Particle ID in high P_T reactions(3)

oVertex detectors and B-tagging

oTop –physics

oParticle ID for Mtop measurement

oParticle ID for SM-Higgs search

oSUSY, Exoticas

oConclusion

Vertex detectors (1)

Requirements based on b-jets parameters

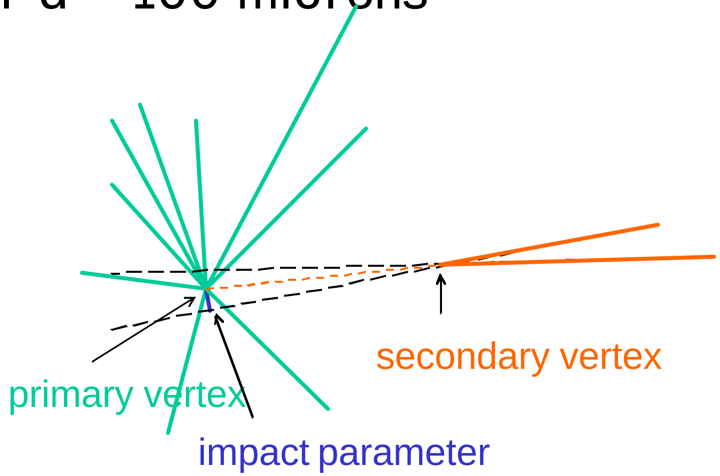
- B hadrons lifetime : average of ~1.6 ps
- semi-leptonic fraction ~10%e, and 10%μ
- $c\tau$ =470 microns → impact parameter d ~100 microns
- need accuracy : < 20 microns on d

Accuracy limited by

- lever arm,
- granularity,
- number of layers

Solution:

- 3 layer pixel detector
- first layer as close as possible to beam pipe
- single hit accuracy < 15 microns in $r\phi$
- equipped with fast electronics

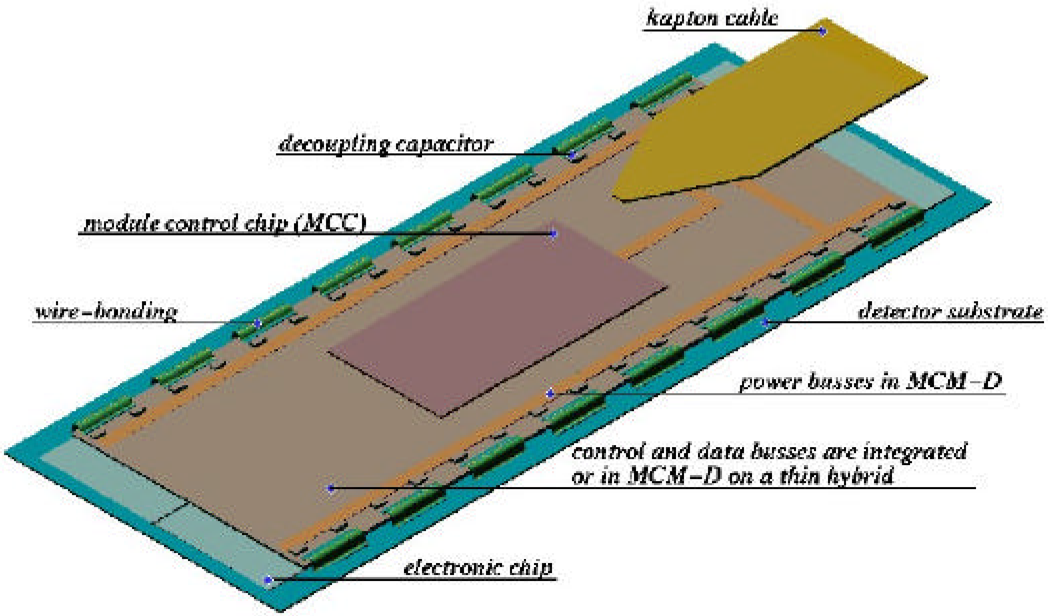


Beware -of radiation damage

- multiple scattering in material
- power dissipation

Atlas pixels

- 3 cylinders R= 5cm , 10cm, 13cm
- 2 x3 disks
- Sensor: " n + n oxygenated " ,
- FE Electronics DeepSubMicron
- 82 M pixels 50 x 400 mm
- 2.8% X_0/layer



Carbon fiber mechanical support
Length about 80cm

Pixels electronics

FE electronics and readout architecture

-80 million channels to be “looked at” every 25 ns !!

-fastpreamp, good S(15ke)/N (200e)for mips →digital or few bits r/o

-all FE chips proceed in parallel, controlled by local MicroControler

-occupancy small (<<10^{-2}) : logic by columns

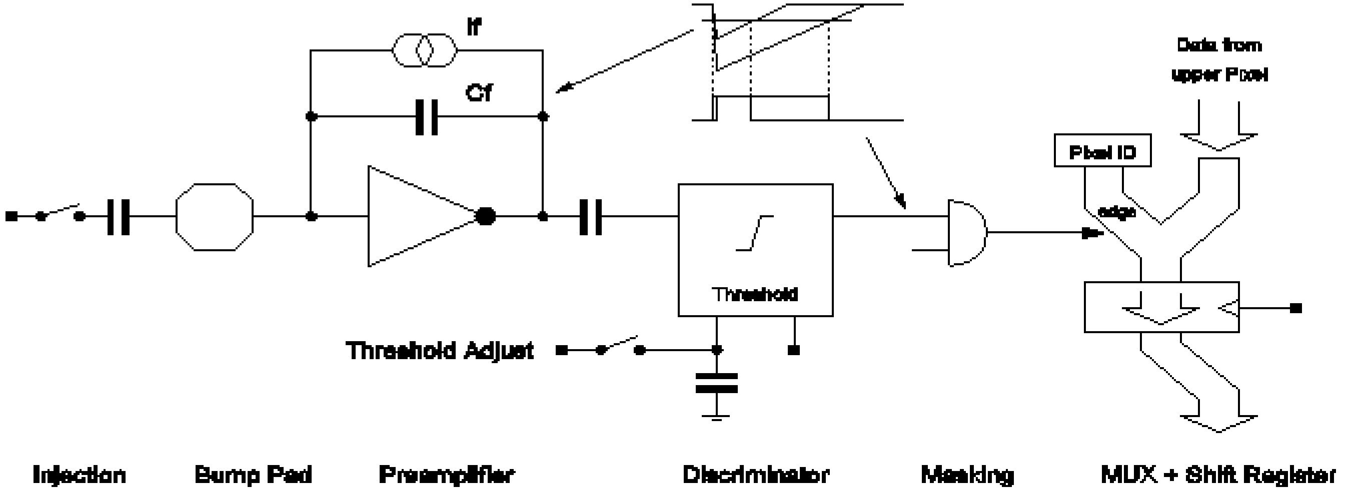
Schematically:

-each FE chip covers 24 columns of 160 cells [400 x 50 μm]=~$1cm^2$

-at the bump bond pad is connected preamp + discriminator

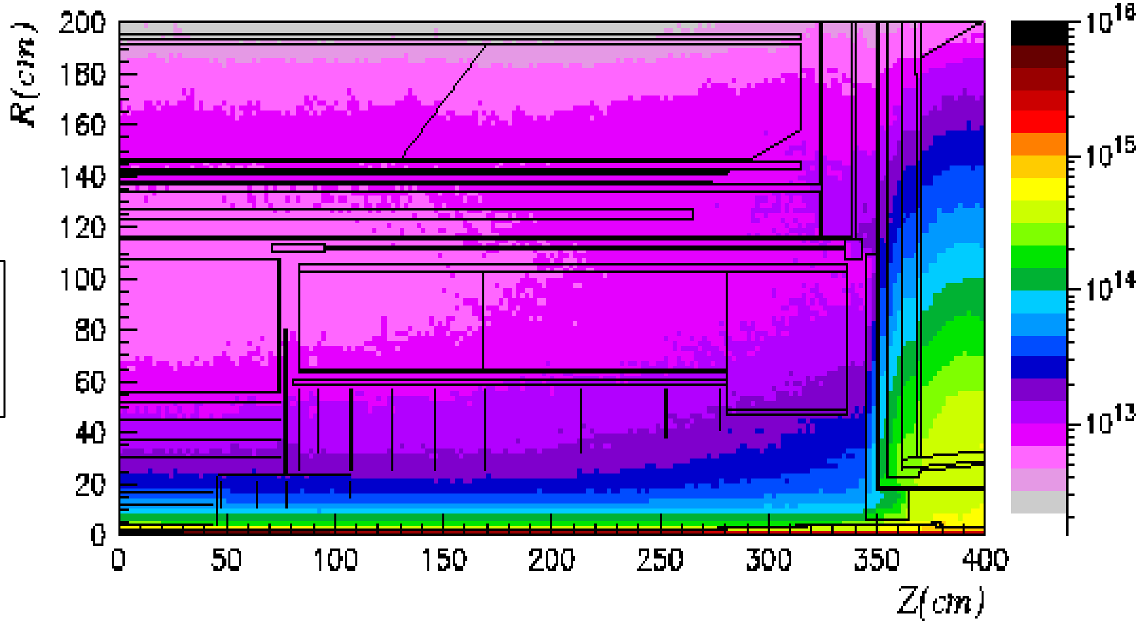
-the End of Column logic drains data from columns=
address of hit pixel(s) in the column +bunch counter

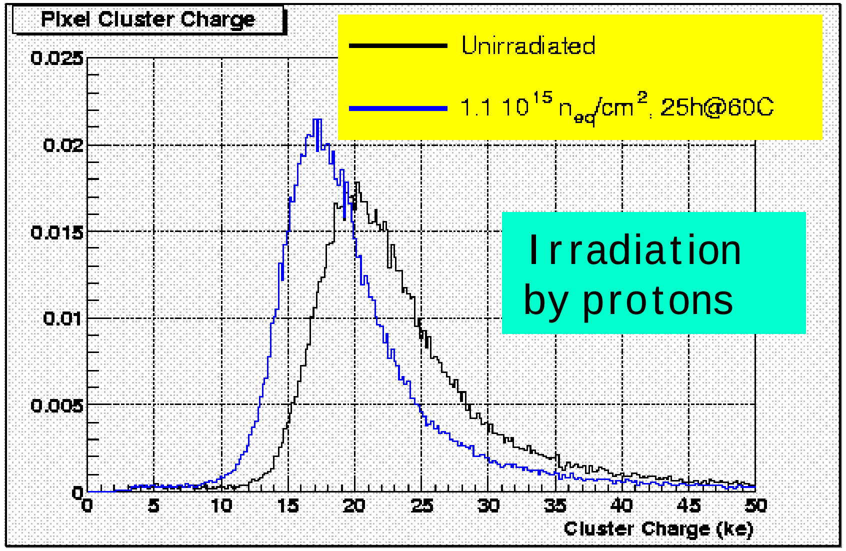
-upon LVL1 signal(<100kHz) the MC scans over its FEchips(~12)
gather the hit pixel adresses +bc ,keeps those with proper bc,and
clears the buffers.



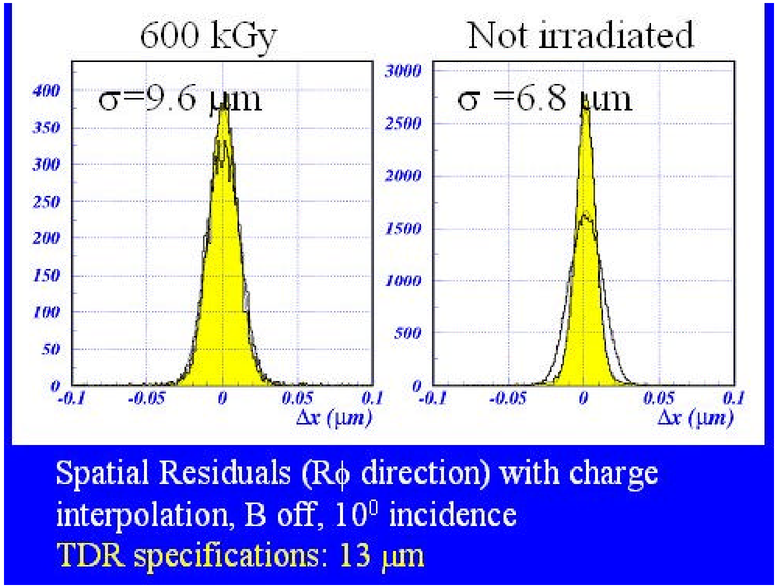
Pixels: radiation damage

Expected neutron fluence per year at high luminosity ®



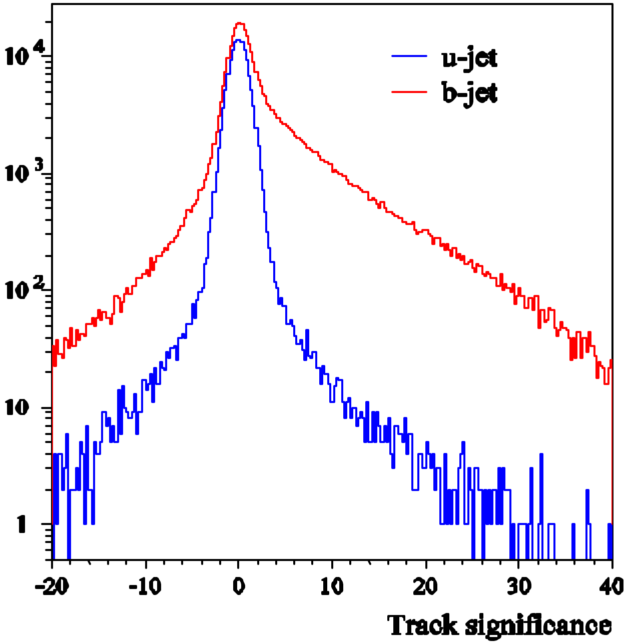


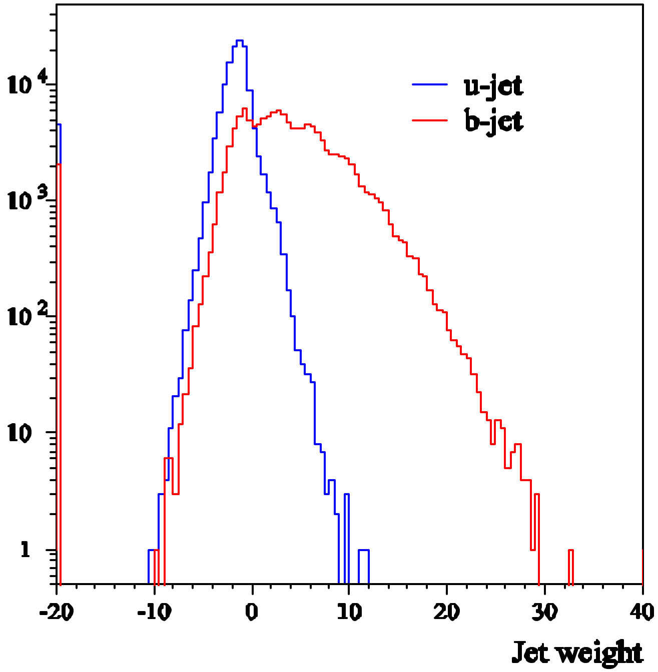
Irradiation by protons



Spatial Residuals (Rϕ direction) with charge interpolation, B off, 10^0 incidence
TDR specifications: 13 μm

B-tagging expected performance



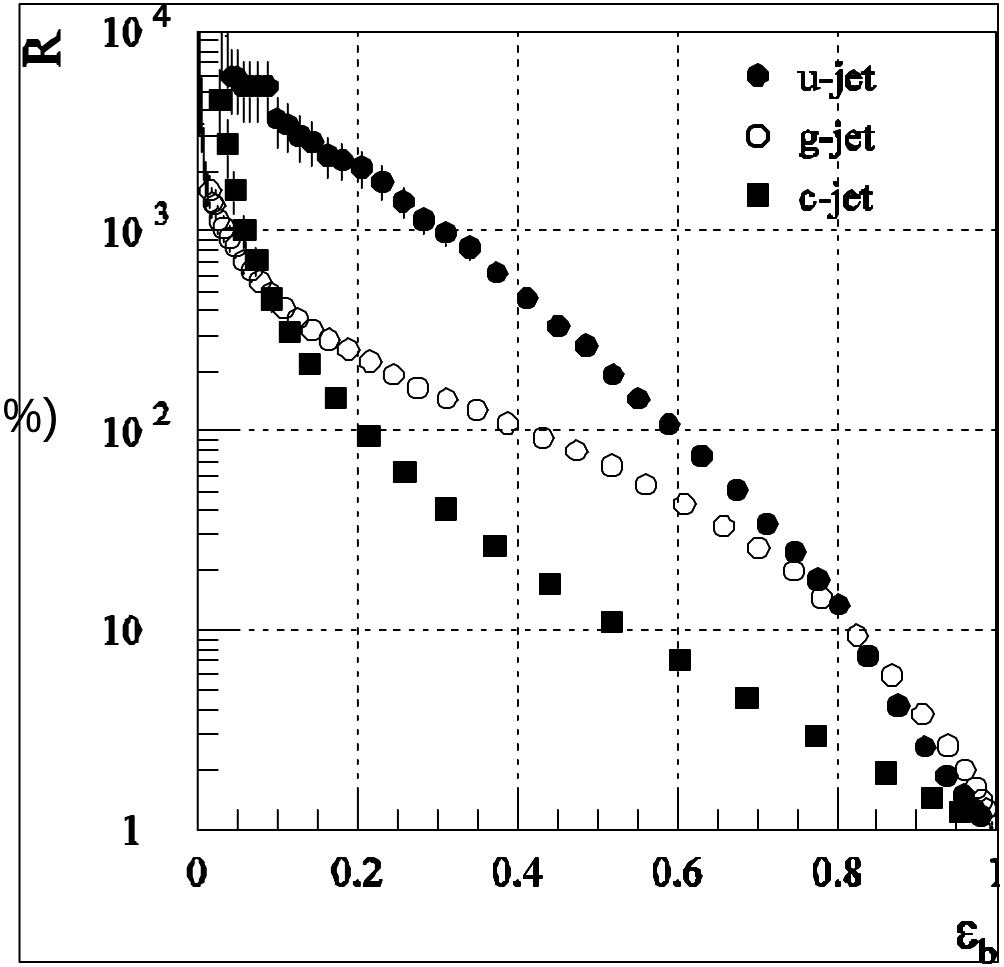


- Start from a calorimeter jet
- Reconstruct tracks, and select those with p_T>cut (~1 GeV/c) and $\Delta R<0.4$
- Measure d (with a sign), calculate s=d/s
- Calculate jet weight as Σlog(signif as b/signif as u) from all its tracks
- Adjust cut position
- Tails in u-jets ? secondary interactions, V_0

B-tagging expected performance

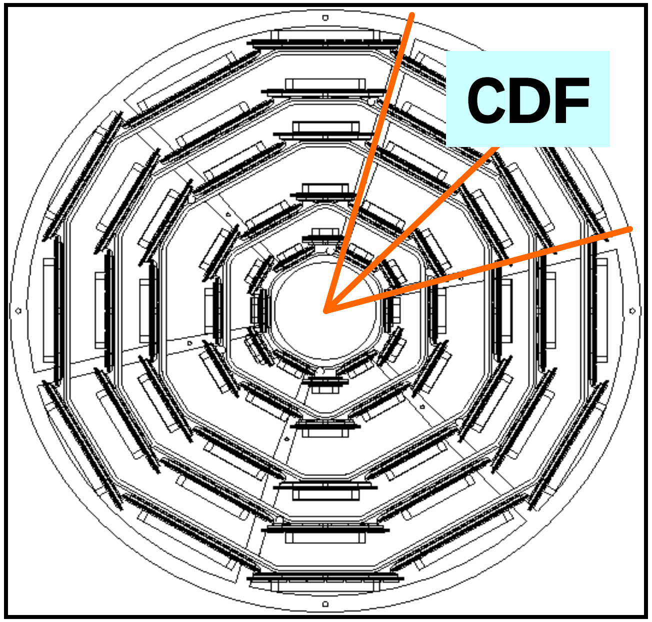
- •Full offline reconstruction
- •Based on jet weights
- •B jet sample from H(100)→bb and H(400)→bb
- •Background from jet-jet events same p_T range
- •L=2 x 10^{33} (at 10^{34} rejection reduced by ~20%)
- •Ru ~100 for 60% efficiency
- •Rc more modest because ct (D+)=300 mm, (D0)=120 mm
- •Rg limited by gluon splitting to cc

- •Soft lepton tag -identification of electrons and muons in cone axis adds a few % efficiency each



B-tagging in HLT?

- CdF is using it for selection of "unbiased" B decays
- Starting from LVL1 with 2 tracks >2 GeV/c pT
- Done in a "hardware oriented" way with a processing time of 25 ms/event



- 12 independent sectors
- 4 layers(out of 5) of micro-strips grouped to 250 mm pitch
- 1 point/tracker (f, p_T) + hit pattern compared to 32000 masks

- Interesting approach in LHCb/Velo

- In ATLAS-CMS events to be processed,at LVL2 have in general several jets
Some trial at LVL2-Atlas, not really convincing
- Need "real tracking" to decide if some of the jets are B-jets or not.
Efficient way to do it is at the Event Filter level, with ~full offline performance

B-tagging in HLT:CMS example

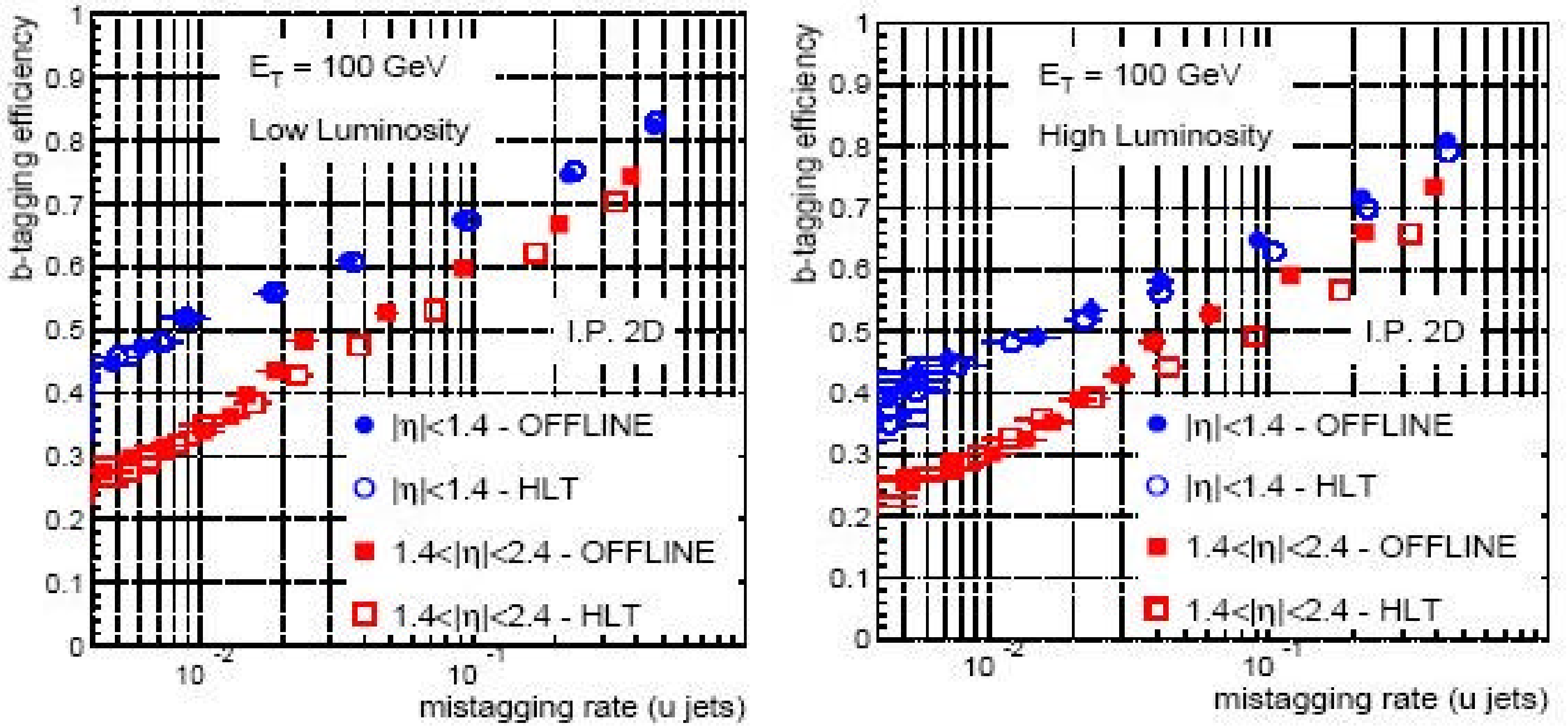


Figure 15-68 Efficiency for the *b*-tag versus mistagging rate for jet with E_T=100 GeV in the low (left) and high (right) luminosity scenarios.

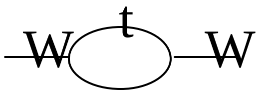
- Reconstruct Tracks in a cone defined by Calo-jet
- Ask for at least 2/3 pixel hits.
- Labelled as b-jet if ≥2 tracks above thresh significance

Particle ID for M(top) measurements

M(W) , M(top) and M(Higgs) are linked in the standard model:

$$m(W) = \left(\frac{\pi\alpha_{em}}{\sqrt{2}\,G_F}\right)^{\frac{1}{2}} \frac{1}{\sin\theta_W\sqrt{1-\Delta r}}$$

F[M(top),log(M(H)]



G_F, a_{EM}, $\sin\theta_W$ known with high precision,

precise measurements of M(top) and M(W)

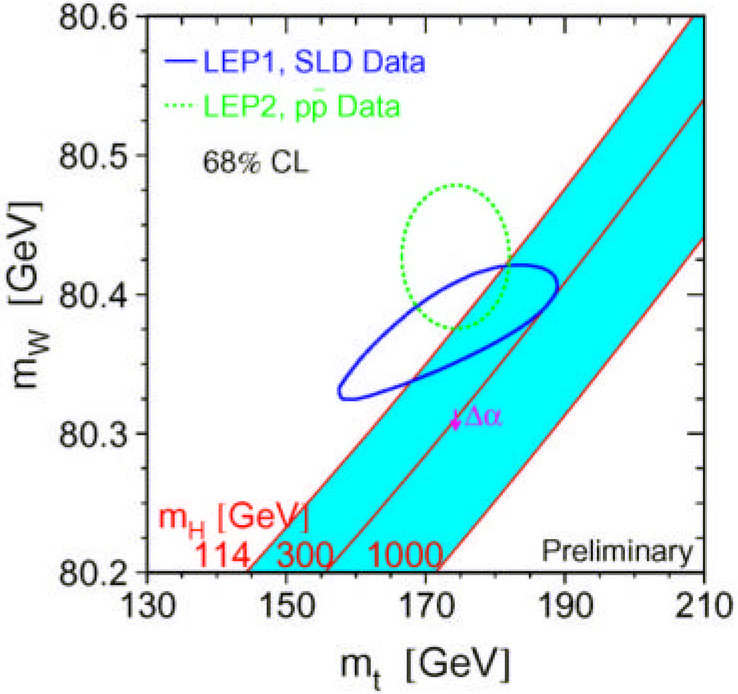
constrain M(H) (weakly because of log term)

10 MeV M(W) →~1 GeV M(top)

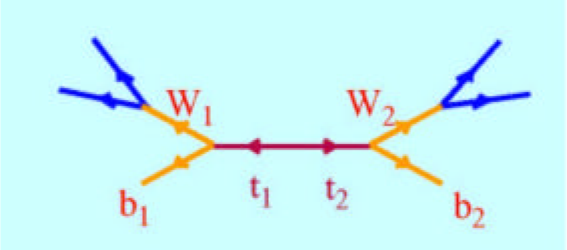
To day (CDF+D0) M(top)=178 ± 5GeV

Best strategy to measure it at LHC?

[event statistics is not the main problem]



Particle ID for M(top) measurements



Inclusive tt cross-section ~0.7 nb

t→bW 100%
W→ln 11%each , 67% hadronic; no Bs

W1→had,W2→had : 44% 2 masses fully rec/ huge QCD BG
W1→e/mn,W2→had (+ 2→1) : 30% 1 mass fully reconstructed
W1→e/m,n ,W2→e/mn : 5% rate; mass not fully reconstructed
Others: one W→t : not appropriate for precise M meast

Semi-leptonic final sate:
expect 2.5 million evts for 10 fb^{-1}
-one electron or muon
-two b jets
-two non-b-jets Minv=M(W)
-missing E_T
-in average 2 or 3 g jets/QCD
-underlying event

LVL1 Trigger

Rejection of QCD bckg
fact 100/jet

Masse scale

Rejection of QCD bckg,
Reconstruction of 2nd top

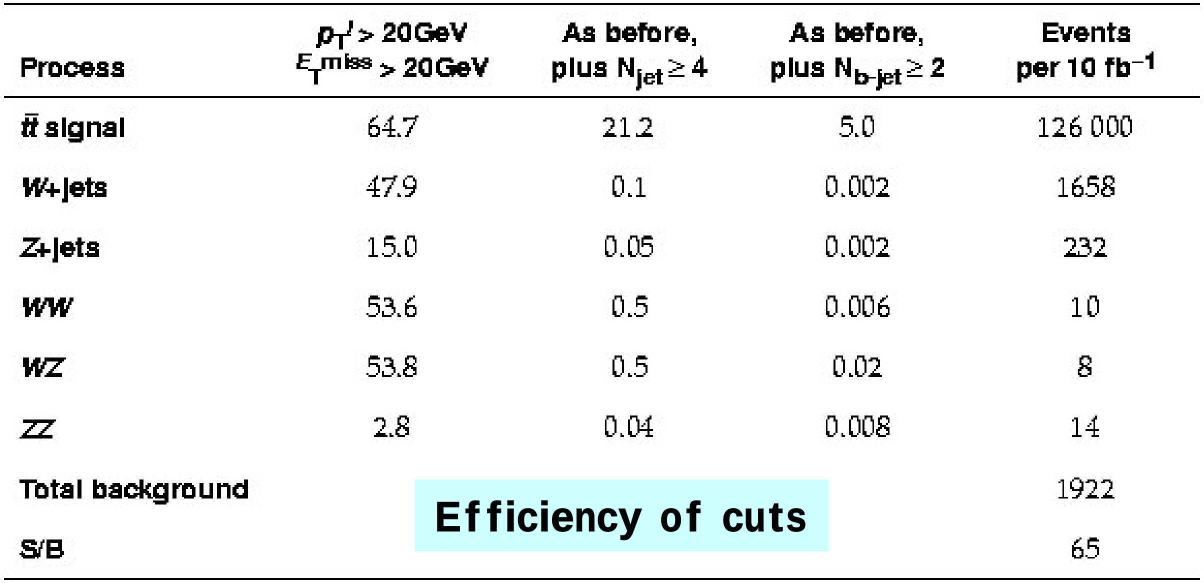
Particle ID for M(top) measurement

Selection

- 1 iso lepton, pT > 20 GeV, |h| < 2.5
- pTmiss > 20 GeV
- = 4 jets with pT > 40 GeV, |h| < 2.5
- = 2 jets with b-tag

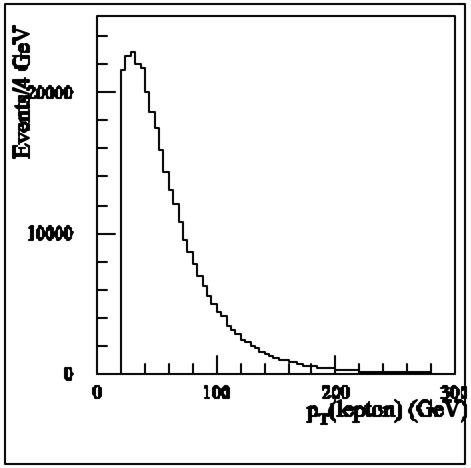
Selection efficiency. = 5%

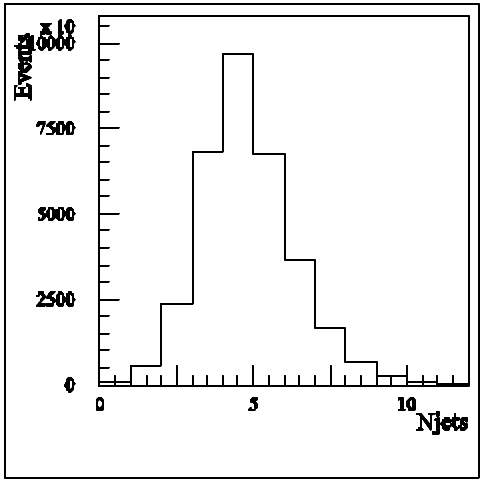
Þ **126k events, with S/B ~65**



Process	$p_T^l > 20$GeV $E_T^{miss} > 20$GeV	As before, plus $N_{jet} \geq 4$	As before, plus $N_{b\text{-}jet} \geq 2$	Events per 10 fb^{-1}
$t\bar{t}$ signal	64.7	21.2	5.0	126 000
W+jets	47.9	0.1	0.002	1658
Z+jets	15.0	0.05	0.002	232
WW	53.6	0.5	0.006	10
WZ	53.8	0.5	0.02	8
ZZ	2.8	0.04	0.008	14
Total background				1922
S/B				65

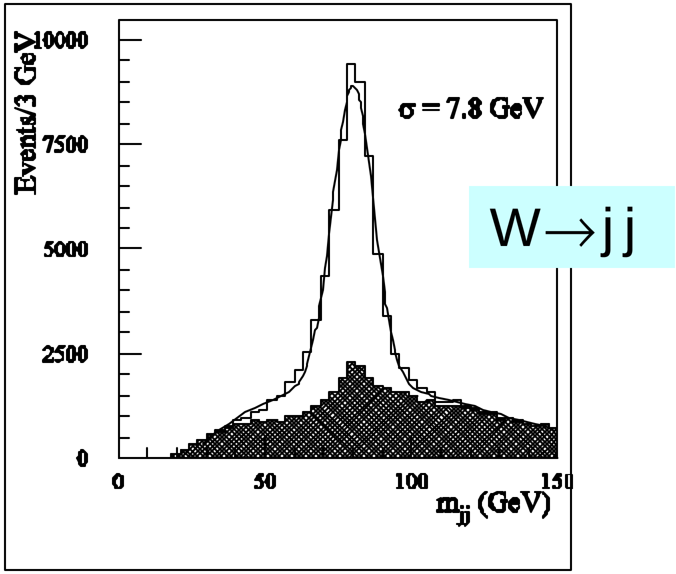
Efficiency of cuts

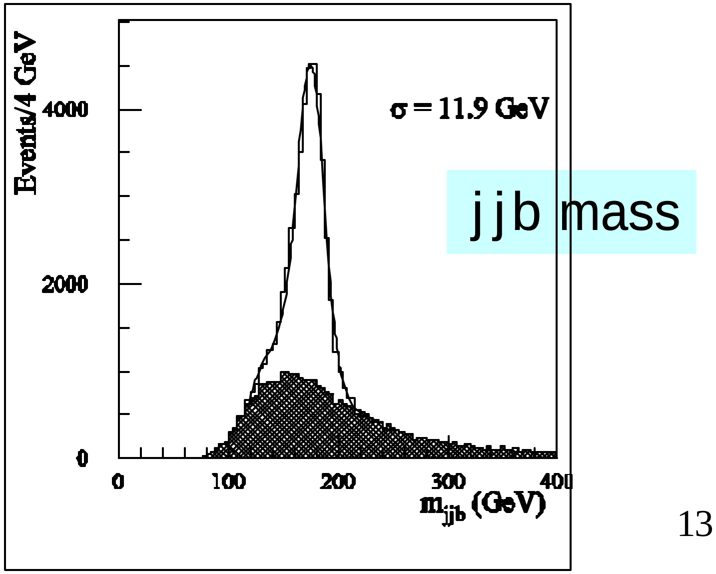




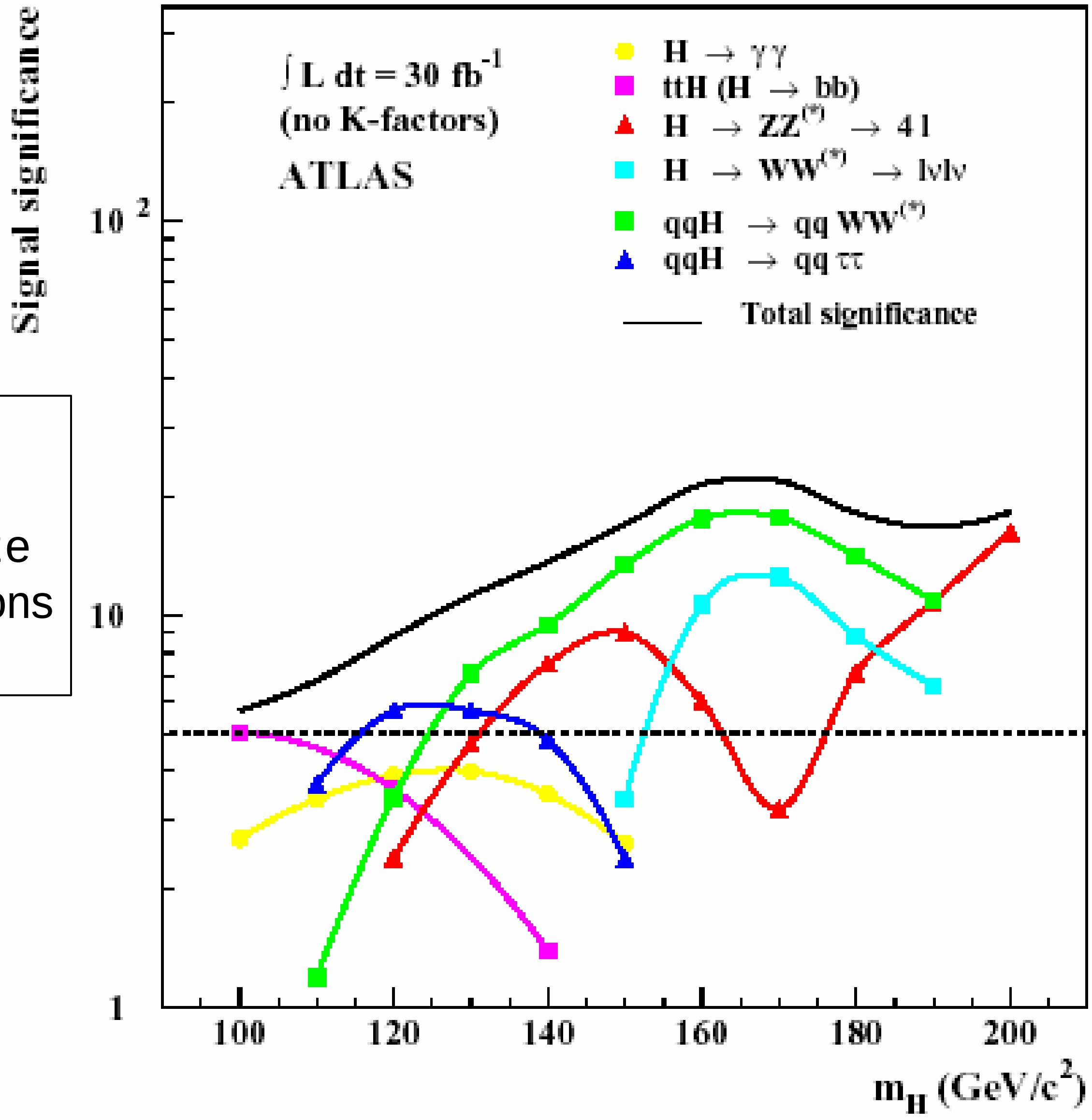
W-ID from “top” sample

- ½ leptonic ttbar events contain W→jet-jet evts with good S/N
  ⇒identified hadronic W decays
- This sample of jets is used to adjust the (non-b) jet –scale, starting from jets normalized using photon-jet evts (p_T balance)
- B-jets are normalized from photon-B-id jets (only)
- Remaining uncertainties on jet scales dominate the top mass systematic uncertainty
- Hadronic Ws in jj used in other places (H→WW,..)



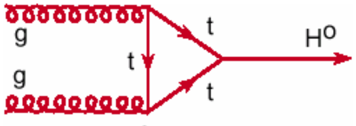


SM-Higgs search global view

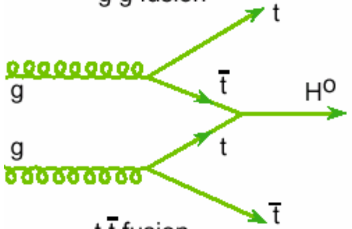


Each channel based
on well identified
particles in the final state
In general containing leptons
and/or gauge bosons

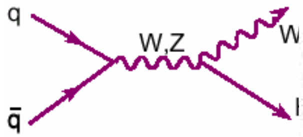
Production and decay



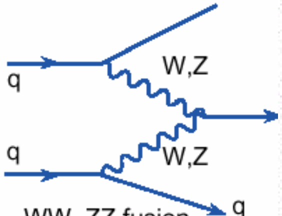
g g fusion



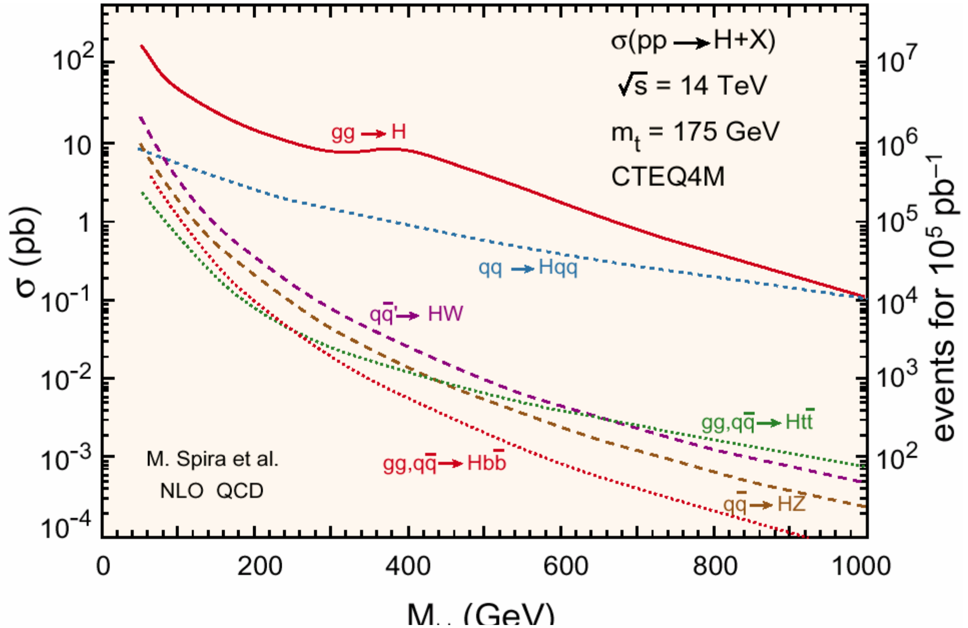
t t̄ fusion

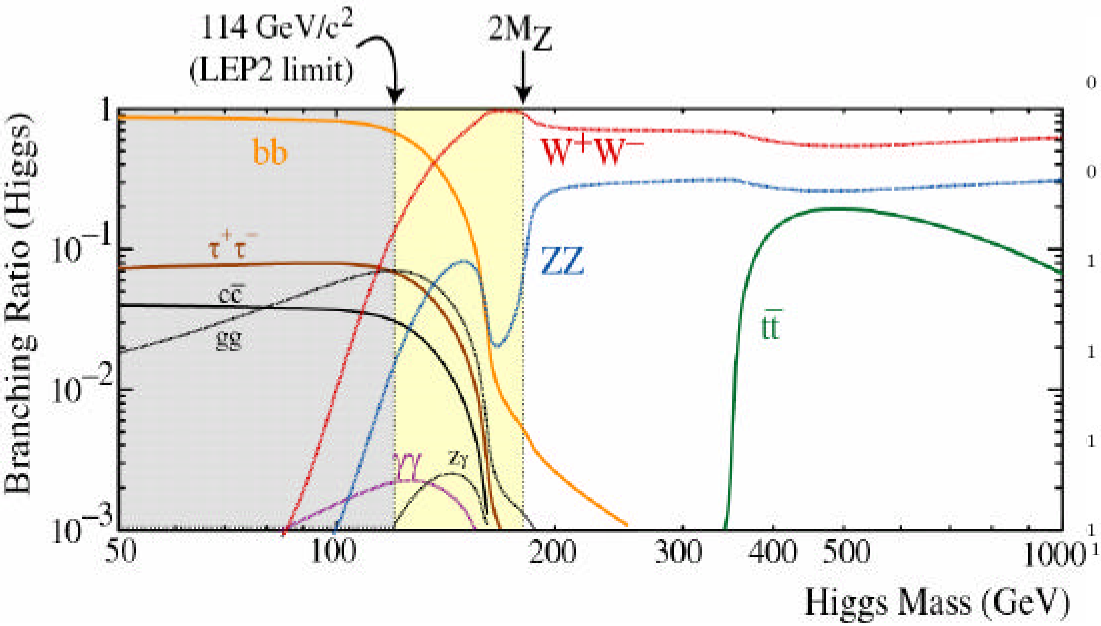


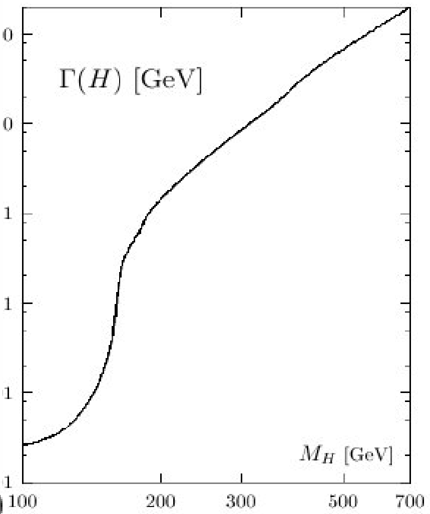
W, Z bremsstrahlung



WW, ZZ fusion



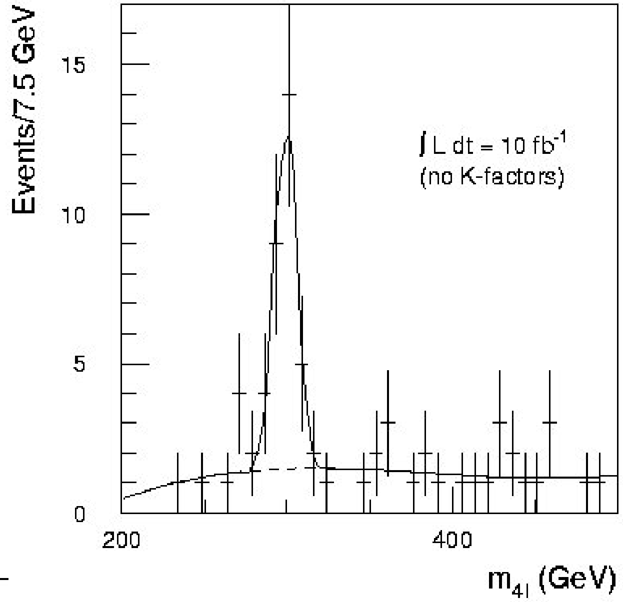


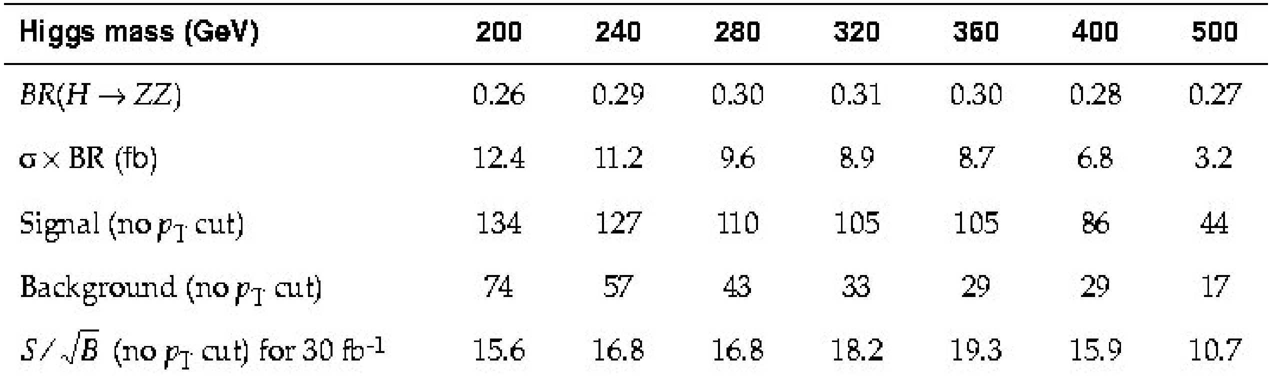


The ZZ “gold plated” mode

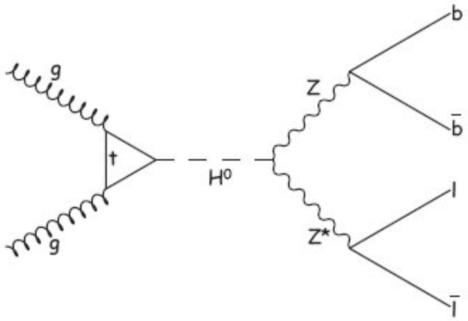
M(H)>180 GeV : ZZ mode open

-”Gold plated channel ” with each Z→ee or mm
- Two M(ll)=M(Z) constraints
- Irreducible background (only) = non resonant ZZ
- Main limitation is rate,when M(H) increases
- Adding evts with one Z ® tt could help (trig/otherZ)
- Using Z→nn (*6 ee or mm) allows to extend search up to 700 GeV





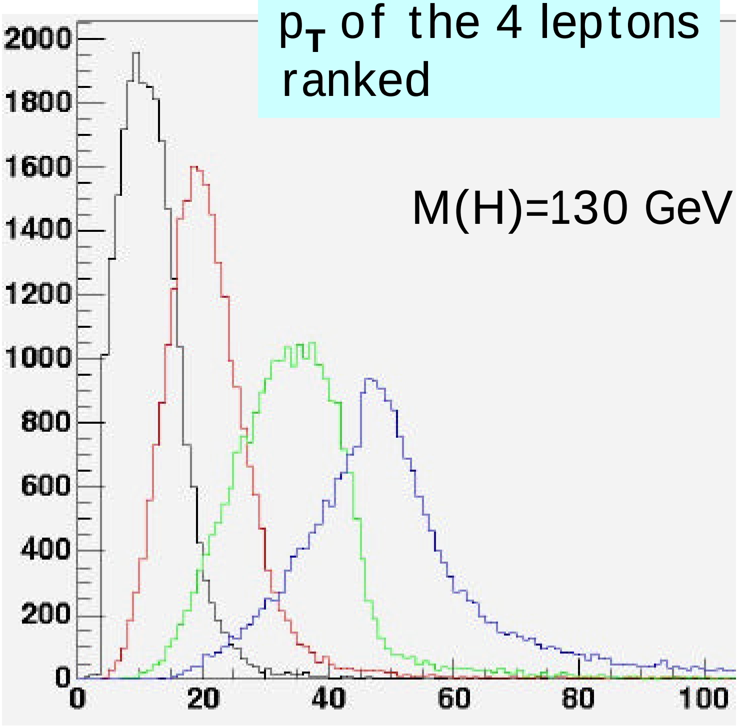
Higgs mass (GeV)	200	240	280	320	360	400	500
$BR(H \to ZZ)$	0.26	0.29	0.30	0.31	0.30	0.28	0.27
$\sigma \times$ BR (fb)	12.4	11.2	9.6	8.9	8.7	6.8	3.2
Signal (no p_T cut)	134	127	110	105	105	86	44
Background (no p_T cut)	74	57	43	33	29	29	17
$S/\sqrt{B}$ (no p_T cut) for 30 fb^{-1}	15.6	16.8	16.8	18.2	19.3	15.9	10.7



-what about one Z in jet-jet? BG “Z +2 jets” is large....
some attempt with one Z in two b jets....

ZZ* 130<M(H)<180 GeV

- still 4 leptons ee or mm
- only one M(ll)=M(Z) constraint remaining
- dip in the BR at 2M(W)
-Zbb main reducible background can be reduced applying a veto on displaced vertices
-important issue : acceptance of the lower PT lepton .Analyses require 2 lepons pT>20 GeV (trigger) and 2 leptons with pT>7 GeV (offline)



p_T of the 4 leptons ranked

M(H)=130 GeV

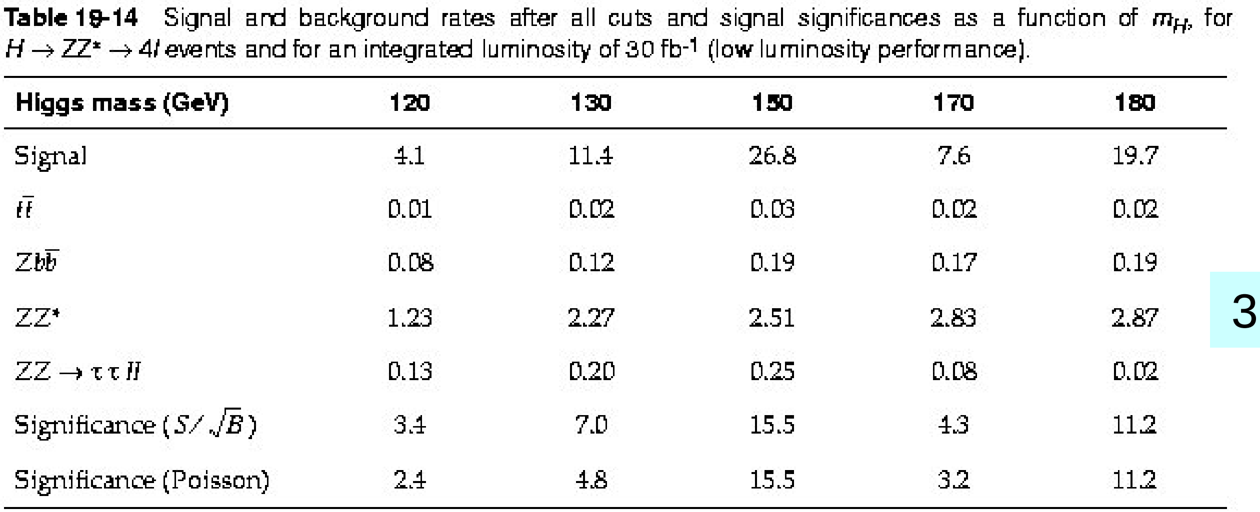
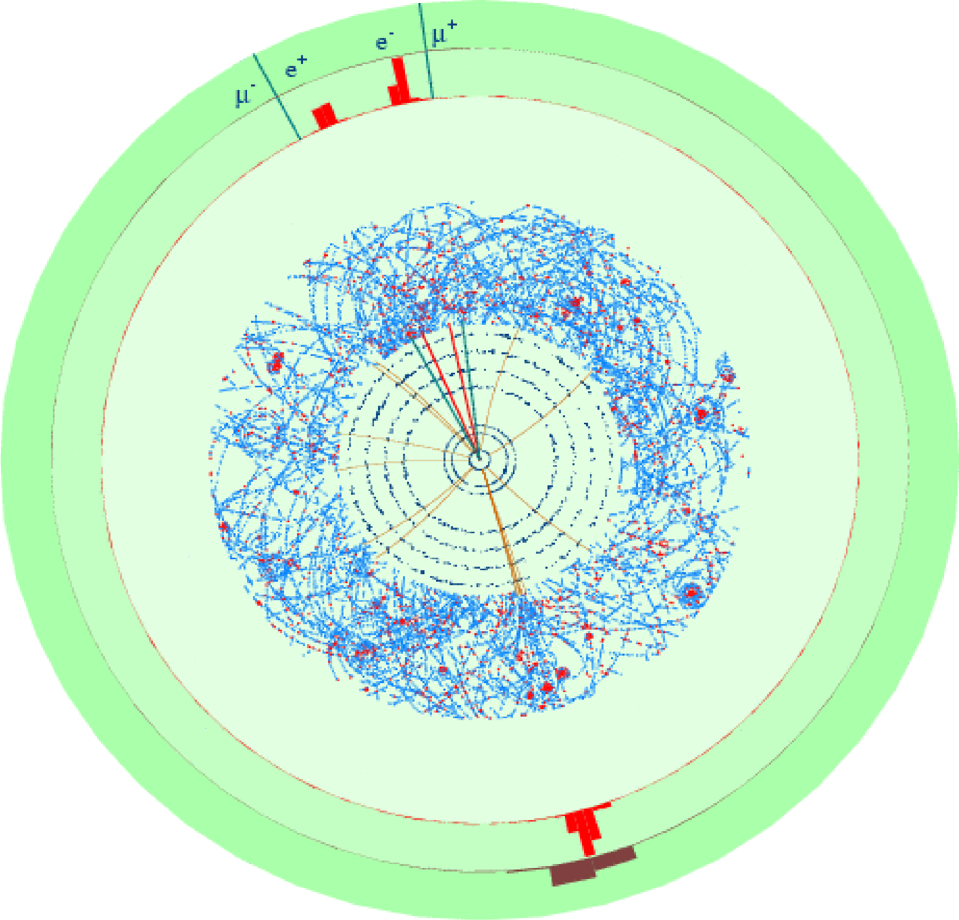


Table 19-14 Signal and background rates after all cuts and signal significances as a function of m_H, for $H \rightarrow ZZ^* \rightarrow 4l$ events and for an integrated luminosity of 30 fb^{-1} (low luminosity performance).

Higgs mass (GeV)	120	130	150	170	180
Signal	4.1	11.4	26.8	7.6	19.7
$t\bar{t}$	0.01	0.02	0.03	0.02	0.02
$Zb\bar{b}$	0.08	0.12	0.19	0.17	0.19
ZZ^*	1.23	2.27	2.51	2.83	2.87
$ZZ \rightarrow \tau\tau ll$	0.13	0.20	0.25	0.08	0.02
Significance ($S/\sqrt{B}$)	3.4	7.0	15.5	4.3	11.2
Significance (Poisson)	2.4	4.8	15.5	3.2	11.2

30 fb^{-1}

ATLAS barrel
$H \rightarrow ZZ^* \rightarrow ee\mu\mu$ (M(H)=130 GeV)



High luminosity

Higgs in 2 photons

For M(H)<150 GeV, most promising channels are:

H→gg and H→tt in association with 2 forward jets (VBF)

Distinctive features of the H→gg mode are:

- -low s x BR
- -large irreducible background
- -potentially large instrumental background (jet-jet and g-jet)
- -clean signature
- -high invariant mass resolution

} Defining criteria for EM calorimeters

Ultimate energy resolution , when all calibration/normalization problems are solved:

CMS : 3%/ √ E ⊕ (200MeV⊕ pile-up)/E ⊕ 0.55%

ATLAS : 10%/ √ E ⊕ (200MeV⊕pile-up /E ⊕ 0.70%

Remember converted photons are somewhat worse

→ΔM(H)/M(H) ~ 1%

At High luminosity the vertex is ambiguous,which worsens the M(H) resolution in the absence of angular measurements (a place where converted photons help)

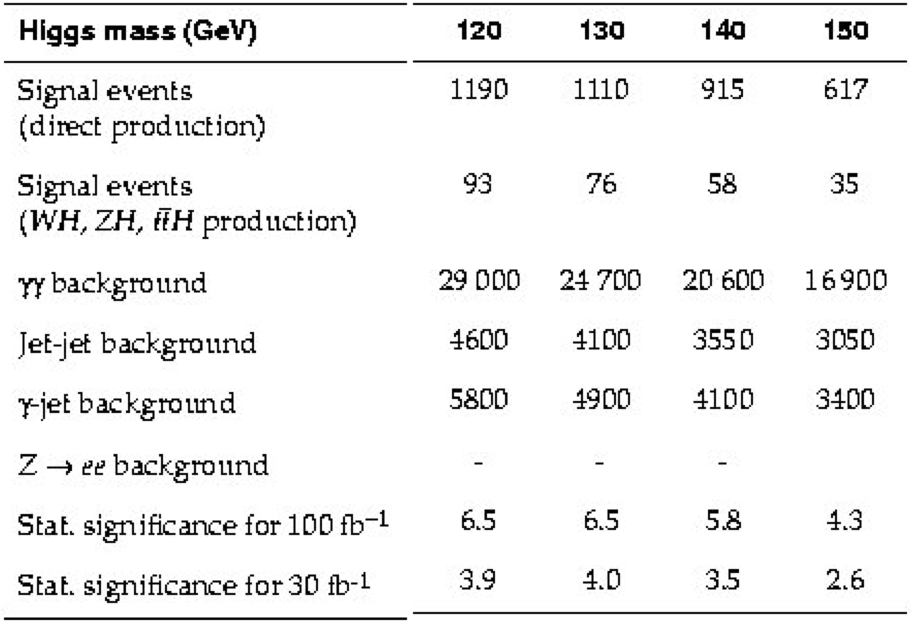
Jet-jet and g-jet rejection

Overall jet rejection obtained in ATLAS MC full simulation, confirmed by test beam (using fine strips):

-1050 for quark jets

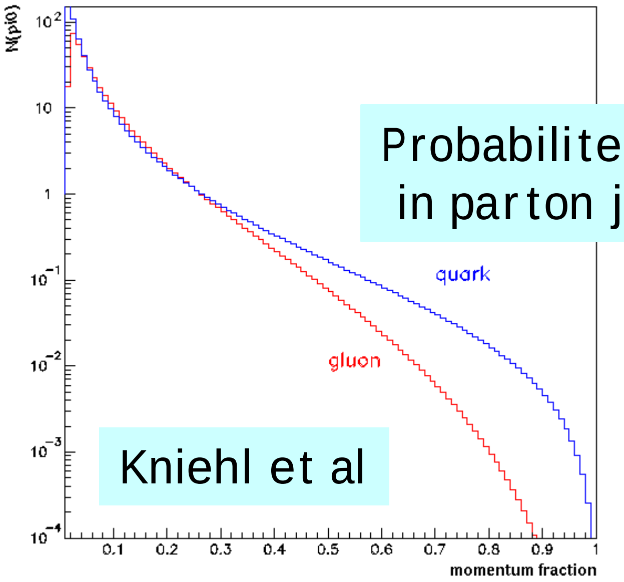
-6000 for gluon jets →Ultimate performance process dependant!

(probability of a high x isolated p^0 is much higher in (MC) quark jet



Higgs mass (GeV)	120	130	140	150
Signal events (direct production)	1190	1110	915	617
Signal events (*WH, ZH, tt̄H* production)	93	76	58	35
γγ background	29 000	24 700	20 600	16 900
Jet-jet background	4600	4100	3550	3050
γ-jet background	5800	4900	4100	3400
$Z \rightarrow ee$ background	-	-	-	
Stat. significance for 100 fb^{-1}	6.5	6.5	5.8	4.3
Stat. significance for 30 fb^{-1}	3.9	4.0	3.5	2.6

- Main jet-jet Bkg=gluon-gluon rejection of 6000 x 6000 OK
- Main g -jet bkg:g - quark rejection=1000....

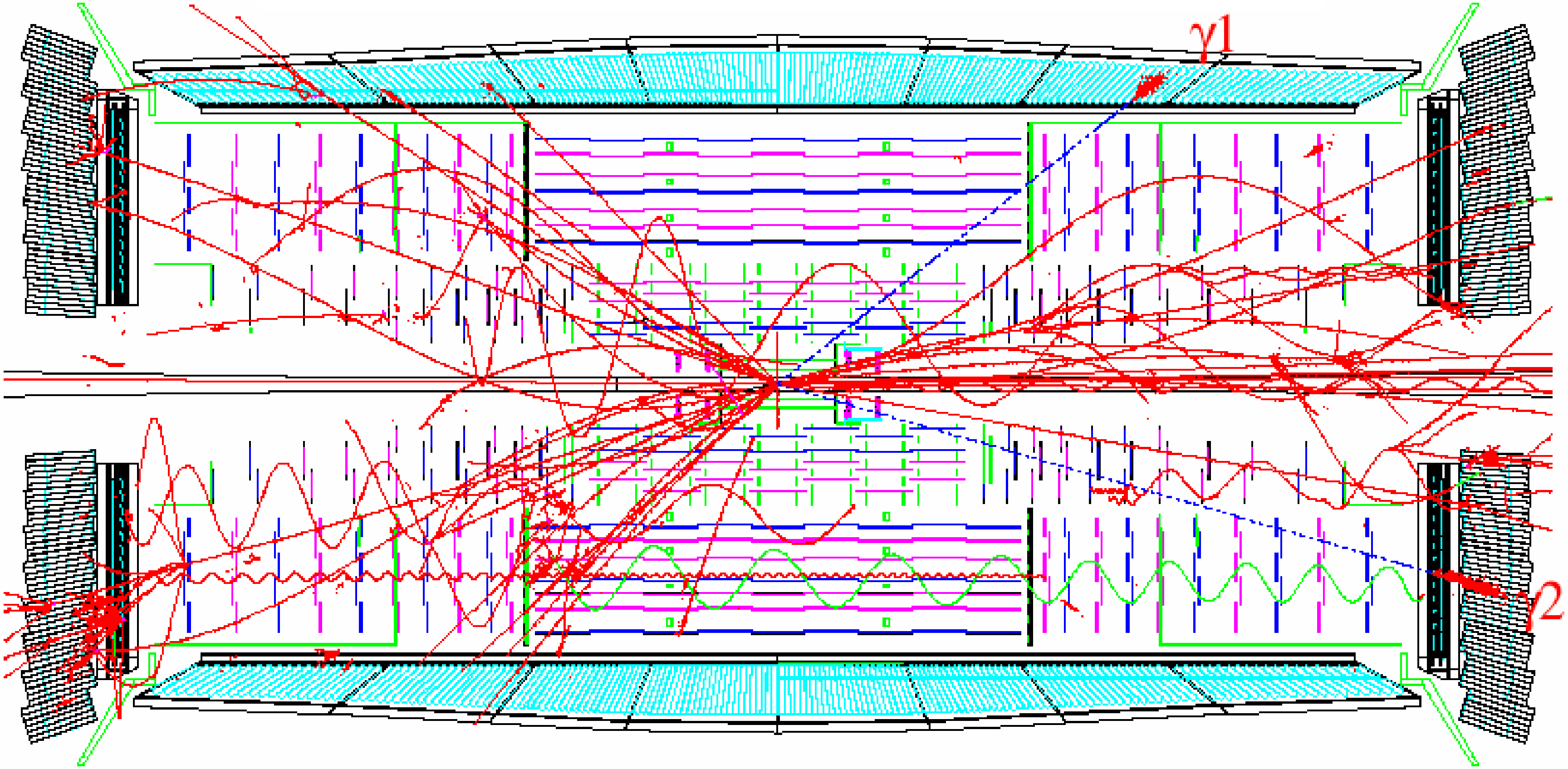


Probabilite of p in parton jet

Kniehl et al

Channel very much dependant on detector
Ultimate performance, resolution and photon/jet identification.

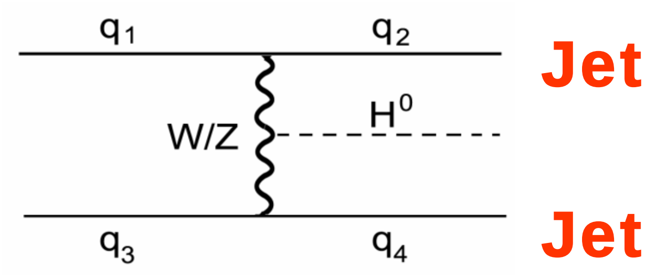
A **H**®g-g event display in CMS

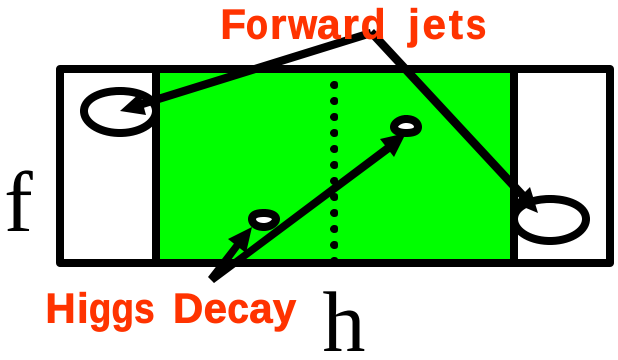


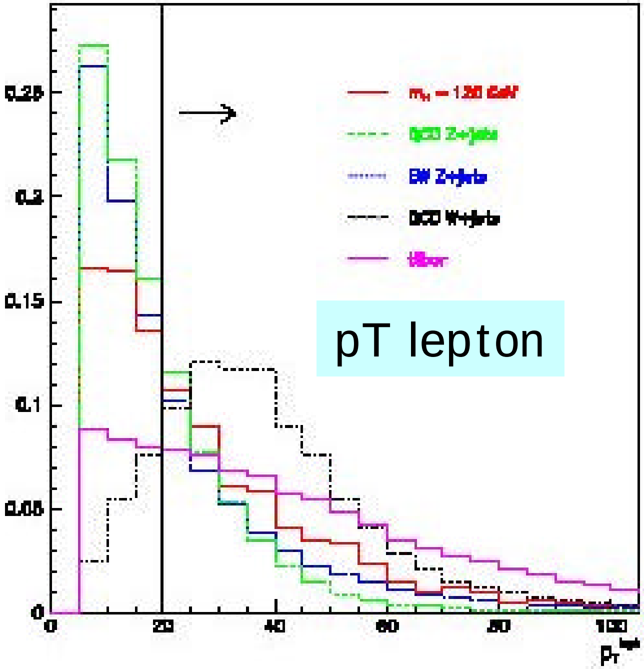
Low luminosity case-1 collision only

Higgs → ττ by VBF

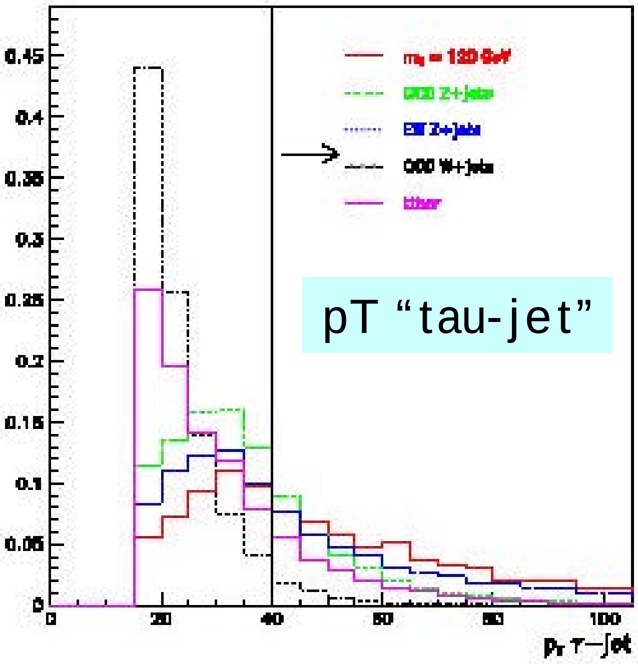
- The tt mode has a larger BR than gg but a weaker signature and worse resolution
- Asking 2 forward jets (and no other jet) selects weak process by WW fusion, which has less background







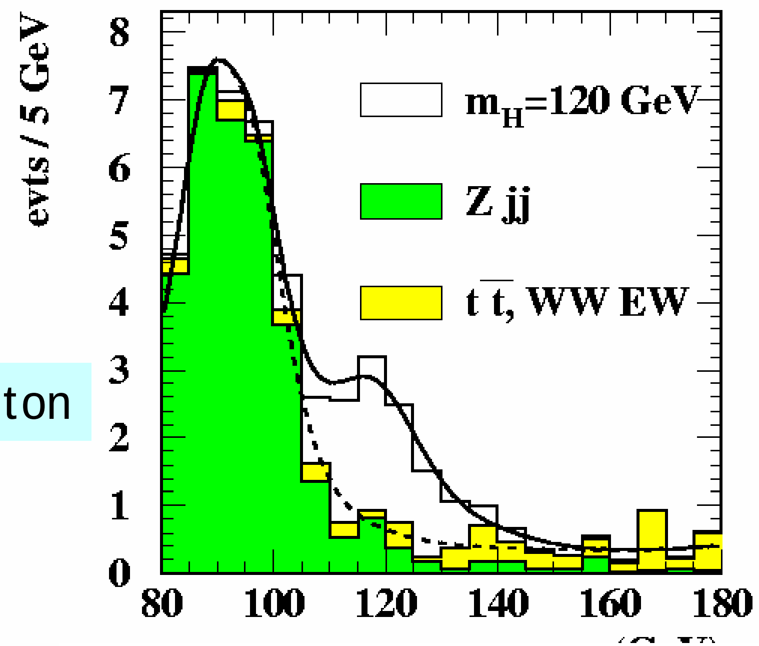
Trigger
Dilepton:
E15mu10
Lepton-hadron
pTlept>20 GeV
or
Tau35 xE45



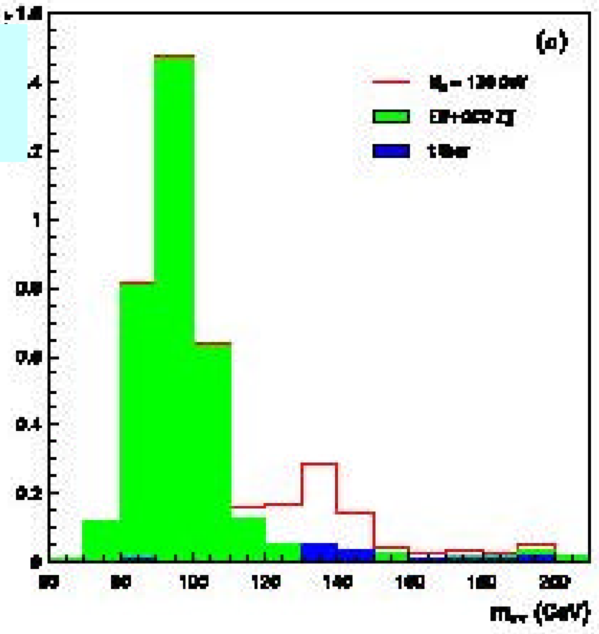
Higgs →ττ by VBF

Tagging jets:
Dh > 4.4
M(JJ) > 700GeV
Backgrounds:
ttbar, Z+2 jets
Invariant mass:
Calculated using the 2 taus and the missing ET

Di-lepton



Hadron-lepton
M(H)=130 GeV



s BR in fb

cuts	Hqq	gg fusion	EW Zjj	W+jets	tt
preselection cuts	28.	101.2	59.3	4.3×10^4	2.07×10^4
lept. trigger	13.7	50.31	22.0	3.4×10^4	1.6×10^4
τ cuts.	6.18	22.65	8.03	3.2×10^3	4.3×10^3
Fwd. tag	1.97	0.176	1.72	30.	29.7
τ decay and reconst.	1.27	0.105	1.09	5.9	6.06
m_T	1.02	0.071	0.92	0.63	1.74
p_T^{miss}	0.81	0.051	0.71	0.58	1.38
m_{jj}	0.71	0.028	0.69	0.37	1.01
Jet veto	0.63	0.014	0.66	0.21	0.14
Mass Window	0.52	0.007	0.06	0.00	0.007

SUSY

- In the MSSM each fermion $f_{L,R}$ has a scalar partner $sf_{L,R}$, and to each Gauge boson is associated a massless spin ½ gaugino.

- Among other virtues, these states coming with an opposite sign to normal particles in loop corrections, cancel the quadratic divergence of the Higgs mass, which would otherwise run to “infinity”.

- None of these particles has been so far observed → heavy!
- sq and sg couple to QCD as usual particles, they should be copiously produced at LHC as soon as threshold is passed.

- In the MSSM R-parity = (-1)**3(B-L)+2S is conserved:
  - s-particles are produced in pair
  - the lightest one is stable= neutralino c^0
- Exact signatures depend on the details of the model.
  A common feature is large SE_T and missing energy (neutralinos)

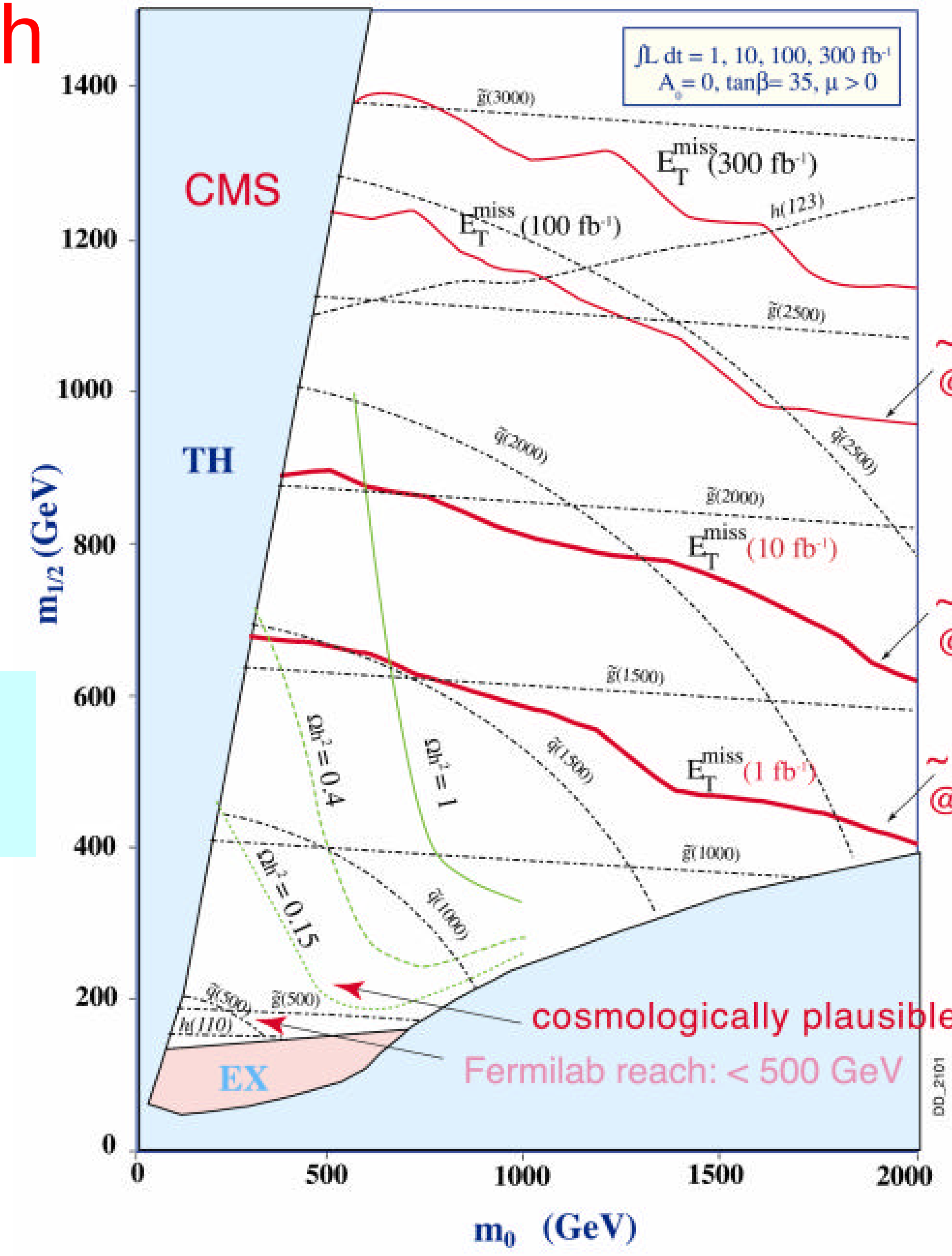
- The reach of experiments can be evaluated and compared using as parameter m_0 ($m_{1/2}$) the common mass of all scalars (spin ½) at GUT scale

CMS-SUSY reach

- Rates are high:
  100 evts /day for
  m(sq,sg) = 1 TeV

- Trigger is easy:
  multijets ⊕ E_T miss

In principle,…in one month
at 10^{33}, s-quarks and gluinos
up to ~2 TeV can be discovered



~ one year
@10^{34}

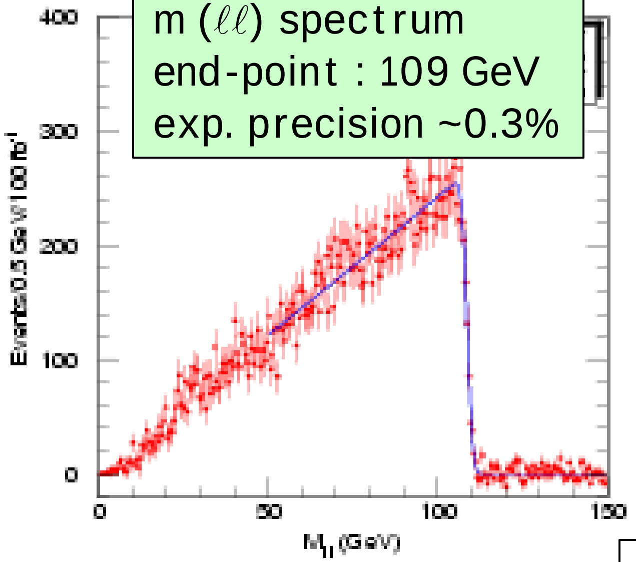
~ one year
@10^{33}

~ one month
@10^{33}

cosmologically plausible region

Fermilab reach: < 500 GeV

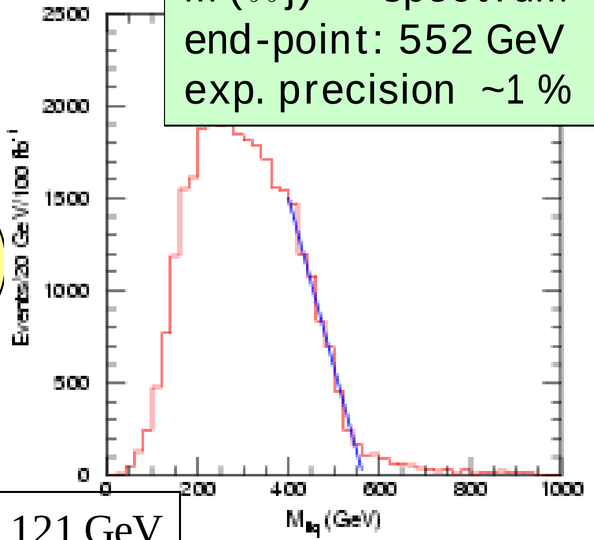
SUSY parameters from decay chain



m ($\ell\ell$) spectrum
end-point : 109 GeV
exp. precision ~0.3%

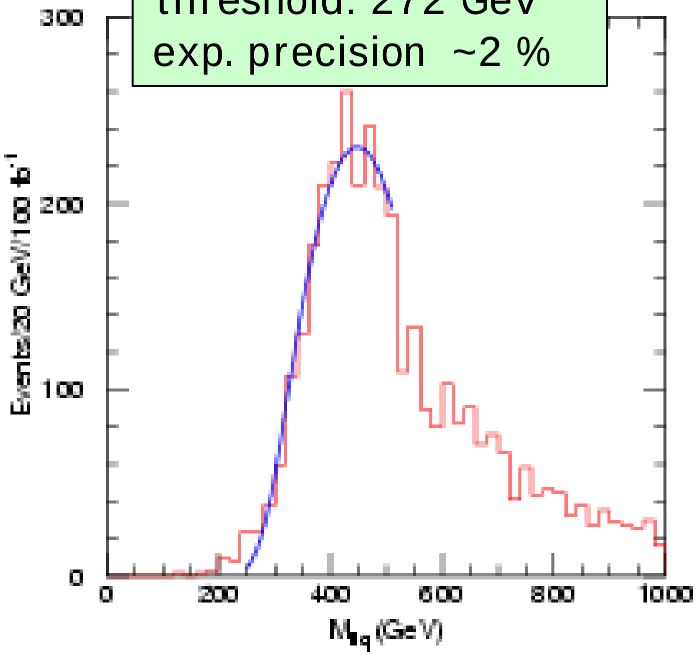
Example: ”Point 5”

$$\tilde{q}_L \rightarrow q\,\chi^0_2$$
$$\hookrightarrow \tilde{\ell}_R\,\ell$$
$$\hookrightarrow \ell\,\chi^0_1$$



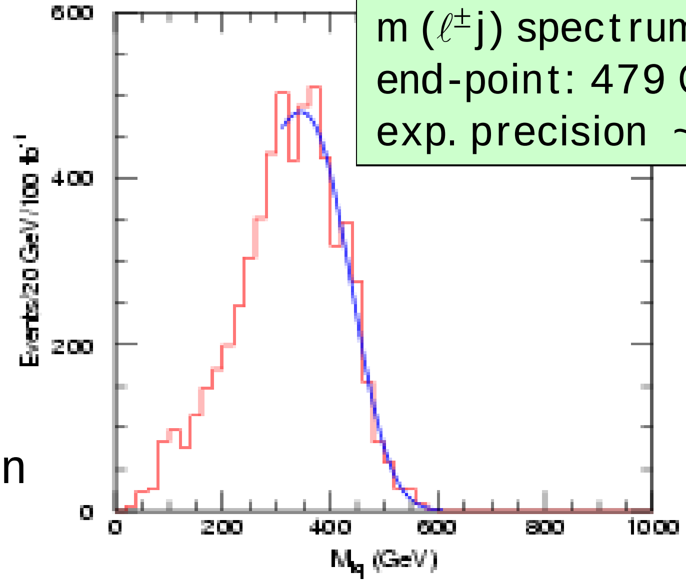
m ($\ell\ell$j)^{min} spectrum
end-point: 552 GeV
exp. precision ~1 %

m ($\tilde{q}_L$, ?$^0{}_2$, $\tilde{\ell}_R$, ?$^0{}_1$) = 690, 232, 157, 121 GeV



m ($\ell\ell$j)^{max} spectrum
threshold: 272 GeV
exp. precision ~2 %

100 fb^{-1}



m ($\ell^{\pm}$j) spectrum
end-point: 479 GeV
exp. precision ~1 %

End-points
↓
Relation between Masses
↓
All masses → M(c$^{\mathbf{0}}{}_{\mathbf{1}}$) to 12% RMS → DM

A,H decays in t t

- In the MSSM there are 5 Higgs bosons : h, H, A, H^{+-}

The 5 masses depend on 2 parameters: M(A) and tg(b)

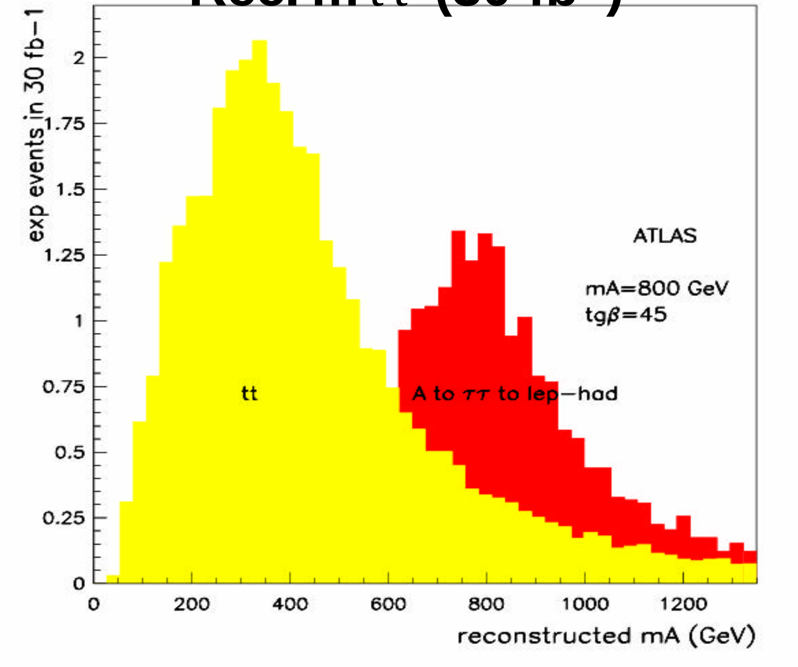
- For large M(A) and tg(b) the H and A couplings to bb and t pairs are enhanced

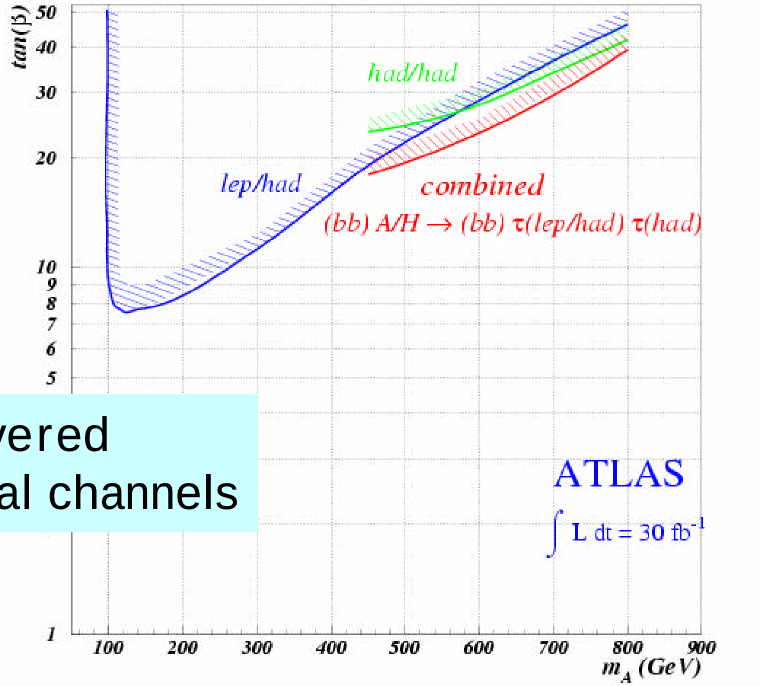
bb→bbA

└→ t t is a favored discovery channel(t t BR=11%, s =760 fb for tg(b)=45,M(A)&M(H)=800 GeV)

- LVL1 Triggers = (one tau-jet or lepton)⊕ETmiss

Rec. m t t (30 fb^{-1})



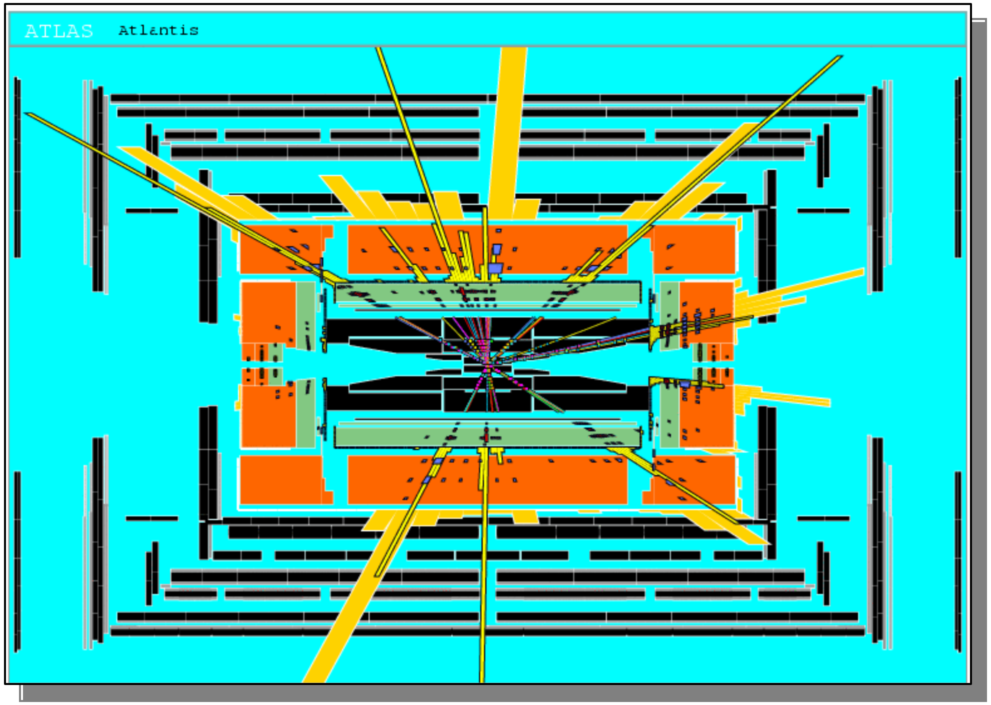


Plane covered
by several channels

An example of exotica :Black hole production..

- Another way of stabilizing the Higgs mass is to assume that there are extra space-dimensions, in which case the Planck mass could be as low as a few TeV.

- When √S reaches Mp Black Holes are produced, which decay “democratically” to quarks, leptons, Gauge bosons.



A typical event (?) could have:
hadrons/leptons/g,W,Z/Higgs ~ 75%/20%/3%/2%

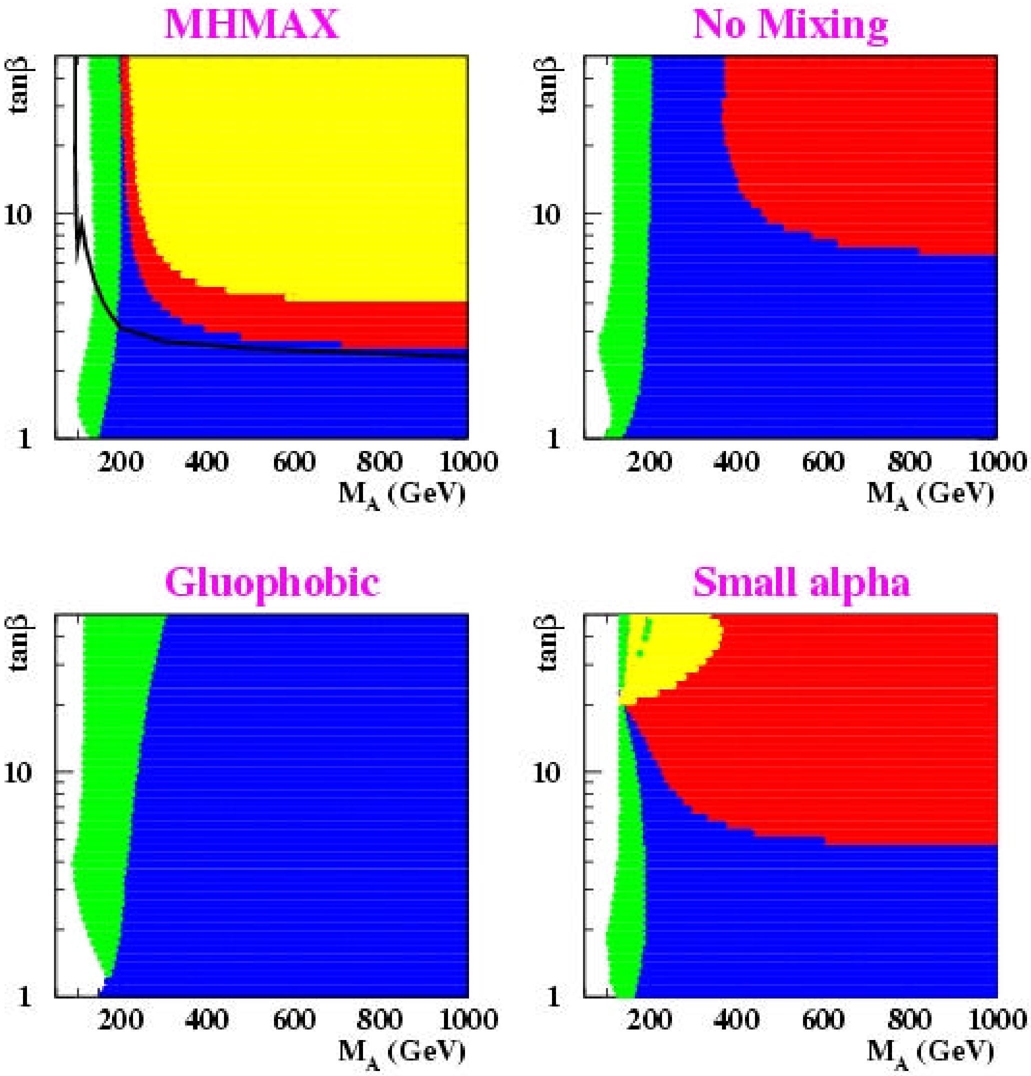
....a dream for particle identification at the LHC

Conclusion-Summary

- Each of the 4 LHC experiment is a challenge
- Particle identification plays in all a major role
- Detectors have been carefully designed and are being built and tested with a lot of care.
- Tuning the triggers at start-up will be a crucial step
- A major issue-not discussed-will be the capacity of the experiments to “digest” the enormous amount of data they will produce, typically 1 Mbyte*200Hz to mass storage
- More in 3+e years, when LHC starts…

Back-up transparency

Light Higgs boson h: 300 fb^{-1}



For high lumi.:

h→gg, tth→bb

h→ZZ→4l

contribute

🟥 **All three**

🟦 **h→gg + tth→bb**

🟨 **h→gg +h→ZZ→4l**

🟩 **only tth→bb**