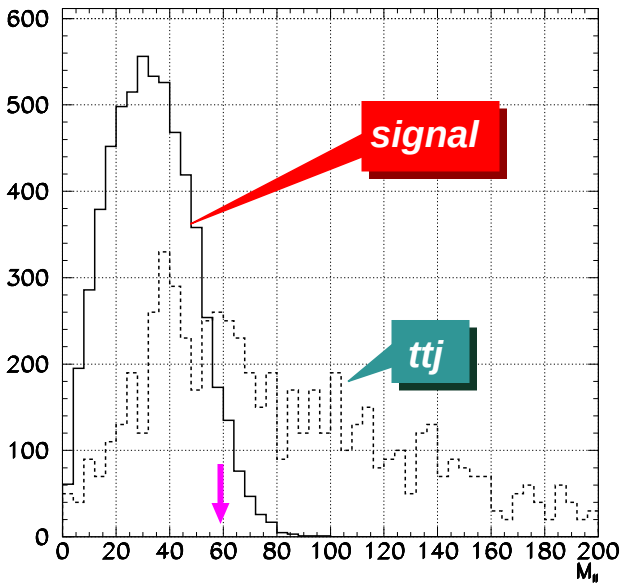
DISENTANGLING SIGNAL FROM BACKGROUND (I)





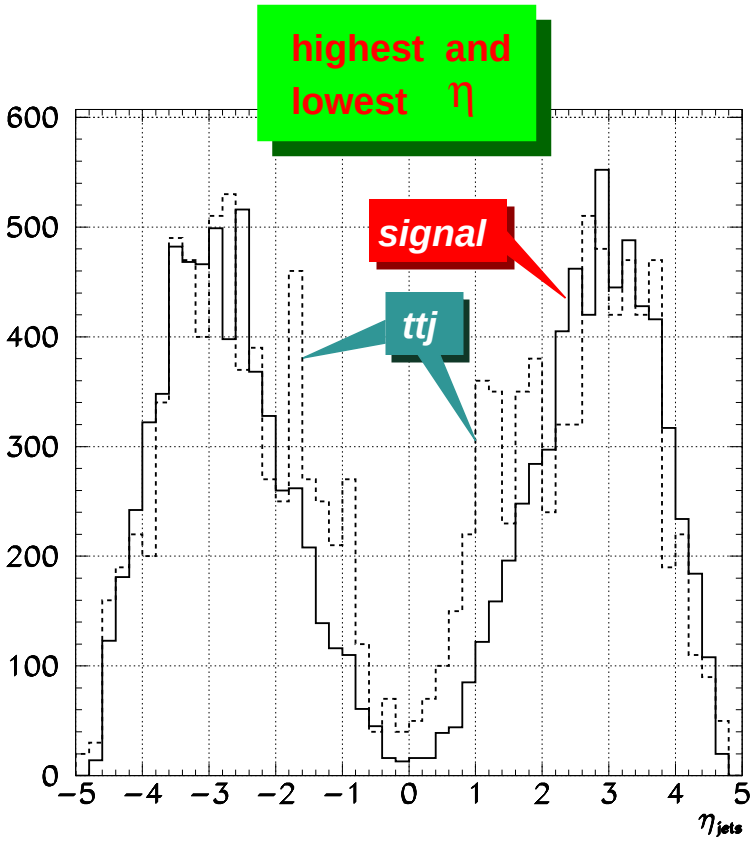
Leptons

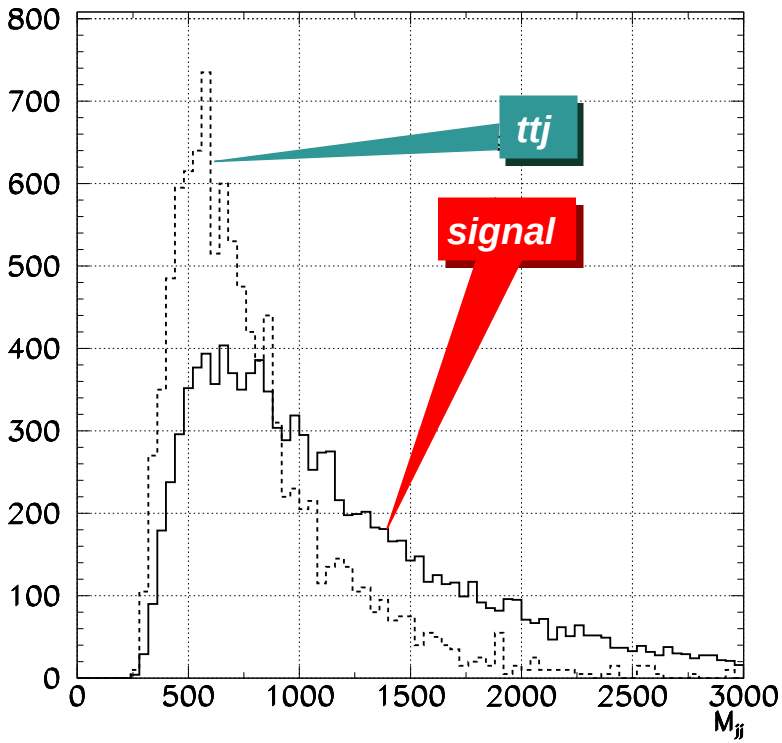




DISENTANGLING SIGNAL FROM BACKGROUND (II)

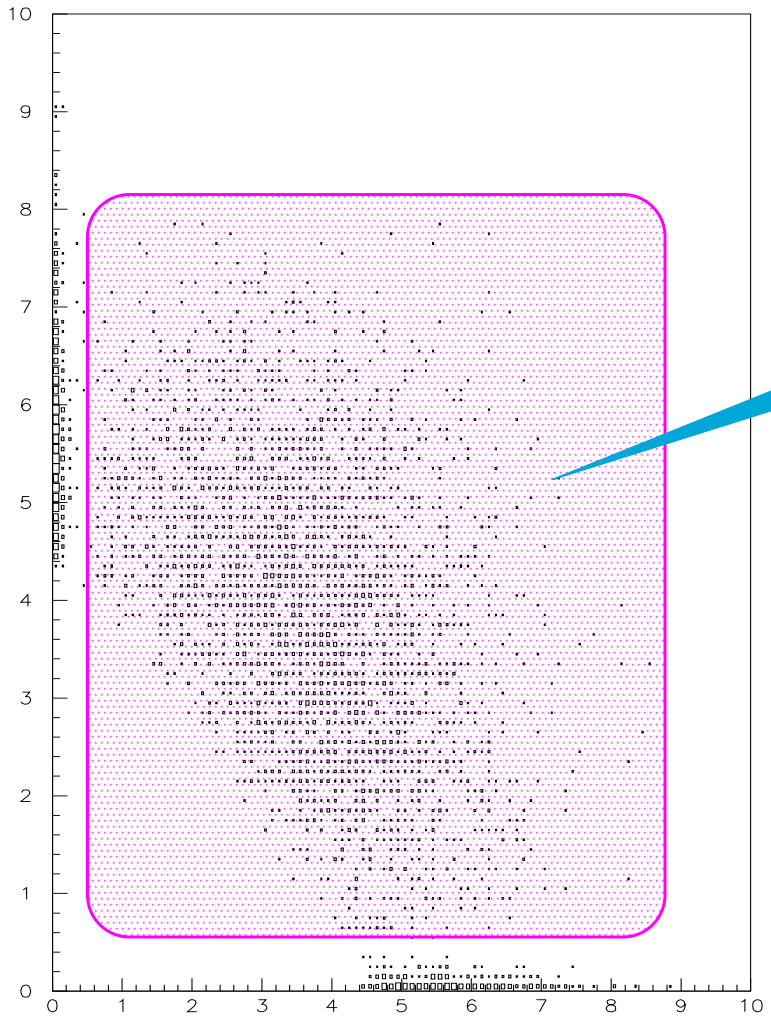
Jets





DISENTANGLING SIGNAL FROM BACKGROUND (III)

ΔR (j2, extra-j)



ΔR (j1, extra-j)

Central jet veto :

jet with $E_T^j > 20$ GeV,

$\eta_{min} < \eta_j < \eta_{max}$

rejected

DISENTANGLING SIGNAL FROM BACKGROUND (IV)

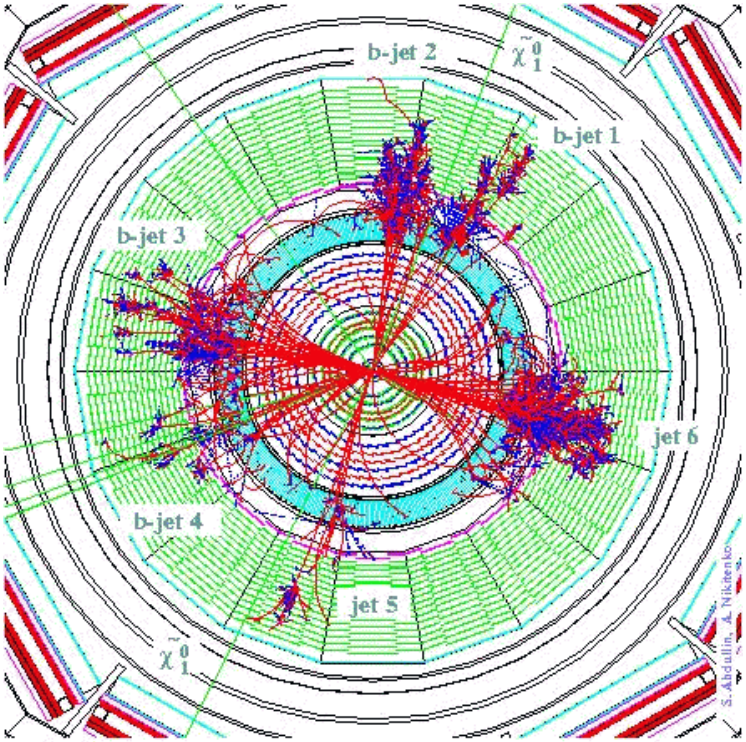
Cuts	Signal (fb)	t t j bkgd (fb)
no cuts	12.7	36,800
forw. jet tagging	8.91	6,410
central jet veto	8.90	620
lepton selection	2.84	142
M_{jj}, M_{ll}, ϕ_{ll}	1.90	11

INCLUSIVE SUSY TRIGGER @ $2 * 10^{33} cm^{-2} s^{-1}$

Salavat Abdullin (University of Maryland)

- What's the SUSY from Jets/MET point of view
- Probing points
- Calculational details
- L1 signal selection
- L2 signal efiiciency vs QCD rate

GENERIC SUSY



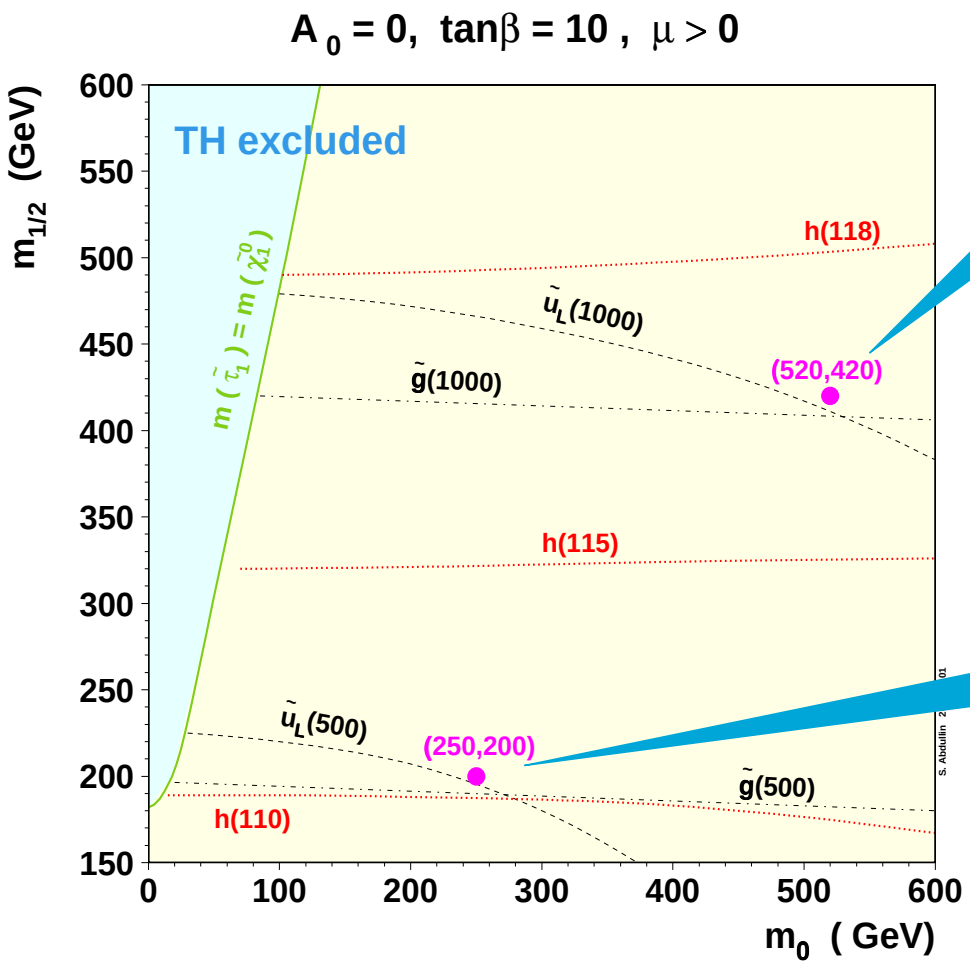
- Multijet + (leptons) + E_T^{miss} events

- Two mSUGRA points are available for low-lumi study

  - M_{SUSY} ~ 500 GeV (beyond Tevatron II reach)
    ~ 1000 GeV
  - $m(\tilde{g}) \cong m(\tilde{q})$
  - $\tan\beta = 10$ ("preferred")
  - $\mu > 0$ - the sign doesn't play a big role,

    though positive one is favoured by g-2 "indirect" constraint - anomaluos magnetic momentum of muon

PROBING POINTS



$m(\tilde{\chi}_1^0) = 177.5$ GeV $m(h) = 116.8$ GeV

$m(\tilde{t}_1) = 726$ GeV

$\sigma = 2.24$ pb, requires $\int Ldt < 100\ pb^{-1}$

typical cuts :

$\not{E}_T > 300$ GeV, $N_j \geq 4$

2 $E_T^j > 200, 100, 50$ GeV

$m(\tilde{\chi}_1^0) = 79.0$ GeV $m(h) = 110.7$ GeV

$m(\tilde{t}_1) = 352$ GeV

$\sigma = 115$ pb, requires $\int Ldt < 10\ pb^{-1}$

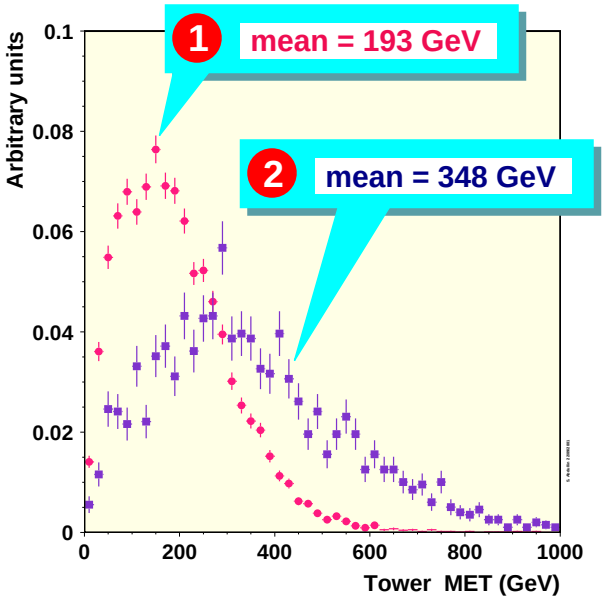
typical cuts :

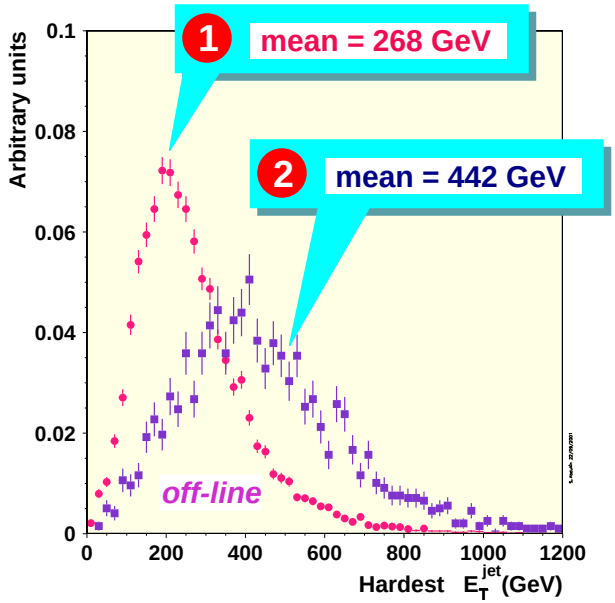
$\not{E}_T > 200$ GeV, $N_j \geq 3$

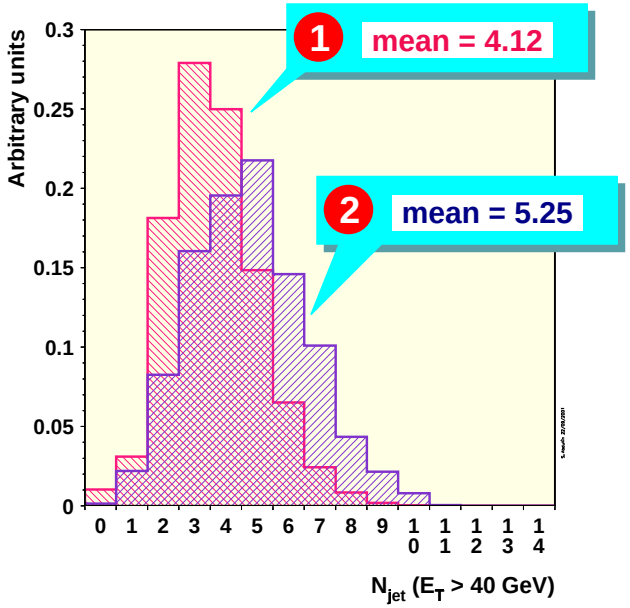
1 $E_T^j > 100, 50, 50$ GeV

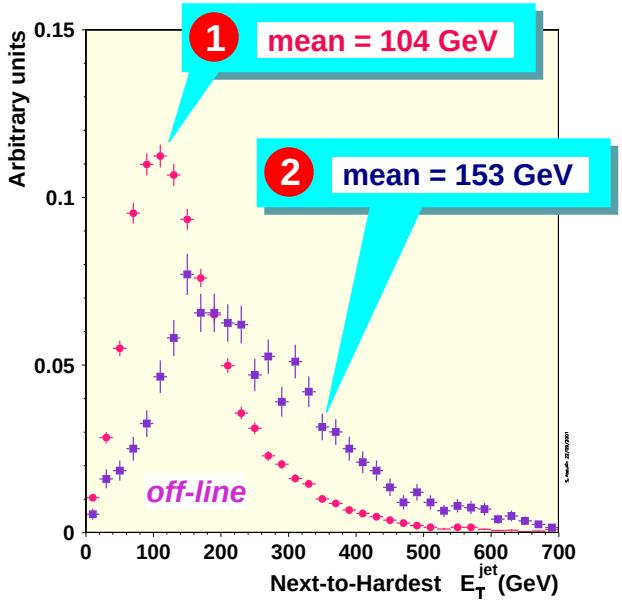
- **Typical efficiency for the signal : 20 - 50 % (0.5 - 1 TeV)**

PROBING POINTS DISTRIBUTIONS









CALCULATIONAL DETAILS

Jet corrections

- Andrei Krokhotine (ITEP)

  for low luminosity :

  http://home.fnal.gov/~sceno/jpg/fall20012e33/...

- applied to both L1, L2 jets

- Jets corrected : $E_T > 30$ GeV

MET corrections

- not applied

- L1 - not quite clear which way it's possible to correct L1 MET ...

- L2 - small effect compared to real MET

L1 cuts taken from CMS IN 2001/42 (Wisconsin team)

- nominal 12.5 kHz L1 Trigger rate limit is assumed
- L1 jet cuts : 120, 90, 70, 50 GeV for (respectively) single, double, triple and quadruple jets
- L1 MET cut : 100 GeV (95 % at 275 GeV !)

L1 SIGNAL SELECTION

- Signal cumulative (individual) trigger efficiencies (%) w.r.t. the entire sample wtihout any preselection

E_T cut (GeV)		Point 1	Point 2
j	120	91.5 (91.5)	97.5 (97.5)
jj	90	93.3 (81.1)	97.7 (93.1)
jjj	70	93.9 (58.6)	98.2 (81.6)
jjjj	50	94.7 (47.4)	98.4 (71.0)
MET	100	94.9 (67.2)	98.4 (88.3)

BACKGROUND

- SM background for fairly low SUSY mass scale (0.5-1 TeV) :
  - single(Wtb)/double top production, multijet QCD (incl. $b\bar{b}$ + X), W/Z + multijets } comparable

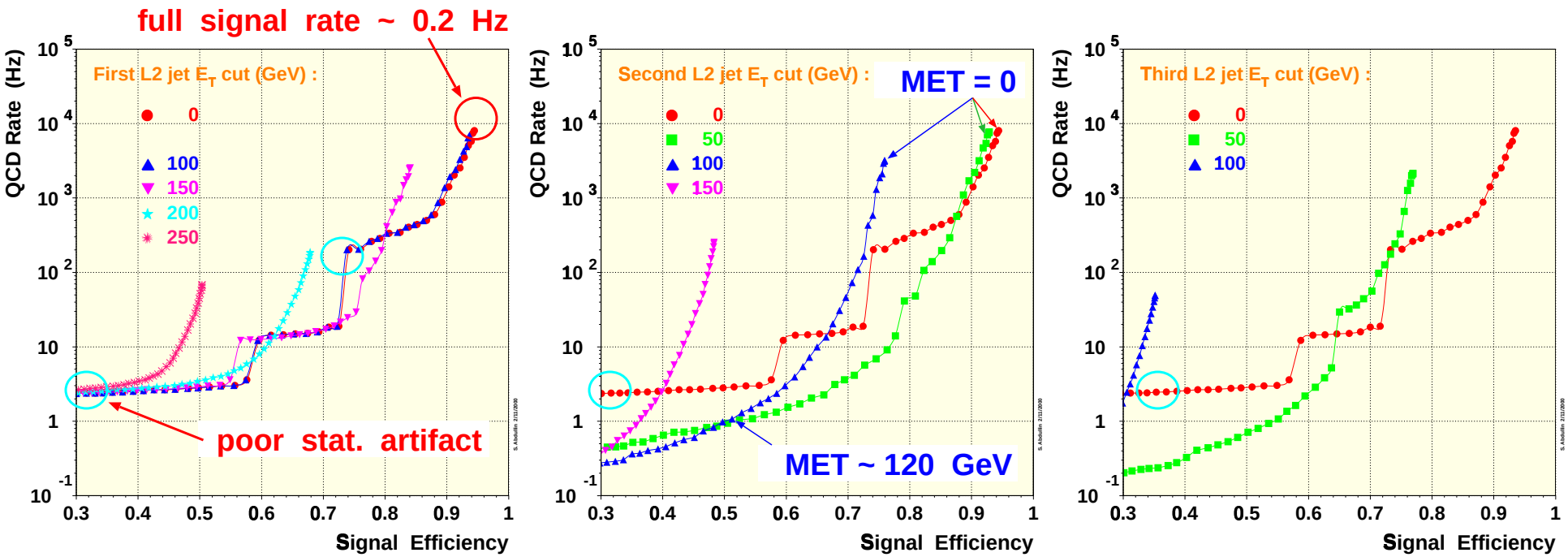
- Even 0.1 fb^{-1} would require (x 100 for 10 fb^{-1})
  - Wj ~ 160,000 events
  - Zj ~ 60,000 events } $\hat{p}_T$ > 100 GeV
  - $t\bar{t}$ ~ 80,000 events + ~ 30,000 for single top (~ 47,000 next week)
  - QCD ~ $7 * 10^6$ events } $\hat{p}_T$ > 200 GeV (~ 10^6 available)

- Physics TDR challenge ?

- QCD is the main problem for HLT
  - Wj ($\hat{p}_T$ > 100 GeV) : 3.5 Hz @ 2e33
  - Zj ($\hat{p}_T$ > 100 GeV) : 1.3 Hz @ 2e33
  - $t\bar{t}$ (entire sample) : 1.6 Hz @ 2e33

  } total rate w/o selection

SIGNAL EFFICIENCY VS QCD RATE AT L2 (I)

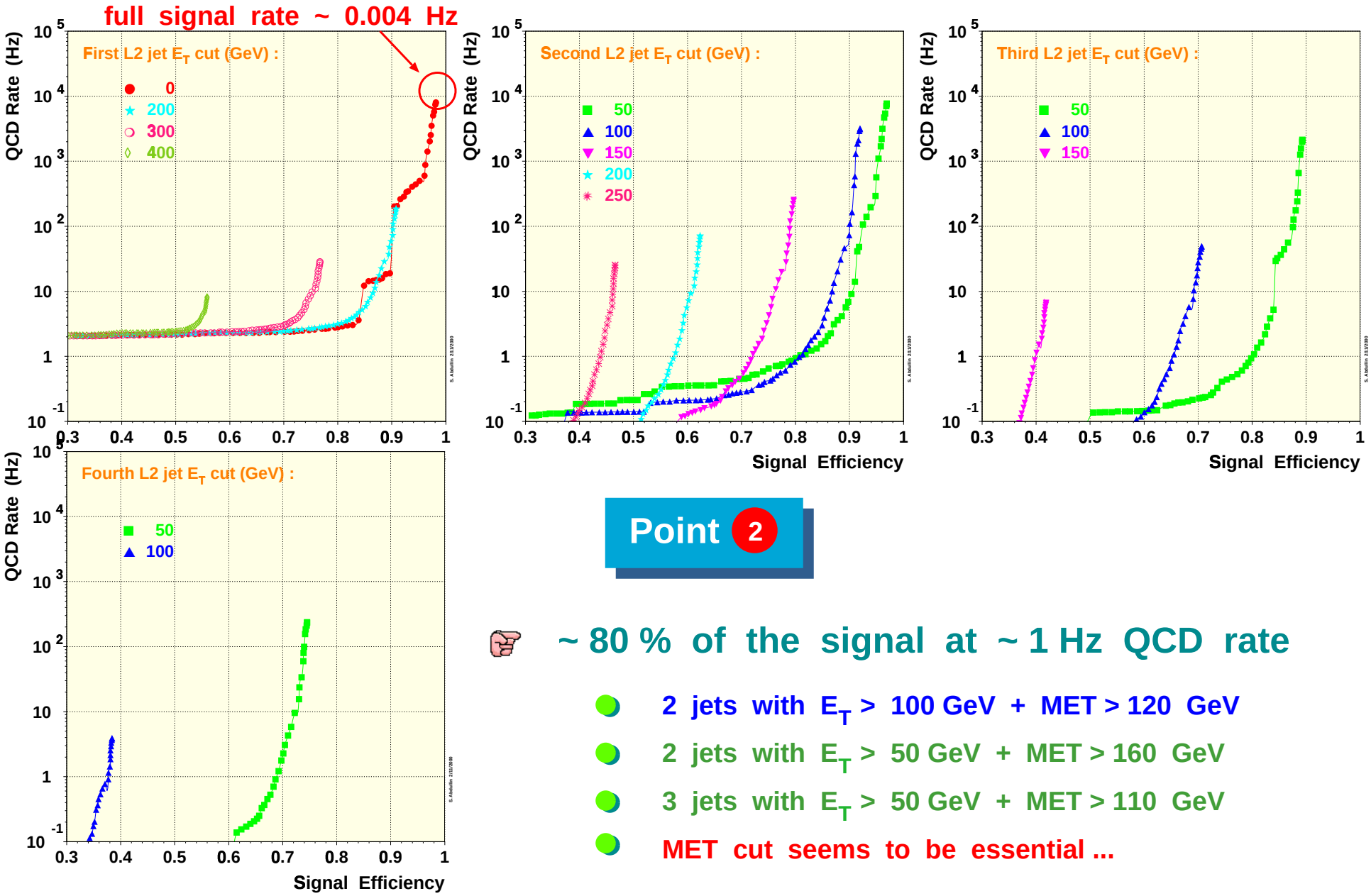


Point 1

☞ **We can preserve ~ 50 % of the signal, while keeping QCD rate at ~1 Hz by one of the next requirements :**

- **2 jets with E_T > 100 GeV + MET > 120 GeV**
- **3 jets with E_T > 50 GeV + MET > 110 GeV**
- **MET cut seems to be essential in reducing QCD rate ...**

SIGNAL EFFICIENCY VS QCD RATE AT L2 (II)



Point 2

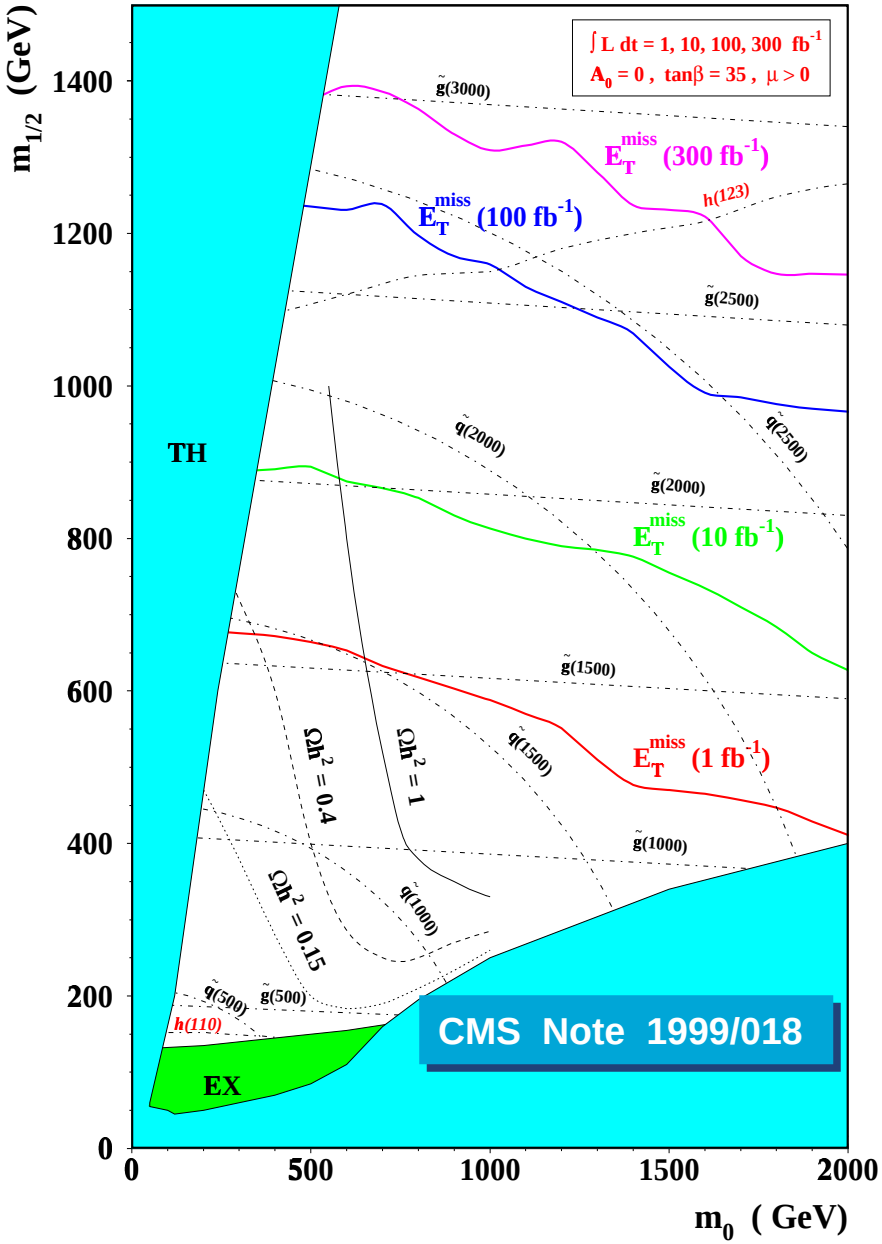
☞ ~ 80 % of the signal at ~ 1 Hz QCD rate

- 2 jets with E_T > 100 GeV + MET > 120 GeV
- 2 jets with E_T > 50 GeV + MET > 160 GeV
- 3 jets with E_T > 50 GeV + MET > 110 GeV
- MET cut seems to be essential ...

MORE PROBING POINTS ...

- Inclusive SUSY signatures (except some degenerate cases) have a kind of "compensating" effect due to multi-particle cascade decays
  - less jets -> harder jets
  - missing E_T slightly depends on internal mass hierarchy (lighter $\tilde{\chi}_1^0$ -> more boosted etc.)
- After cuts optimization the observability of inclusive SUSY signal depends mainly on the mass scale of strongly interacting sparticles (squarks and gluino)
- Still $m_0 << m_{1/2}$ and vice versa have some particularities
- 3 more points are in production at the moment (hep-ph/0106204)
  - point "B" - less "normal jets", much more taus
  - point "C" - less "normal jets", more sleptons->leptons
  - point "E" - more jets, especially b-ones

PLANS



... I like the striking hugeness of our plans ...

- Top background to add
- More signal points ...
- Optimal combination of 1, 2, 3, ... jets + MET triggers
- M_{SUSY} ~ 2 TeV is probably reachable already at low lumi ? According to the LHC plans, 10 fb^{-1} are to be collected in the first 7-months run ...