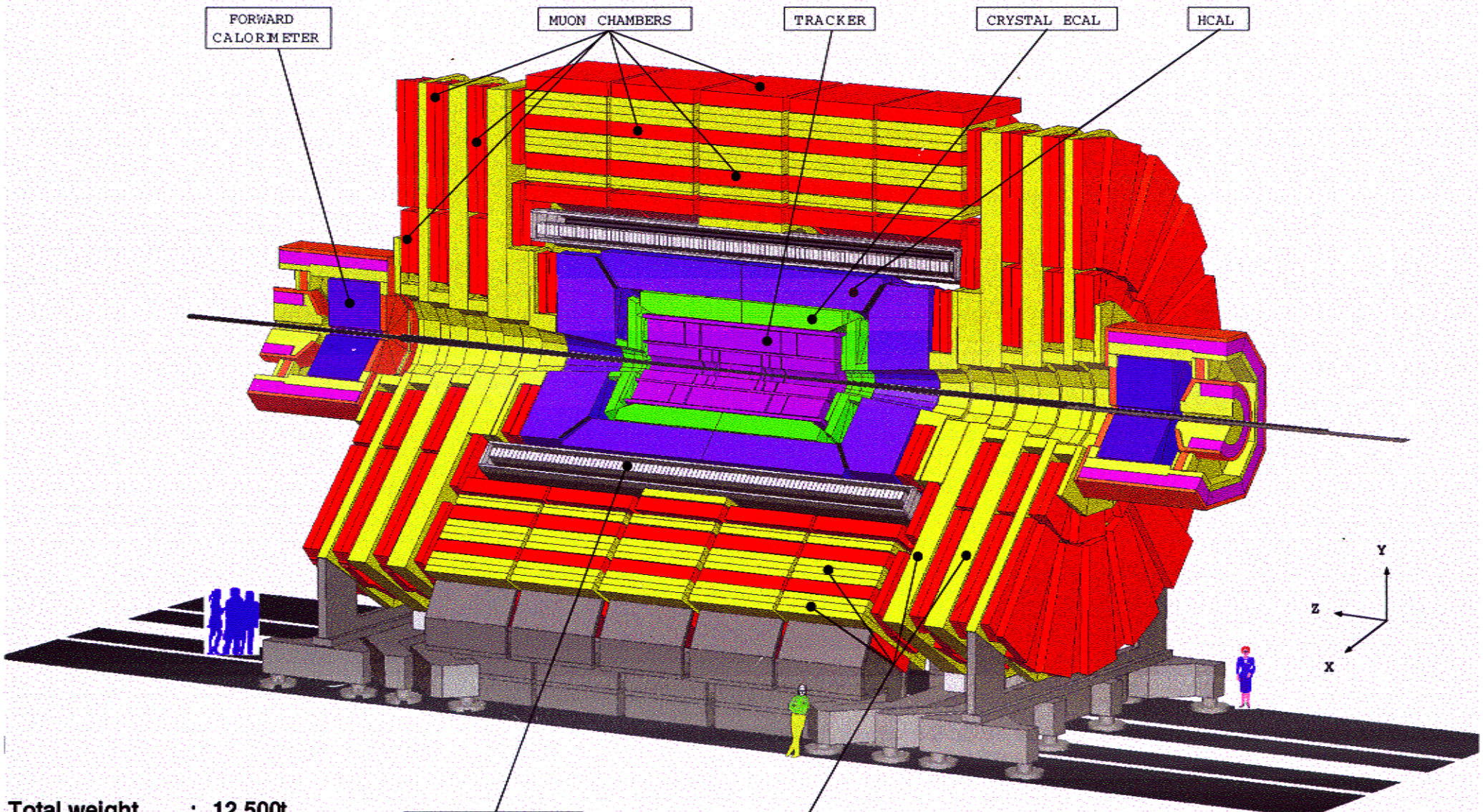
October 28, 1999
Fermilab

Prospects for Higgs (SM and MSSM) searches at LHC

D. Denegri, CE Saclay

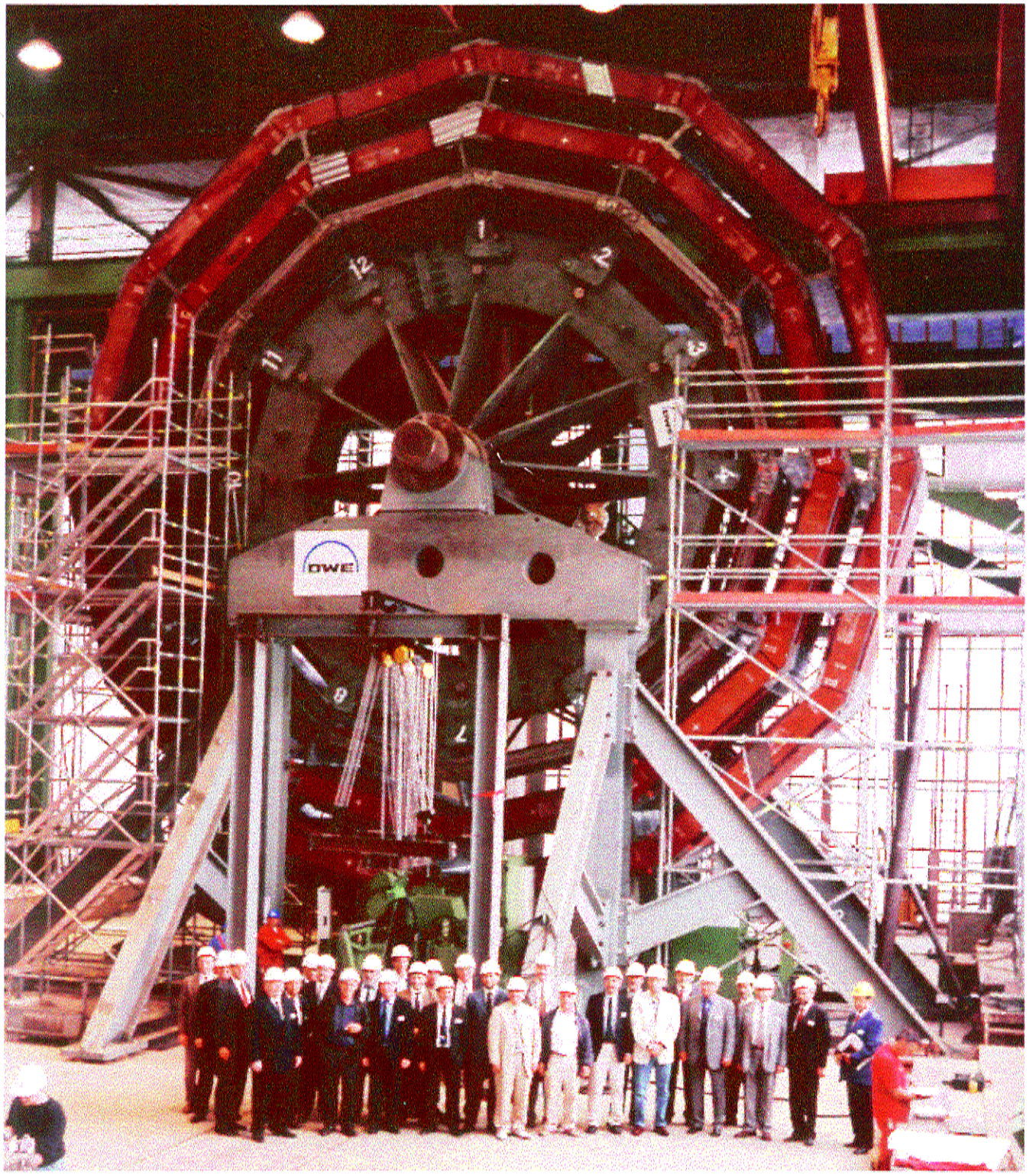
- SM Higgs,
  channels, mass reach, precision
- SUSY Higgs searches,
  channels, parameter space coverage

CMS
A Compact Solenoidal Detector for LHC



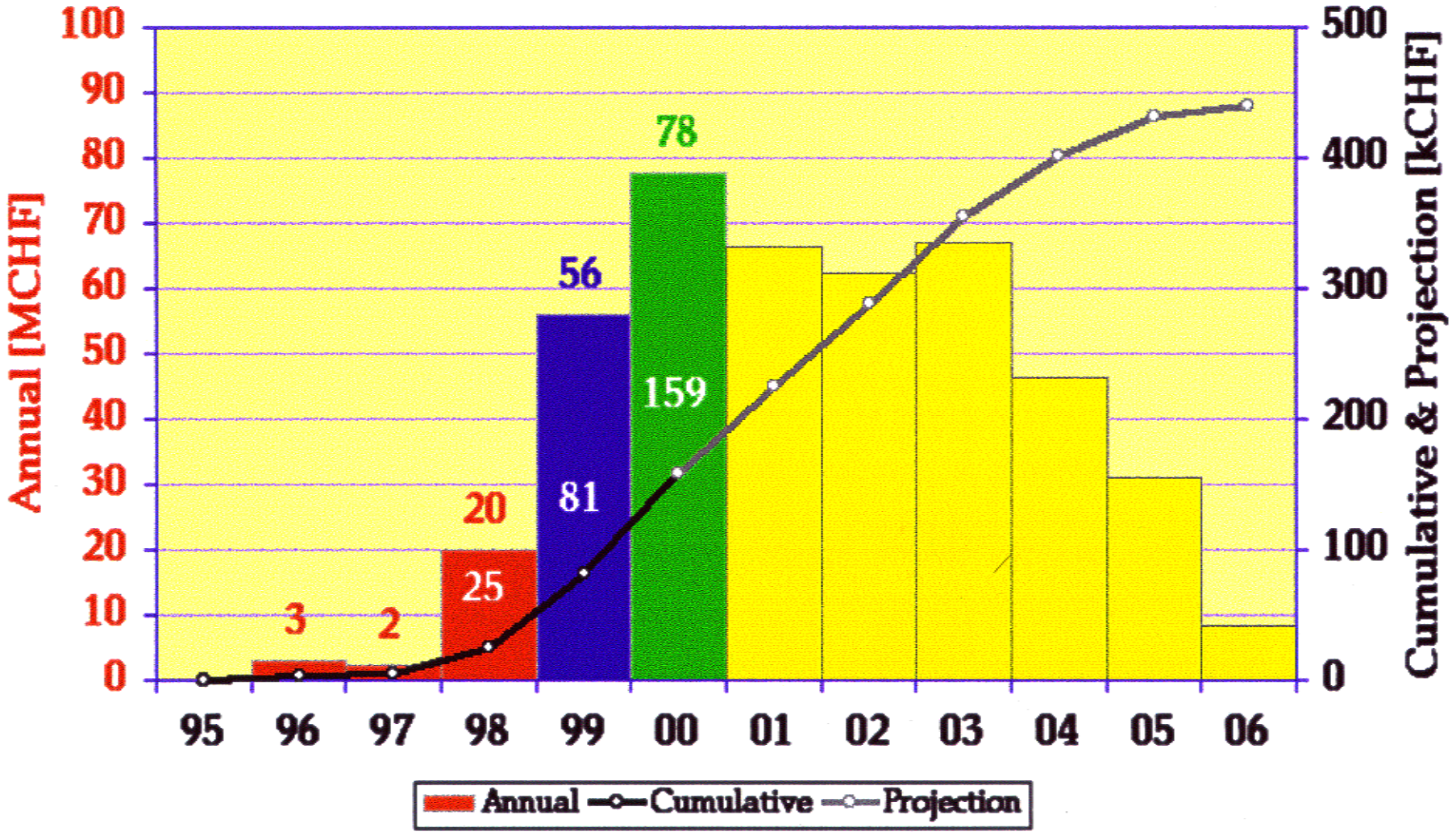
Total weight : 12,500t.
Overall diameter : 15.00m
Overall length : 21.60m
Magnetic field : 4 Tesla

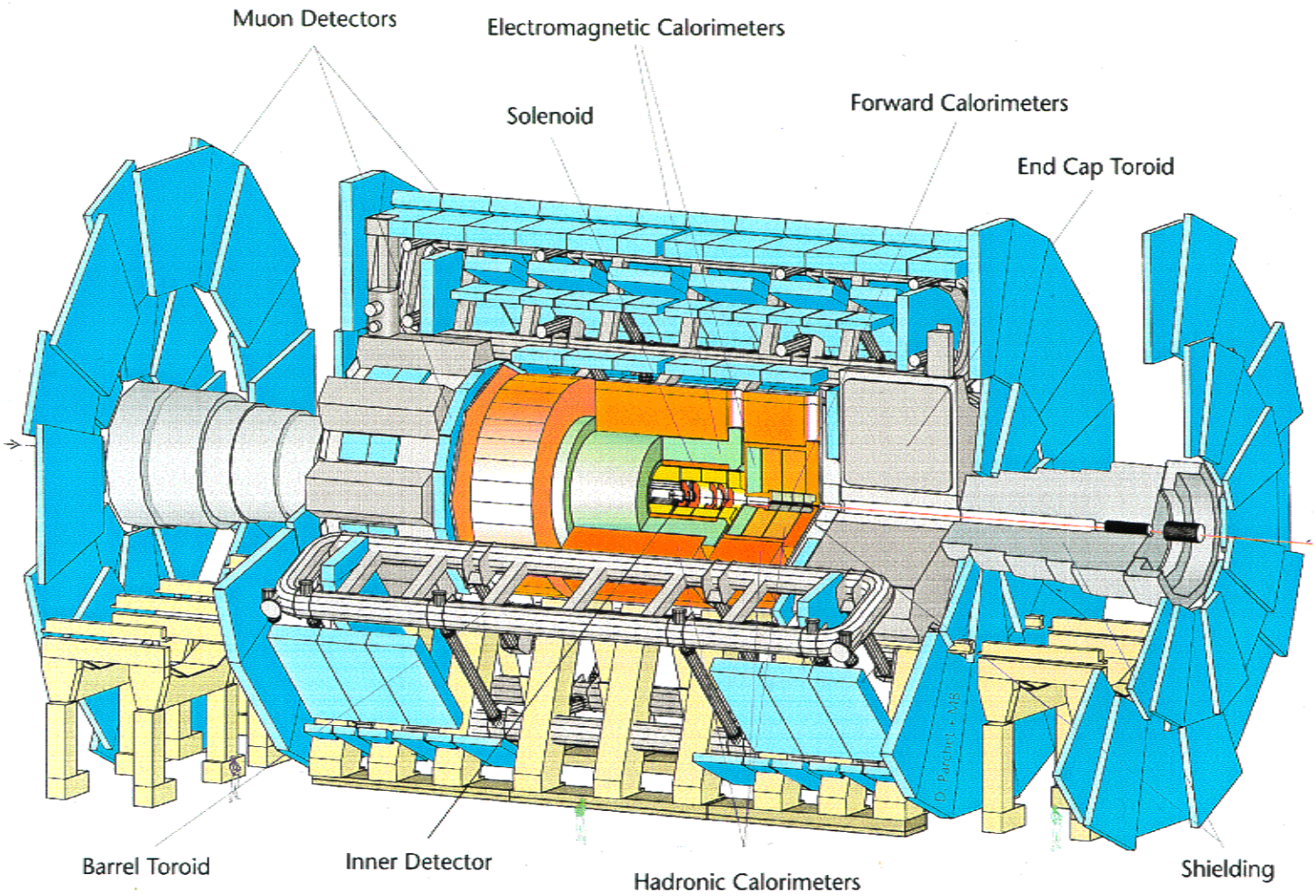
CMS-PARA-001-11/07/97 JLB.PP


OWE

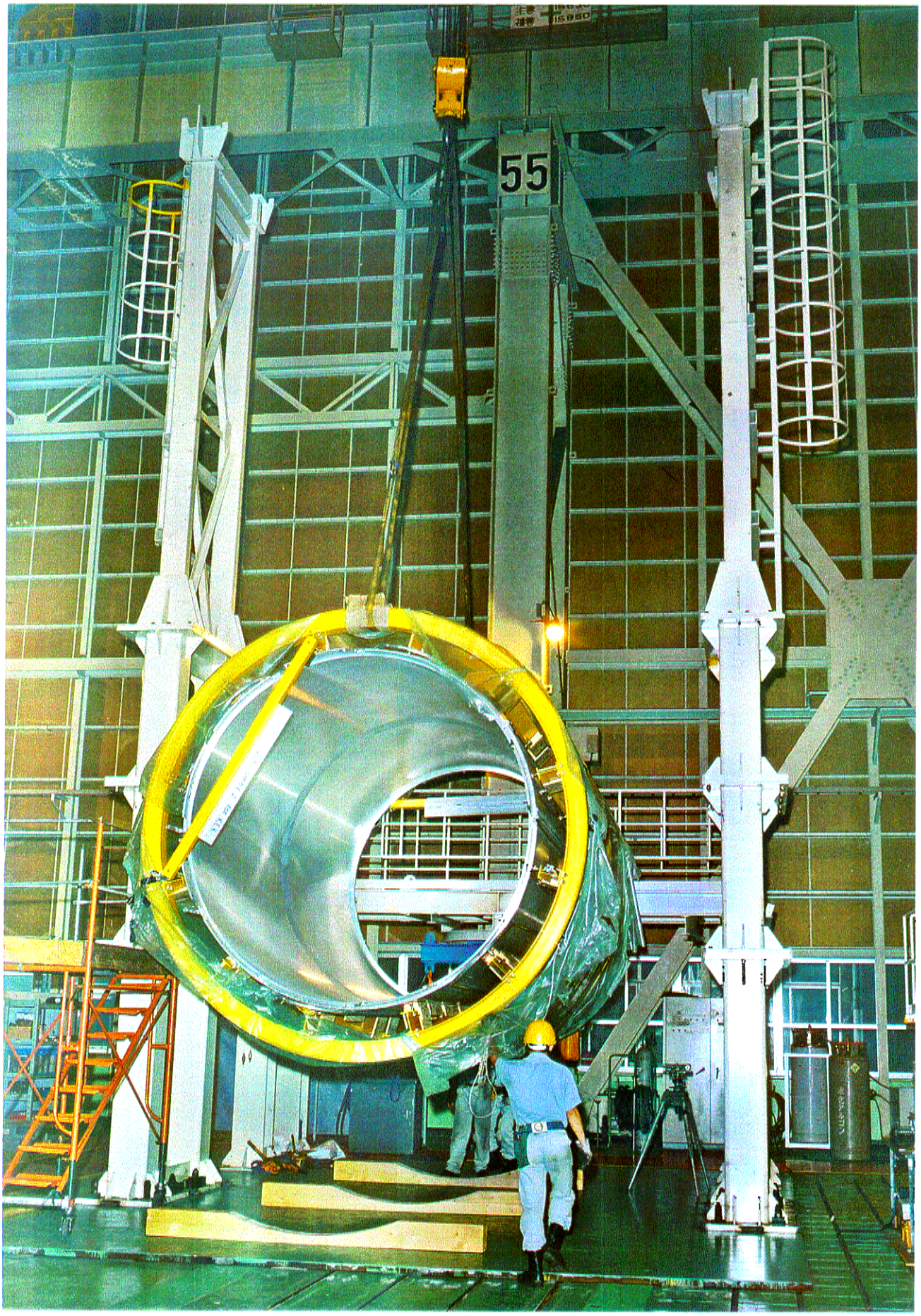
HCAL Beam Test Layout

Payments for CMS Construction




Muon Detectors
Electromagnetic Calorimeters
Solenoid
Forward Calorimeters
End Cap Toroid
Barrel Toroid
Inner Detector
Hadronic Calorimeters
Shielding

ATLAS Solenoid - Toshiba

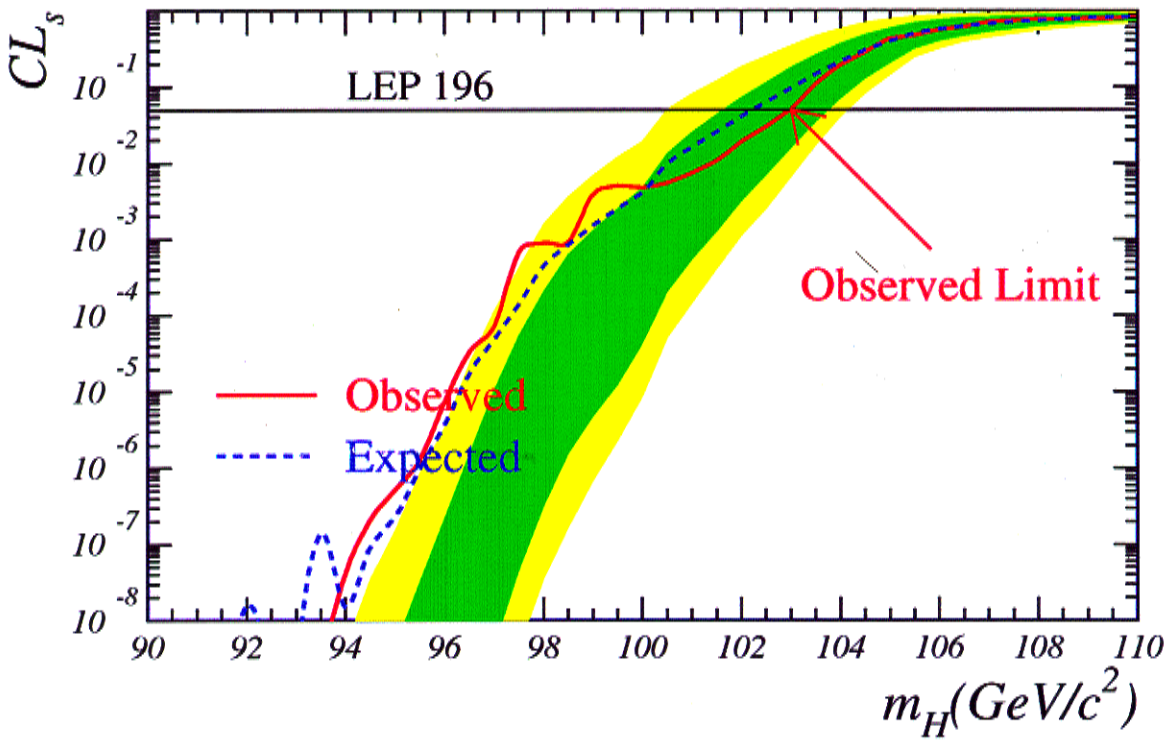


Point 5 - SX Roofing steelworks - September 17, 1999 - CERN ST-CE

The SM Higgs

Standard Model Higgs Limit

To set limits on Higgs mass hypothesis, look at CL_s:



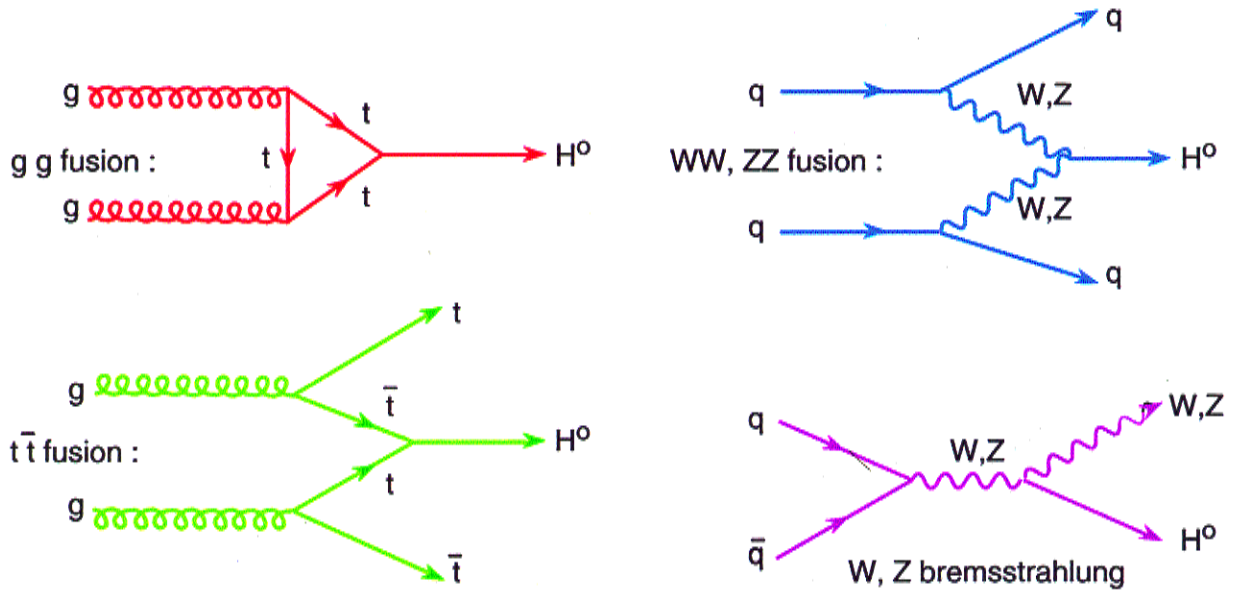
For all combination methods,
all $m_H \leq 102.6$ GeV/c^2, $CL_s \leq 0.05$.

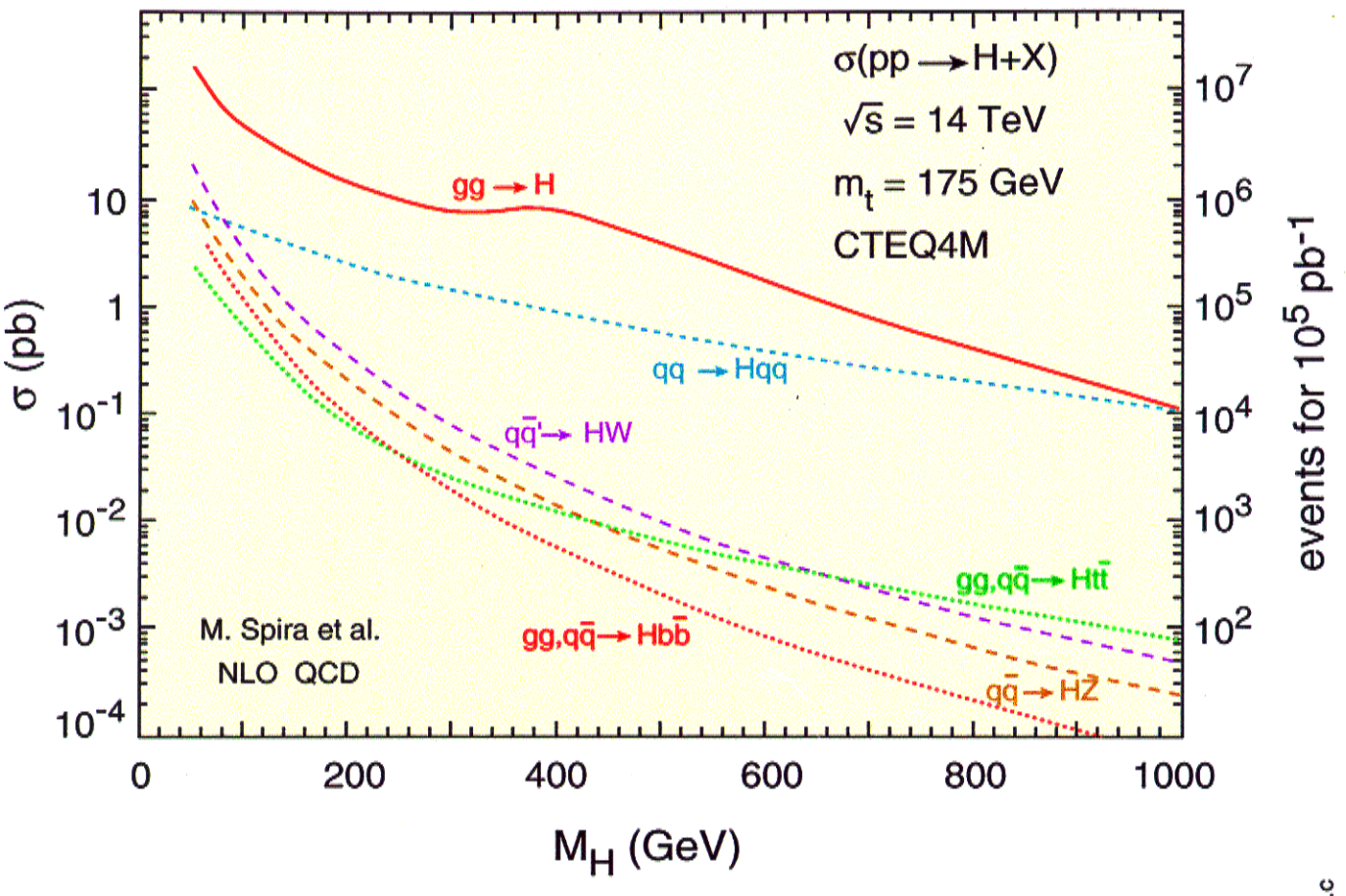
Therefore, a limit on the Higgs mass is set:

$m_H > 102.6$ GeV/c^2 @ 95% C.L.

(with 102.3 GeV/c^2 expected)

H^o production at hadron colliders:





But : $BR(H \to Z^oZ^o \to 4l^{\pm}) = 1.4 \cdot 10^{-3}$

$BR(H \to Z^oZ^o \to 4\mu^{\pm}) = 3 \cdot 10^{-4}$

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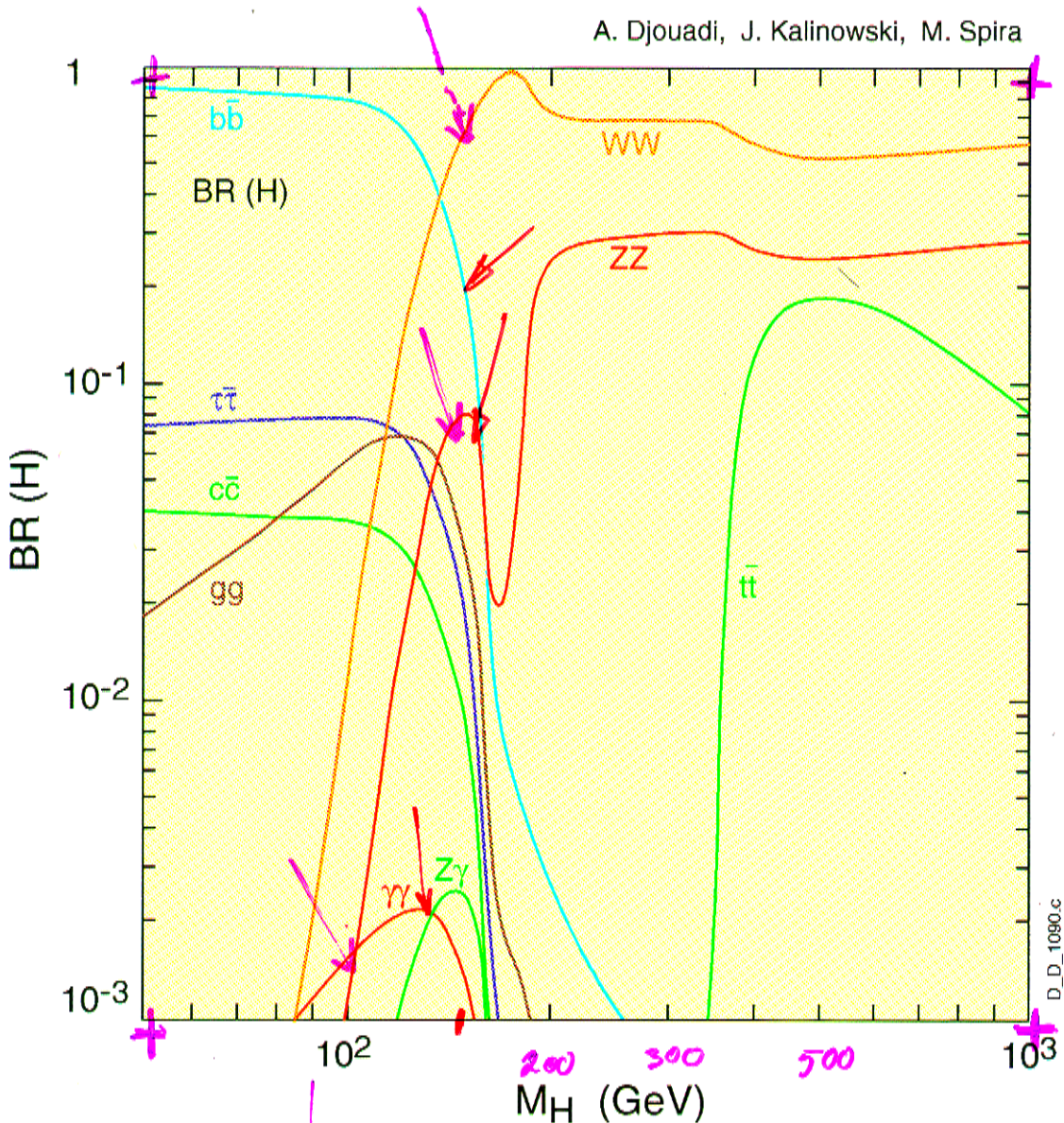
Higgs Branching Ratios



the most promising SM Higgs mass range

the MSSM (h) mass range

the SUSY h mass range

S.M. Higgs Searches

- $H \to \gamma\gamma$ for $100 \leq m_H \leq 150$ GeV
  in inclusive $H \to \gamma\gamma$ and in WH, ttH
- $H \to b\bar{b}$ for $90 \leq m_H \leq 120$ GeV
  in WH, ttH
- $H \to ZZ^* \to 4\ell^\pm$ for $130 \leq m_H \leq 200$ GeV
- $H \to WW \to \ell\nu\ell\nu$ for $140 \leq m_H \leq 180$ GeV
- $H \to ZZ \to 4\ell^\pm$ for $200 \leq m_H \leq 750$ GeV
- $H \to ZZ \to 2\ell^\pm + 2\nu$ for $0.5 \leq m_H \leq 1$ TeV
- $H \to WW \to \ell\nu jj$ for $m_H \approx 1$ TeV
- $H \to ZZ \to \ell\ell jj$ for $m_H \approx 1$ TeV

more recently:

$H \to Z\gamma$

$qq \to qq H$
$\hookrightarrow \tau\tau$

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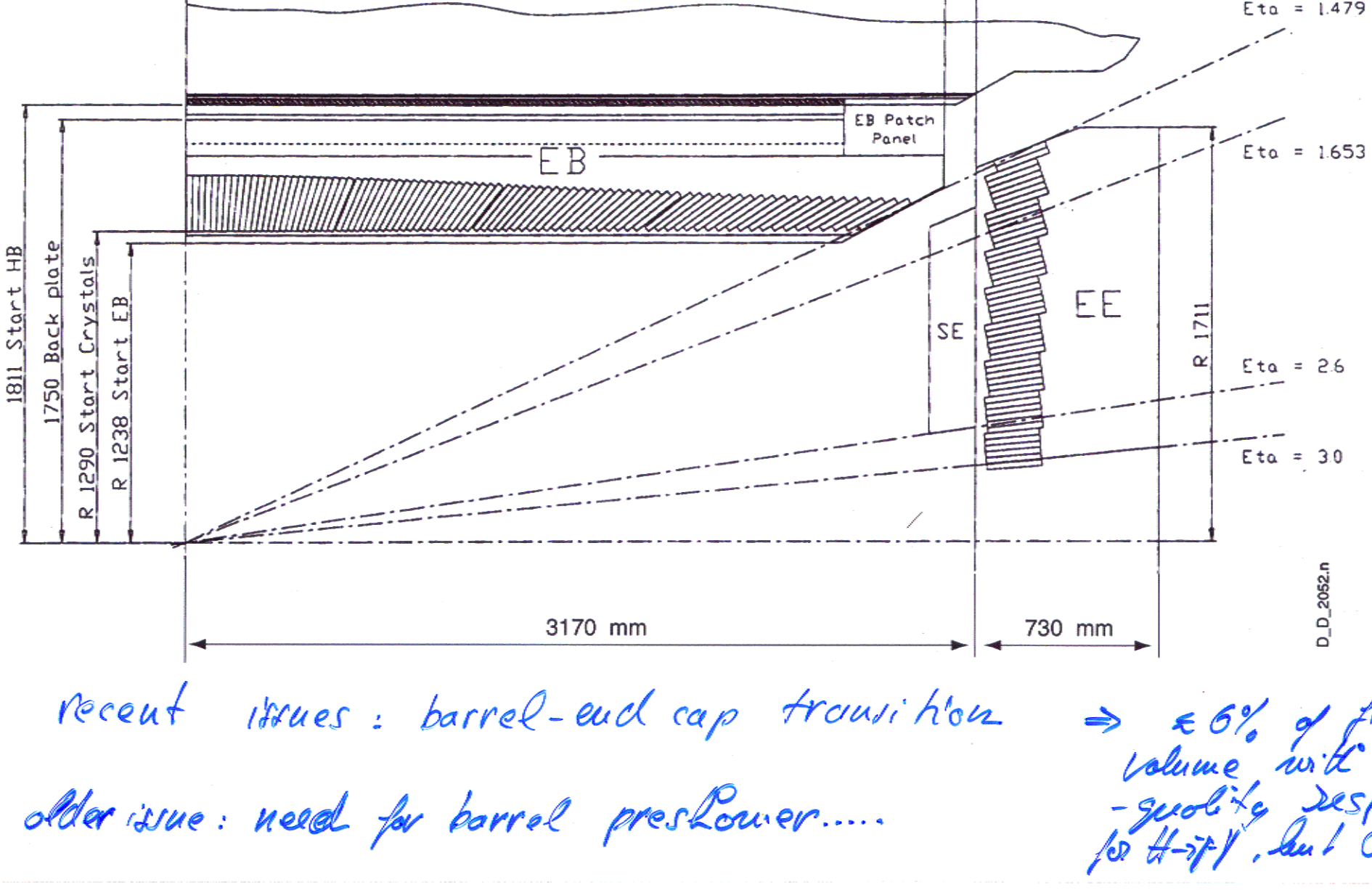
$H_{SM} \rightarrow \gamma\gamma$

$PbWO_4$ crystal calorimeter of CMS

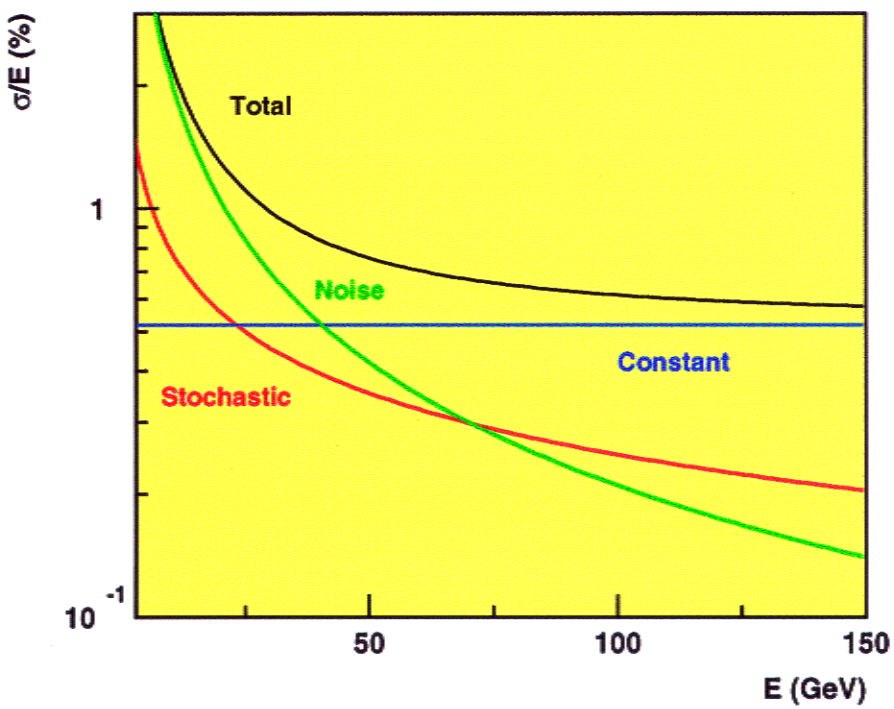


- recent issues: barrel-end cap transition ⇒ ≈ 6% of fiducial volume with reduced-quality response for $H \to \gamma\gamma$, but OK for Z
- older issue: need for barrel preshower.....

Lead tungstate ($PbWO_4$) crystal calorimeter

61200 $PbWO_4$ crystals of $22 \times 22 \times 230$ mm^3 in the barrel ($|\eta| < 1.48$) and 16000 crystals of $29 \times 29 \times 220$ mm^3 in the endcaps ($1.48 < |\eta| < 3.0$).

Design goal: $\Delta m_H < 1\%$ at $m_H = 100$ GeV



Energy resolution:

- Crystal light yield + photodetector (APD)
  → Stochastic term 2.5%
- Crystal non-uniformity + calibration
  → Constant term 0.52%
- Readout electronics
  → Noise 210 MeV/5x5 array

H -> γγ

A γγ mass resolution of ≈ 1 GeV at $m_{\gamma\gamma}$ = 100 GeV is needed

NLO cross sections

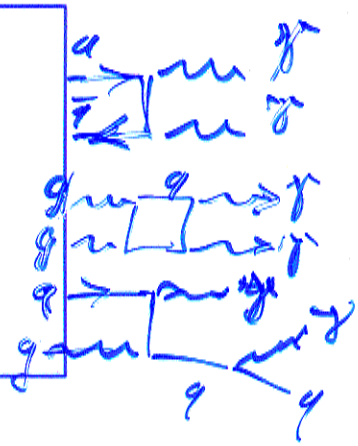
with kinematic cuts ($p_t^{\gamma 1}$ > 40 GeV, $p_t^{\gamma 2}$ > 25 GeV, $|\eta|$ < 2.5)

and isolation

H -> γγ, m_H = 100 GeV, σ * BR :	86.1 fb

Irreducible γγ backgrounds (at $m_{\gamma\gamma}$ = 100 GeV):

qq -> γγ	92 fb / GeV
gg -> γγ	167 fb / GeV
Isolated bremstrahlung	120 fb / GeV



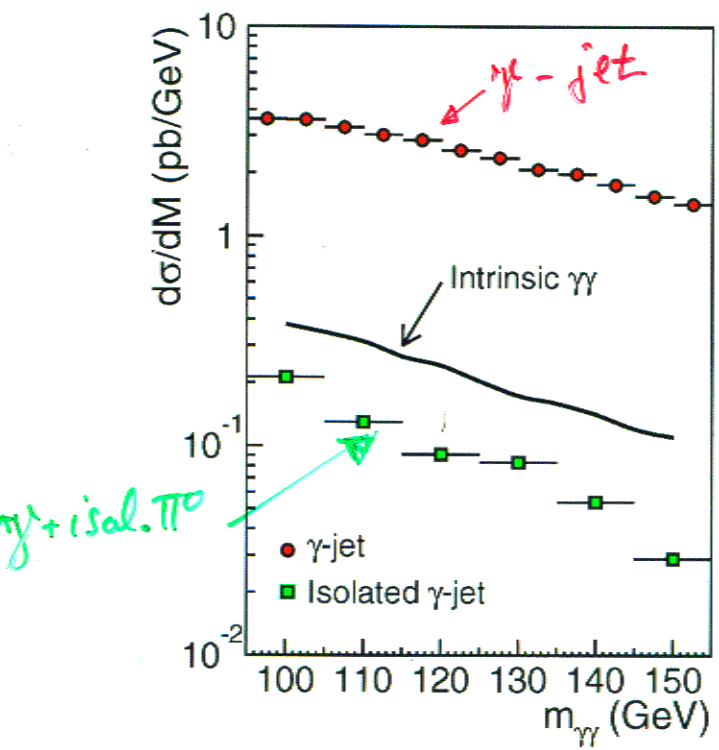
Main reducible background from γ+jet (with "jet" ≡ "π°" = "γ")

≲ 15 % of irreducible γγ background

Reducible background

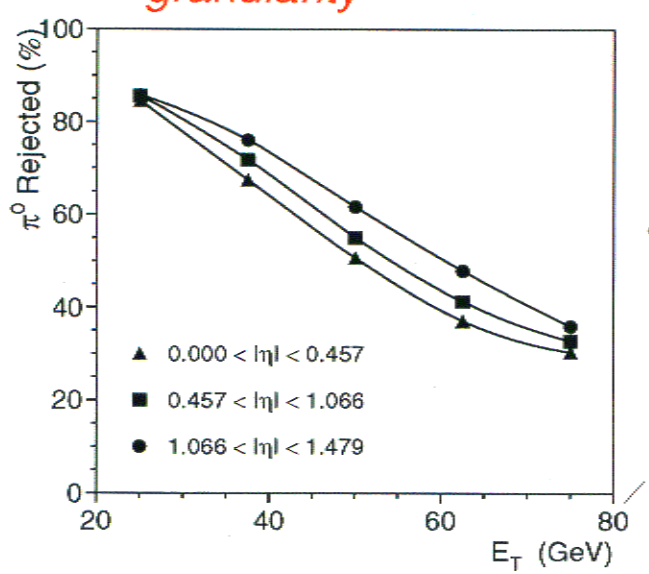
- **Predominantly γ + jet, where most of jet $E_{T\,is}$ carried by a π^0 which is reconstructed as a photon**

isolation cuts

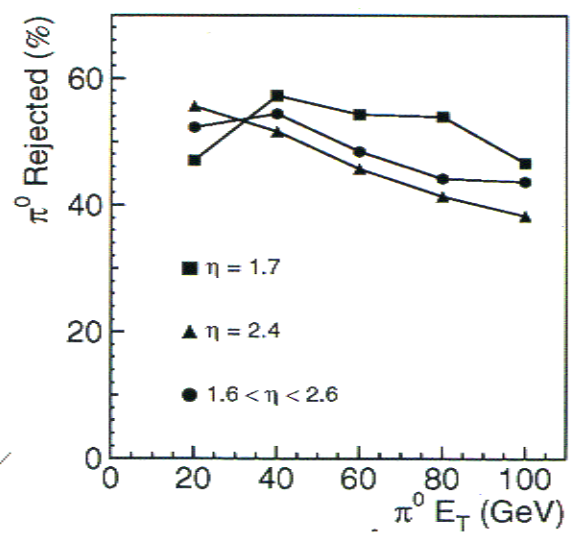


π^0 rejection

Barrel: uses crystal granularity



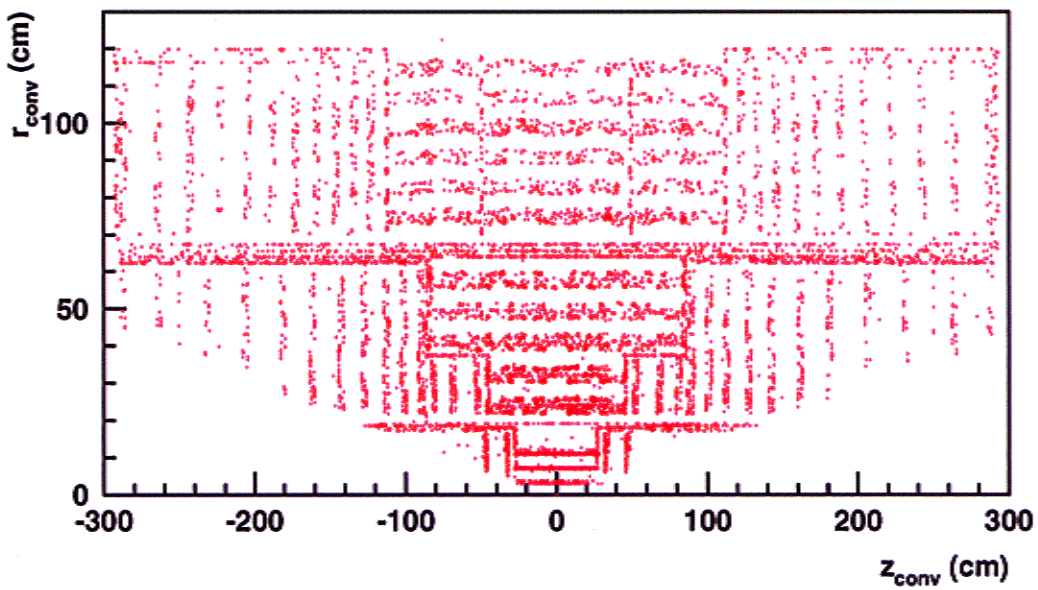
Endcap: uses preshower strips

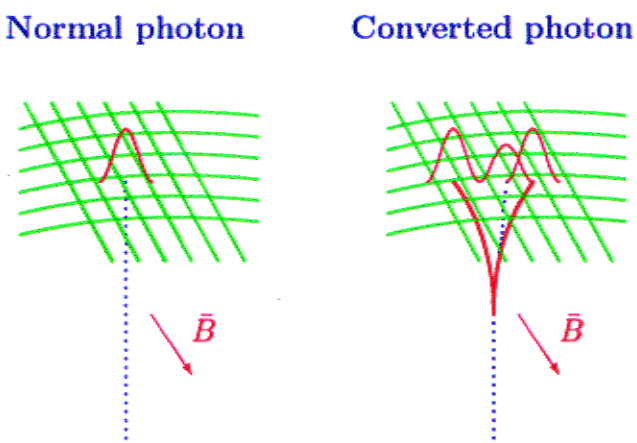


Rejection power shown for 90% γ efficiency

After isolation and π^0 rejection jet background below m_H = 100 is ≈15% of intrinsic $\gamma\gamma$ background

Photon conversions

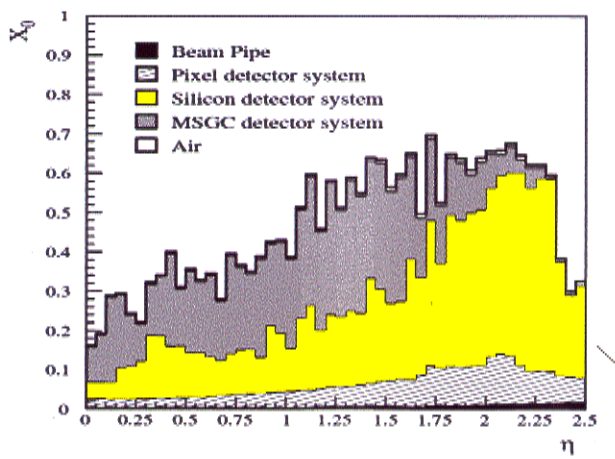




1. Conversion identification in the tracker
   - measurement of the invisible conversions with the same precision as the normal photons

2. E_γ measurement with a similar precision for normal photons and visible (identified) conversions.

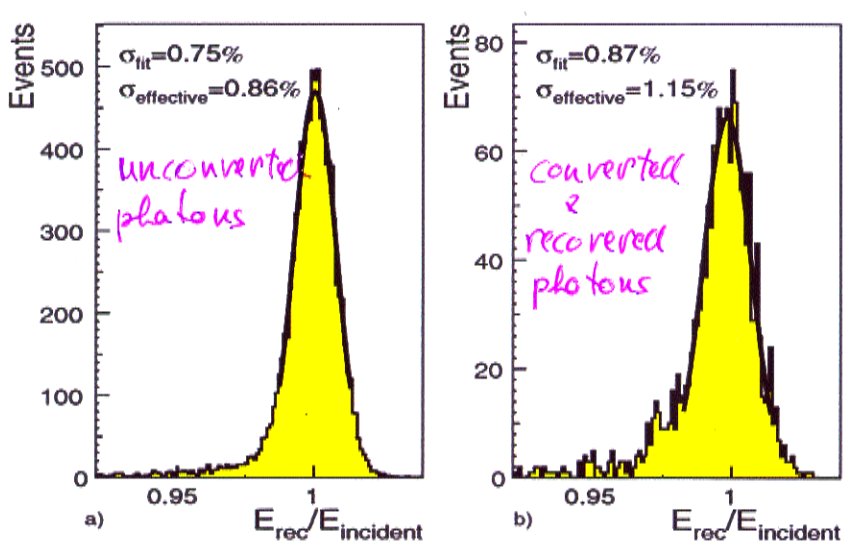
Recovery of conversions



Tracker material, in radiation lenghts, between the interaction point and the ECAL as a function of η

For H -> γγ, m_H = 100 GeV:

Photons converted: 23.8% in Barrel, 34.9% in Endcaps



In barrel 75.4% of the visible conversions reconstructed, 95.4% of all photons

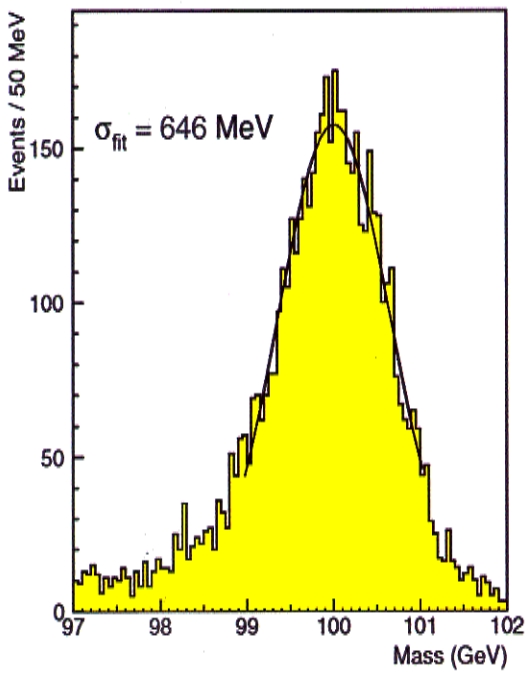
In endcaps 64.5% of the visible conversions reconstructed, 90.7% of all photons

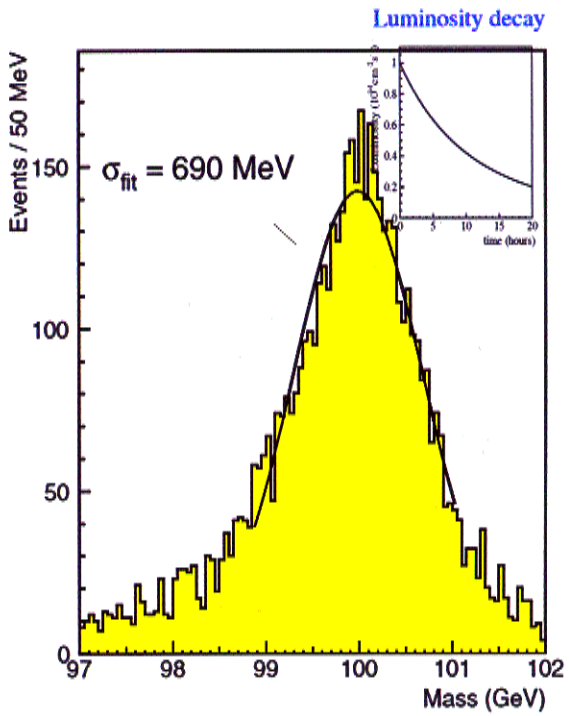
Higgs mass reconstruction in H -> γγ

Energy resolution assumed

in barrel: $2.7\%/\,E^{1/2} + 0.55\% + 155$ MeV(210 MeV)/E for low (high) L

in endcap: $5.7\%/\,E^{1/2} + 0.55\% + 770$ MeV(915 MeV)/E for low (high) L





Low luminosity

Constant $10^{33}cm^{-2}s^{-1}$

73% of events in $\Delta m_{\gamma\gamma} = 1.9$ GeV

High luminosity

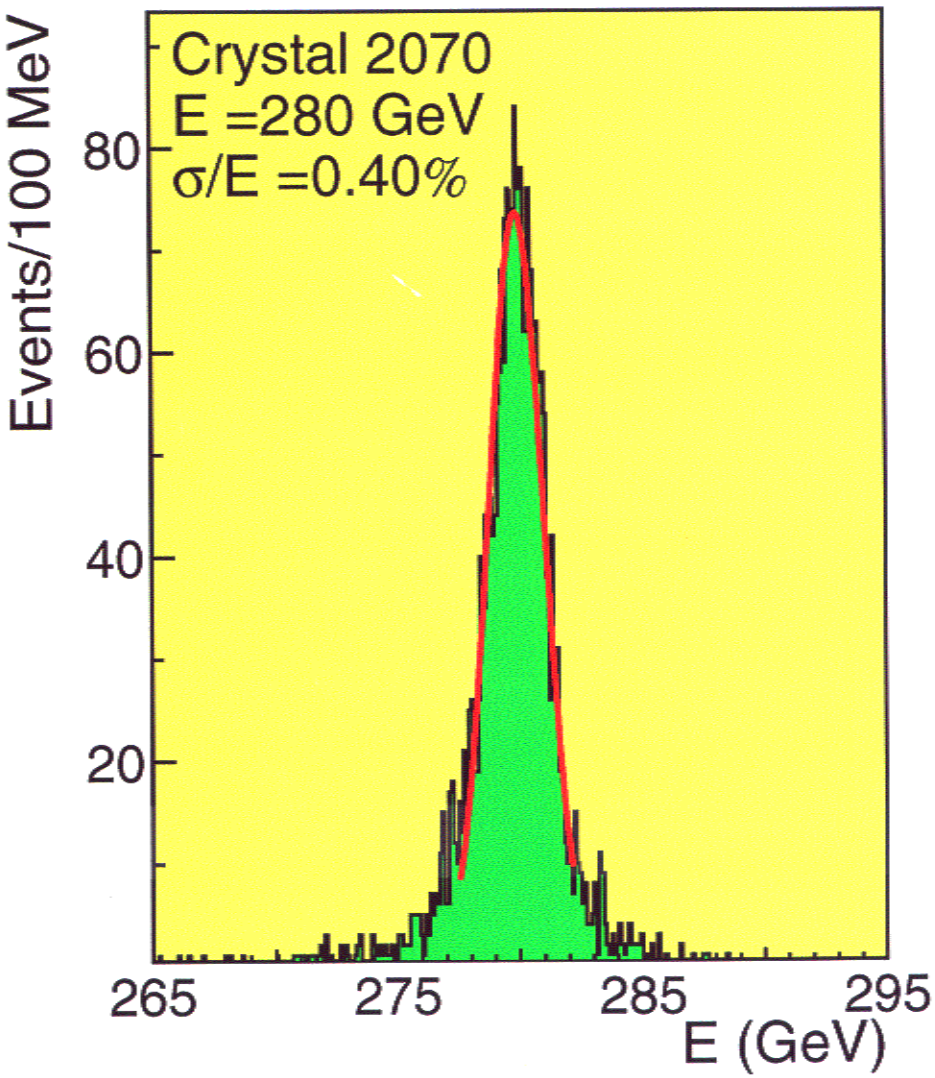
$10^{34}cm^{-2}s^{-1}$ at injection

69% of events in $\Delta m_{\gamma\gamma} = 2.0$ GeV

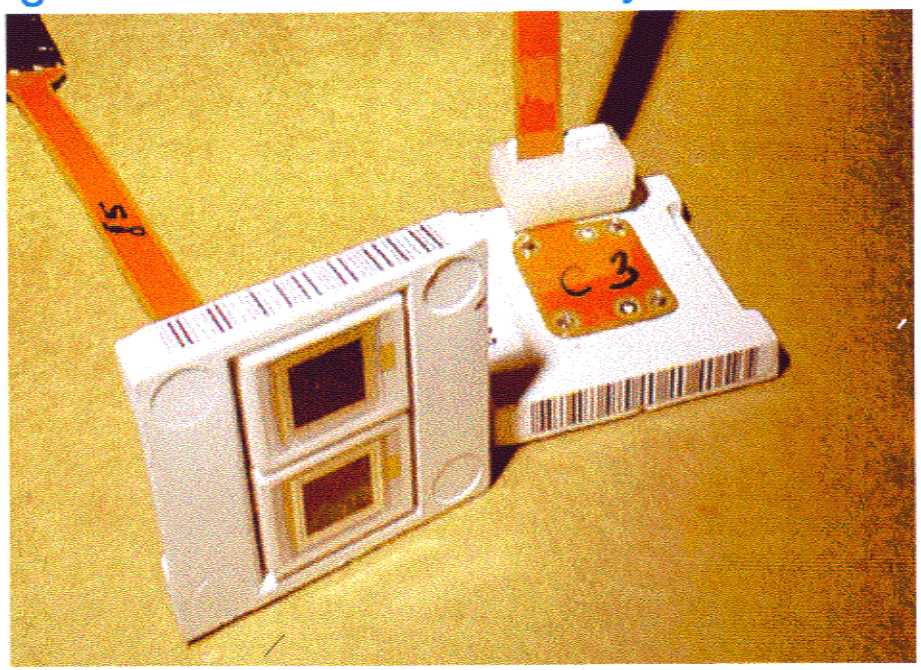
Single photon reconstruction efficiency:

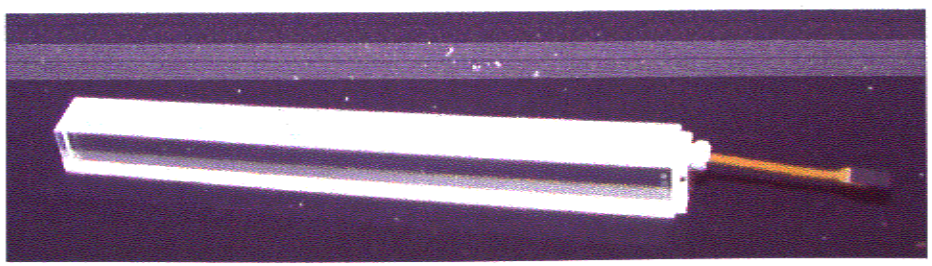
Fiducial area cuts within $\lvert\eta\rvert < 2.5$	92.5%
Unrecoverable conversions	94%
Isolation cuts	95%
π^0 rejection algorithms	90%
Total reconstruction efficiency	74.5%

Test Beam Results 1999: Barrel



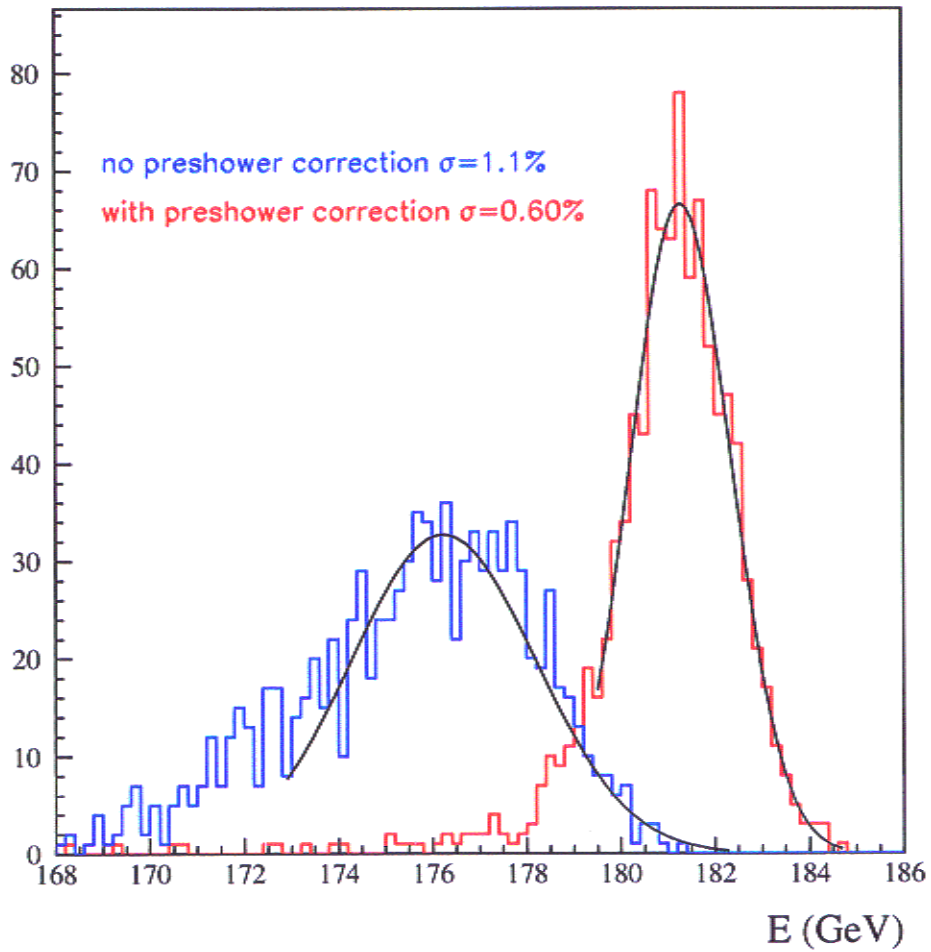
Two APDs 5 x 5 mm surface mounted in a supporting structure (capsule) glued at the rear of the crystal

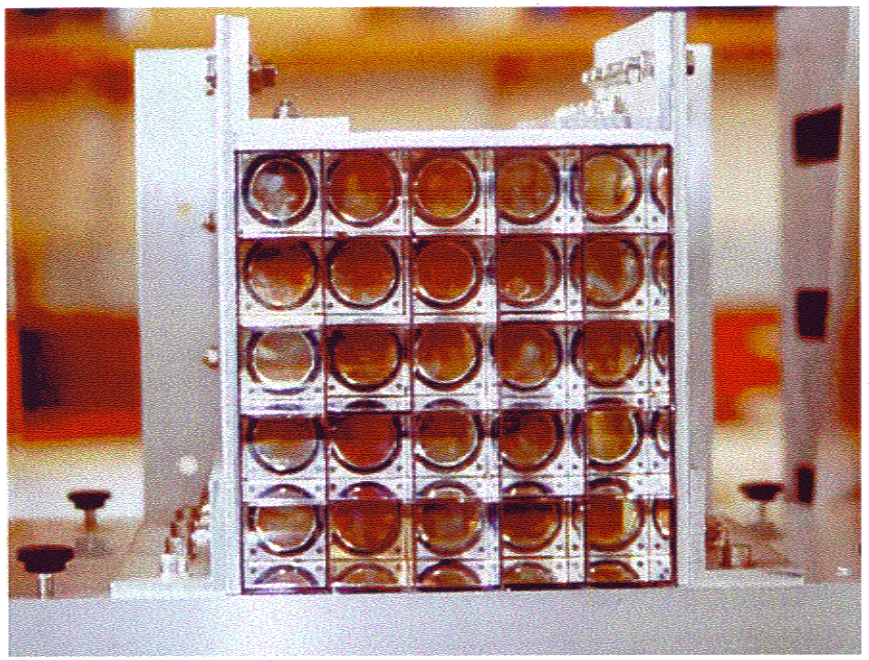




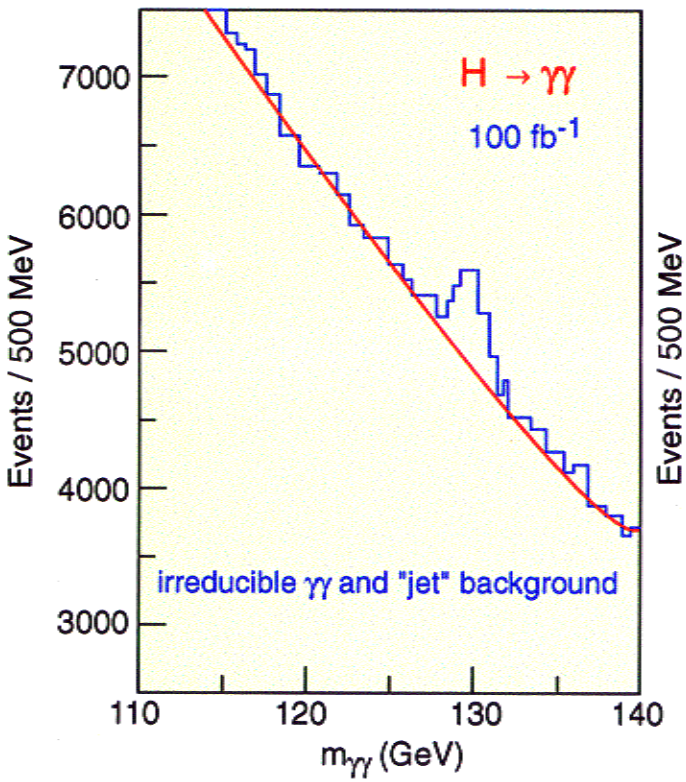
Test Beam Results 1999: Endcap

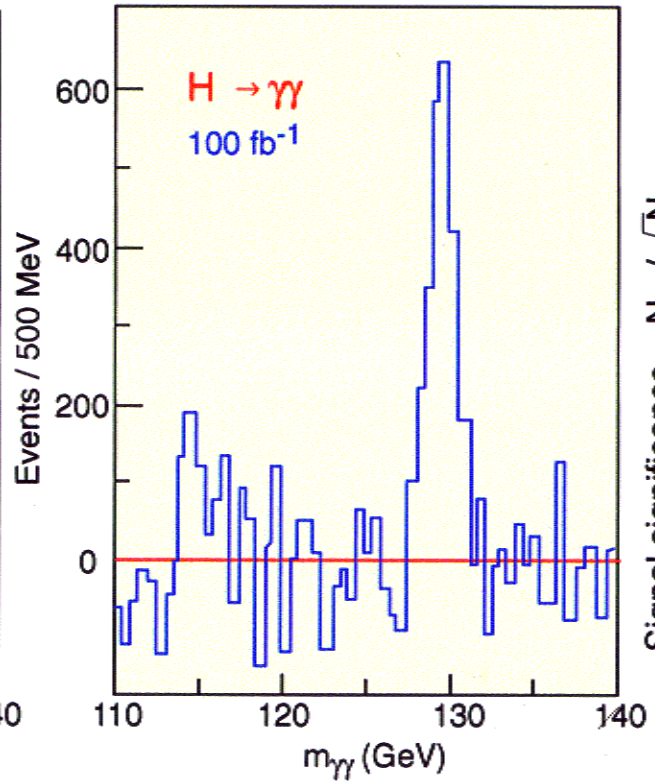
180 GeV Electrons at normal incidence

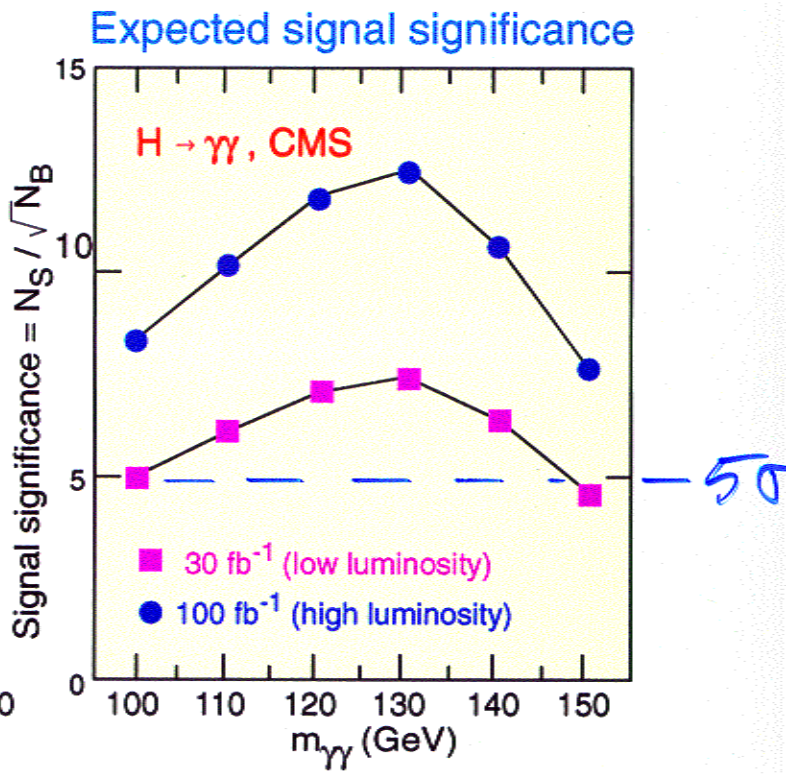




$H_{SM} \rightarrow \gamma\gamma$ in CMS $PbWO_4$ calorimeter







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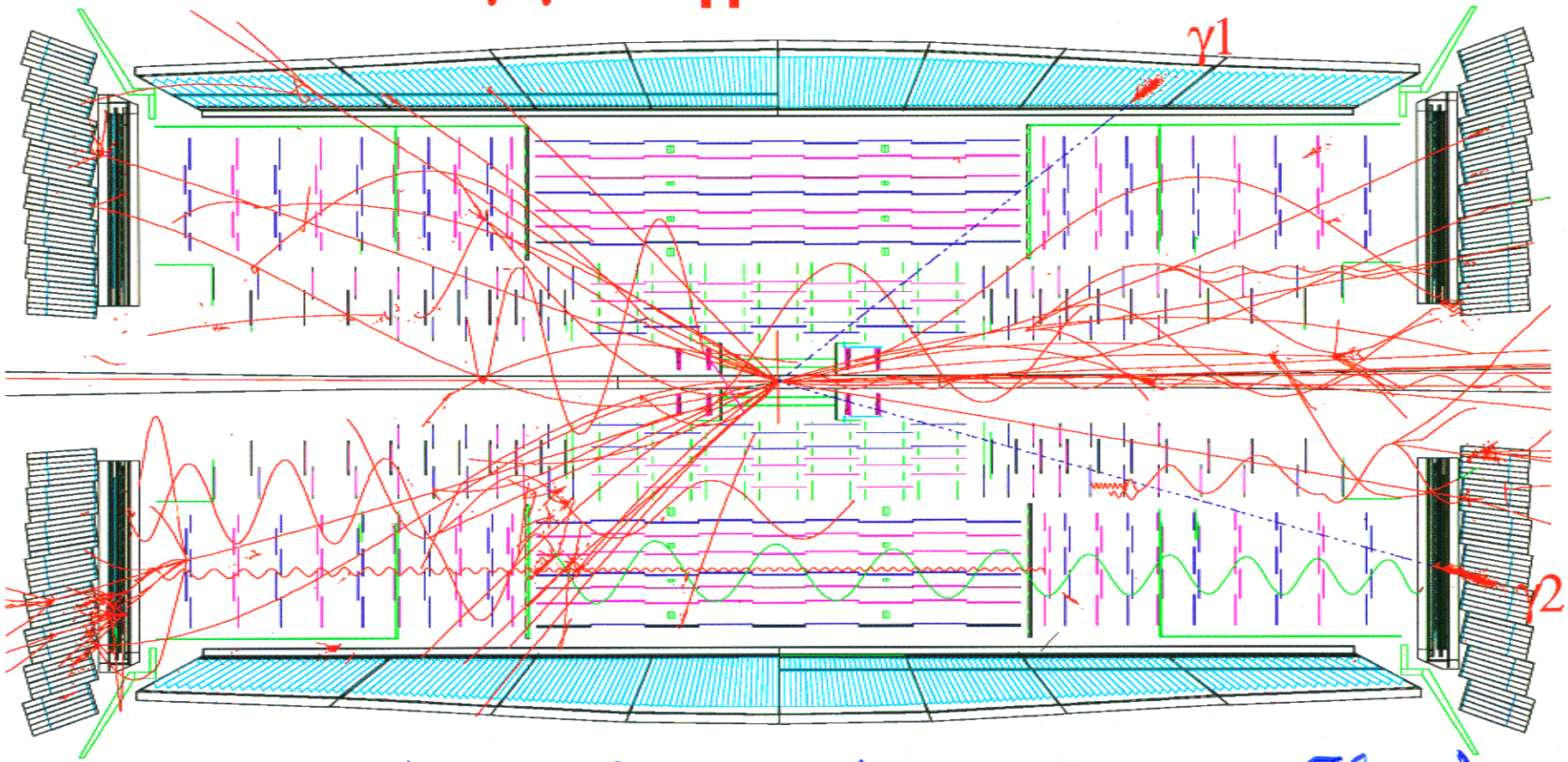
Problems with p_t^H

and the efficiency of vertex designation algorithm

in $H \rightarrow \gamma\gamma$

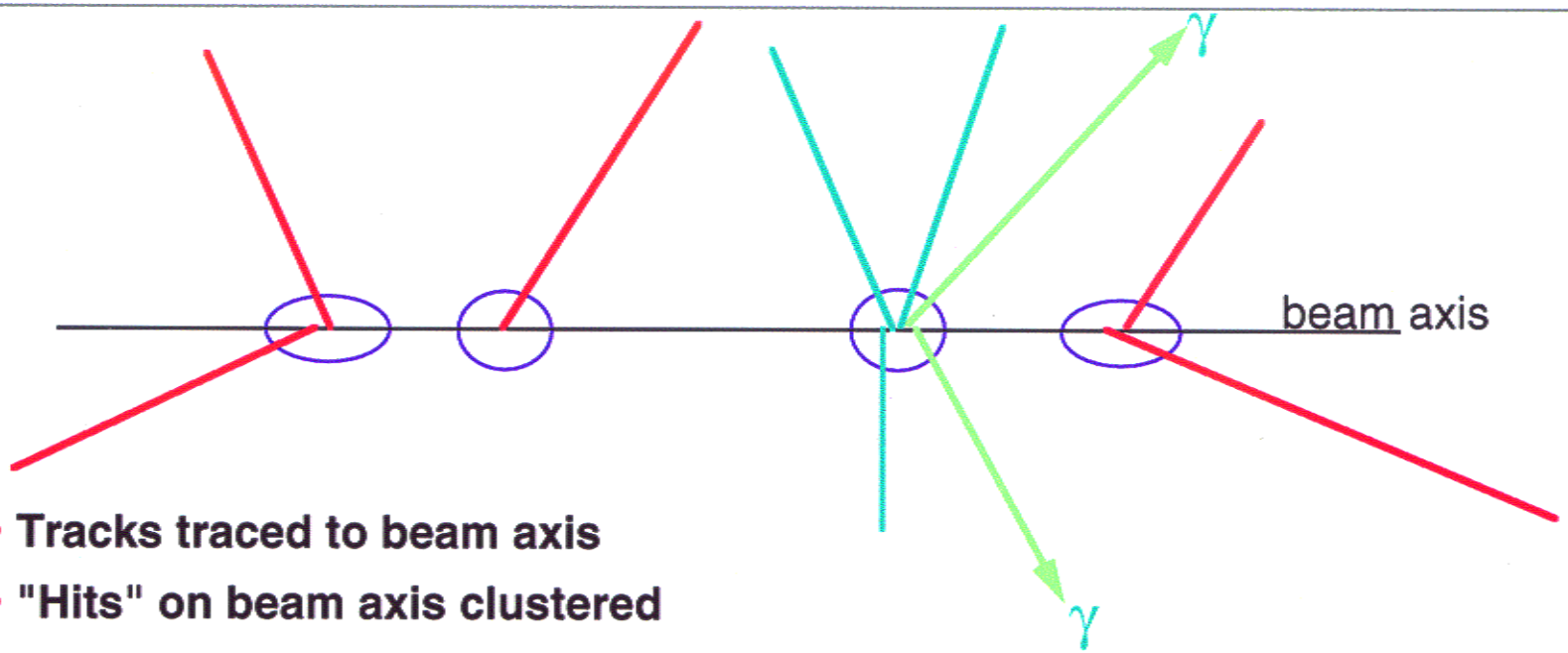
H -> γγ , M_H = 100 GeV



γ-γ mass resolution: $\frac{\delta M}{M} = \frac{1}{2}\left(\frac{\delta E_1}{E_1} \oplus \frac{\delta E_2}{E_2} \oplus \frac{\delta d}{tg(\vartheta/2)}\right)$

⇒ at high $\mathcal{L}_{instantaneous}$, if vertex not known ($\sigma_{vtx} \approx 5.3$ cm) δd-term dominates error δM i.e. $\delta M_{\gamma\gamma}^{d=vtx} \approx 1.4$ GeV ⇒ develope methods to find vertex – or build preshower to measure γ direction!

Track algorithm



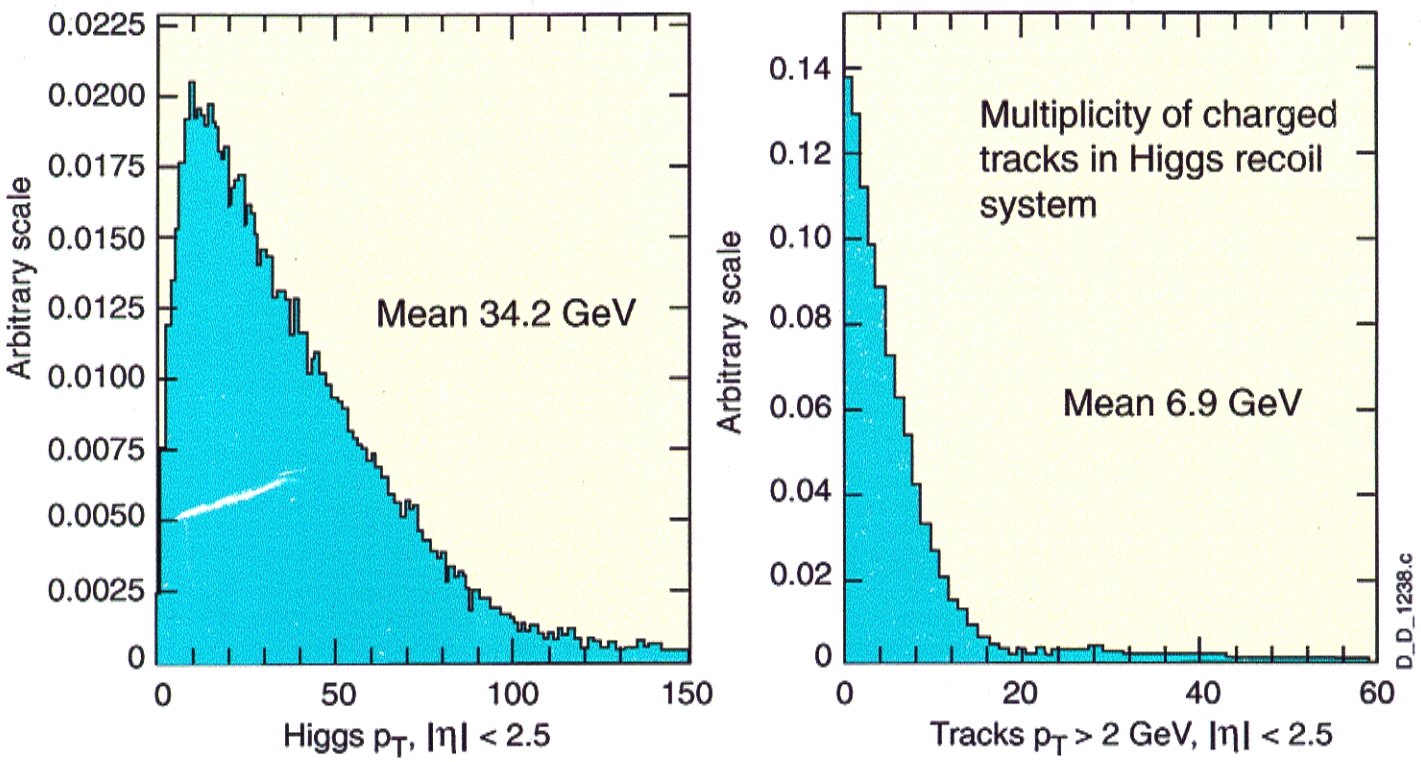
- **Tracks traced to beam axis**
- **"Hits" on beam axis clustered**
- **Cluster with largest number of tracks taken as Higgs vertex**
- **Algorithm involves choice of p_T threshold and ϕ cut**
  - At present choice is made on the basis of luminosity
  - Choice on the basis of bunch crossing activity perhaps better — under development
- **Important parameters are σ_z(vertex) and ε_{track}**
  - We assume σ_z(vertex) = 2 mm, and ε_{track} = 95% but 5 mm and 80% are OK

Higgs production mechanisms considered

PYTHIA 5.7 + Kunszt and Stirling

Mechanism	$\sigma \cdot B$	%	$< p_T >$	$< N_{tracks >2 GeV} >$
$gg \rightarrow H$	1.5 x 38.9 fb	81.9	31.1 GeV	4.48
$WW / ZZ \rightarrow H$	7.4 fb	10.4	53.2 GeV	4.96
$gg \rightarrow tt\,H, VH$	5.5 fb	7.7	93.0 GeV	31.13
Total	71.25 fb	–	34.2 GeV	6.9

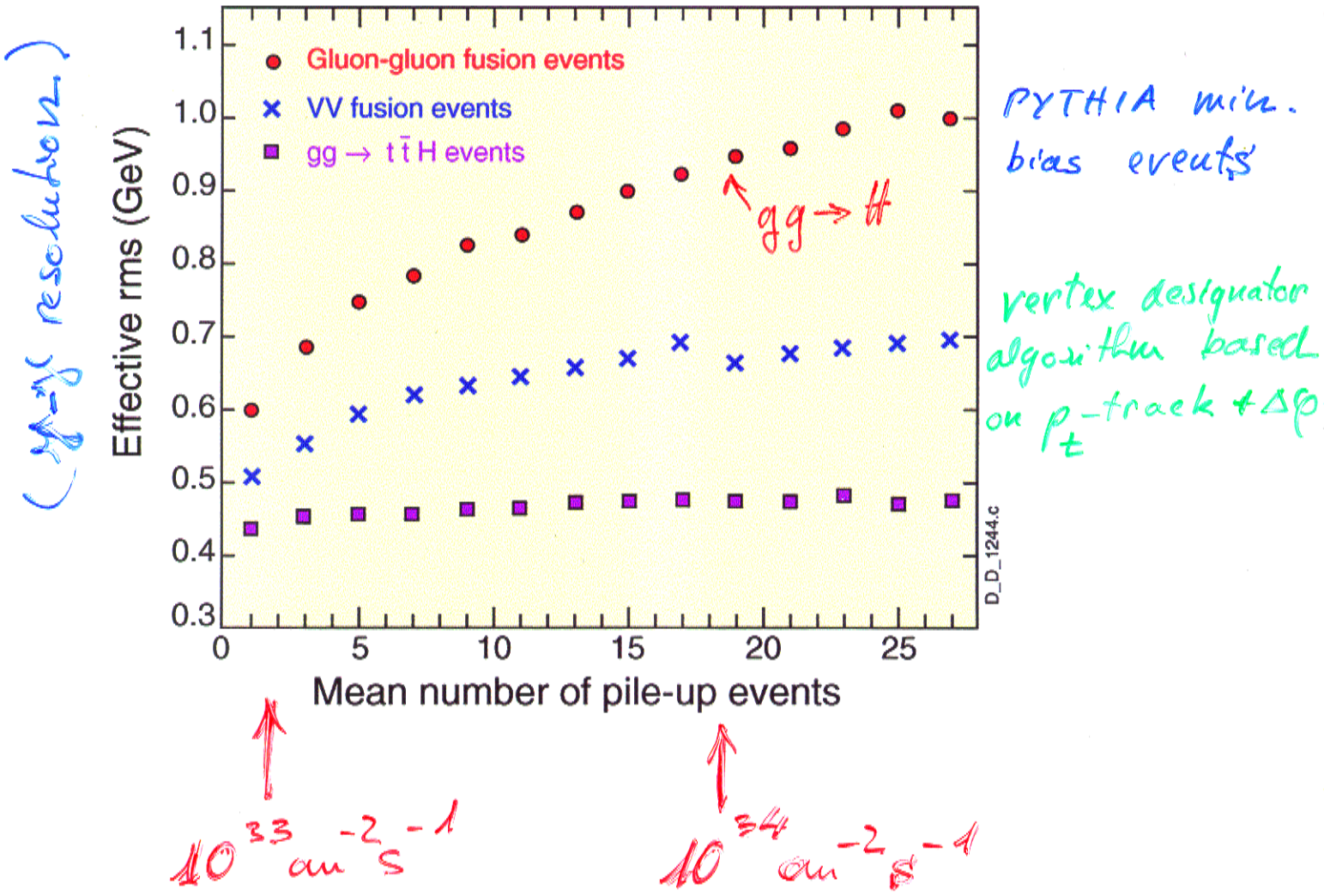
Distributions of Higgs p_T and multiplicity of charged tracks with $p_t > 2$ GeV



PYTHIA 5.7 !

$H \rightarrow \gamma\gamma$ mass reconstruction

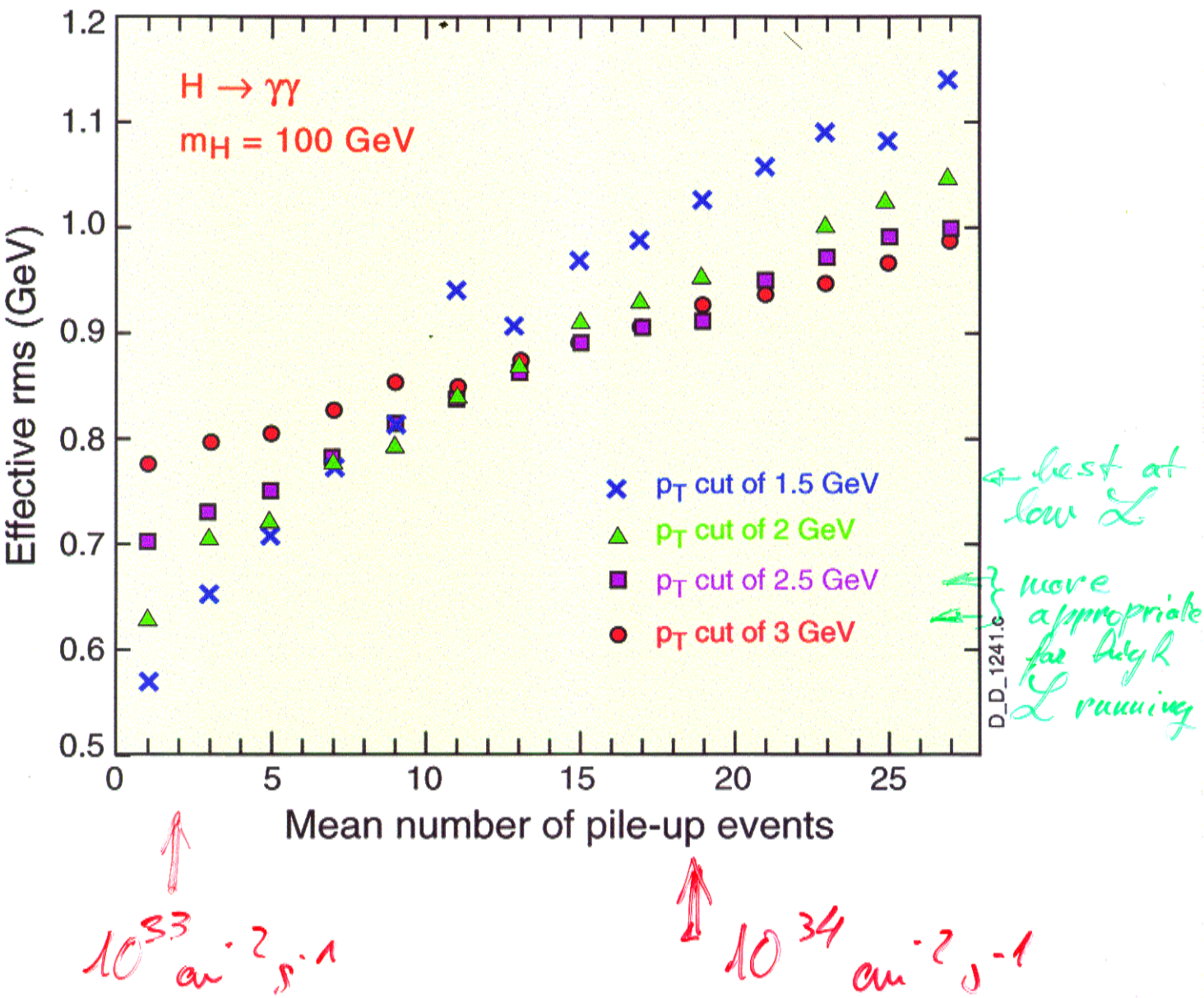
Effective rms as a function of the mean number of pile-up events for each of Higgs production mechanisms considered individually.



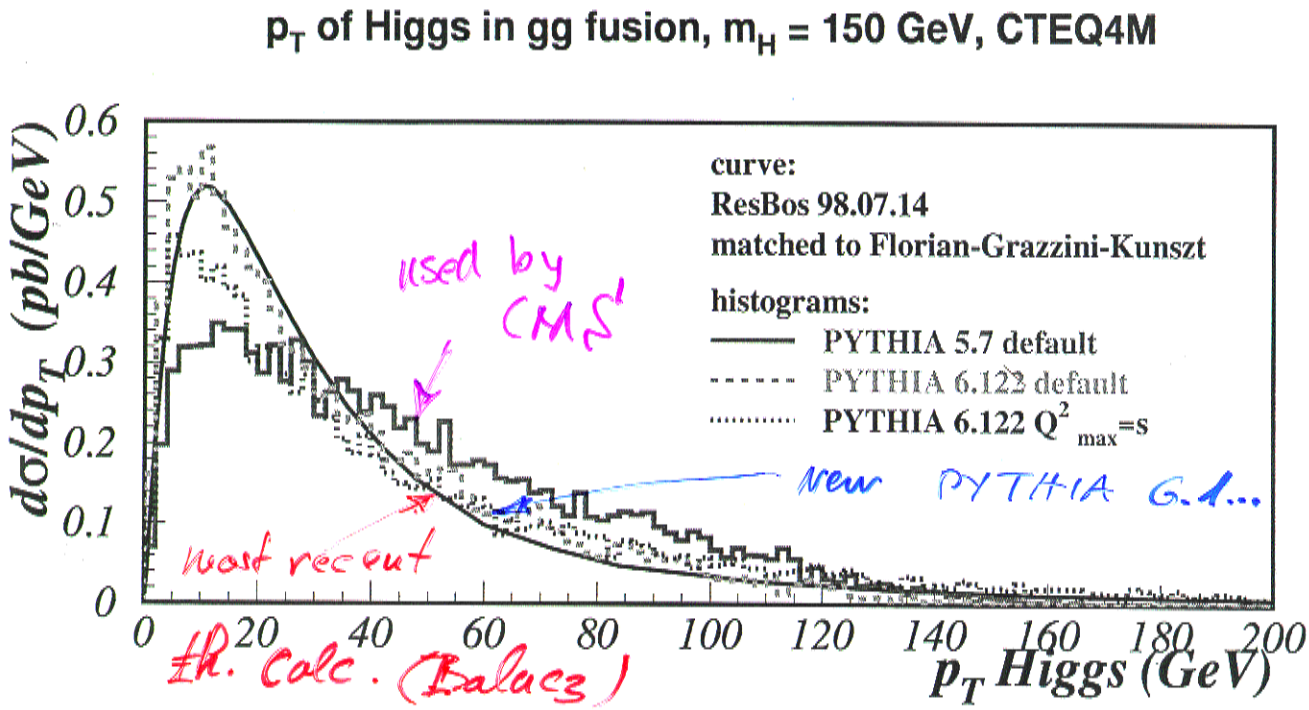
Optimisation of vertex-designator algorithm versus luminosity

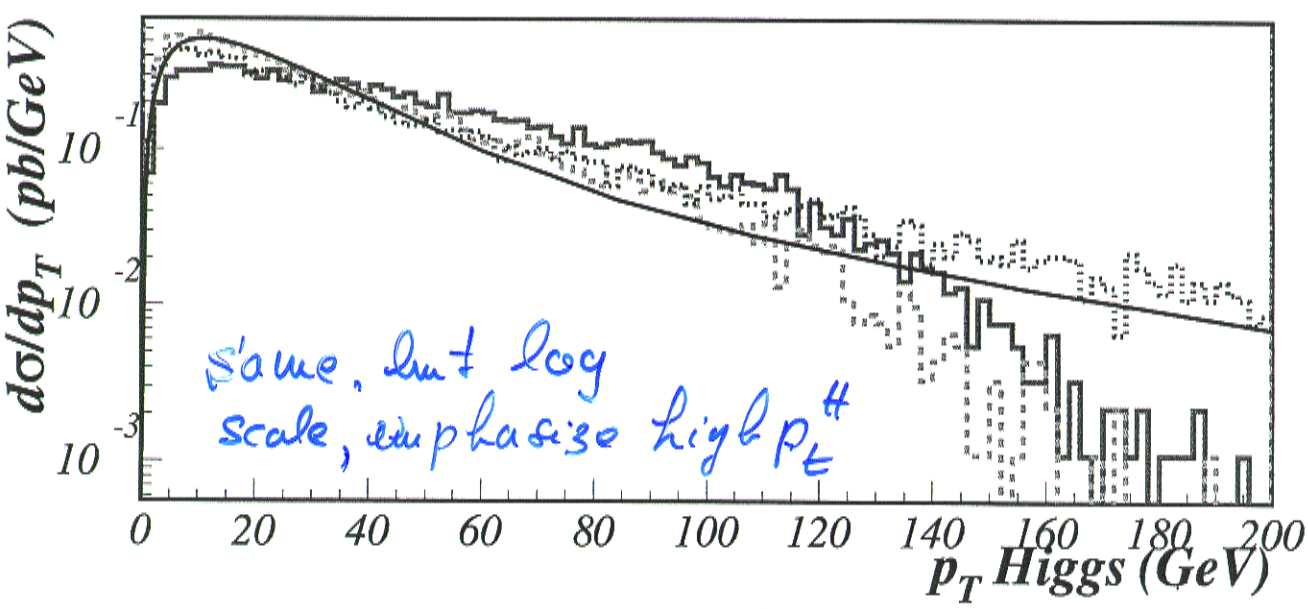
$H \rightarrow \gamma\gamma$ reconstruction

Effective rms as a function of the mean number of pile-up events for 4different p_t cuts on tracks



The bad news:
p_t^H from $gg \to H$ became significantly softer recently:



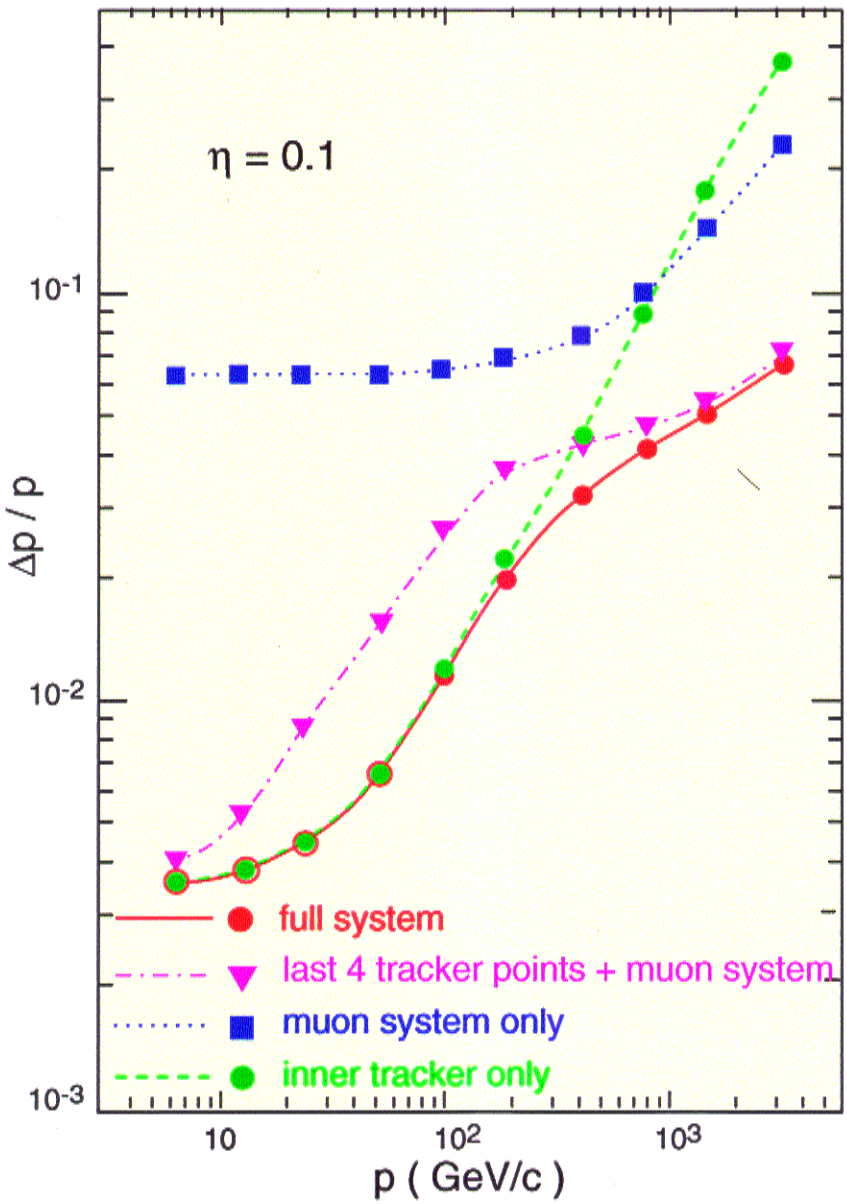


⇒ loss of efficiency of vertex-designator algorithm on basis of presence of hard tracks in $H \to \gamma\gamma$ events

$H \rightarrow Z^*Z, ZZ$

D.D.89

CMS muon momentum resolution

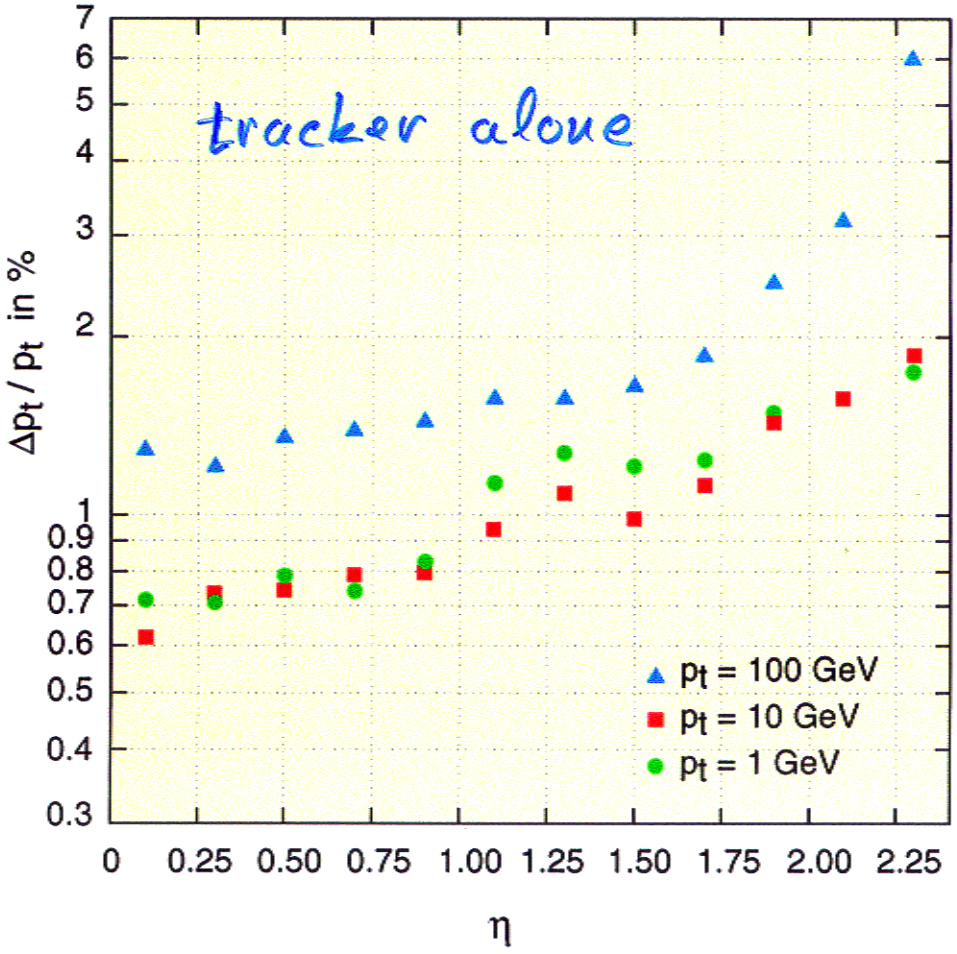


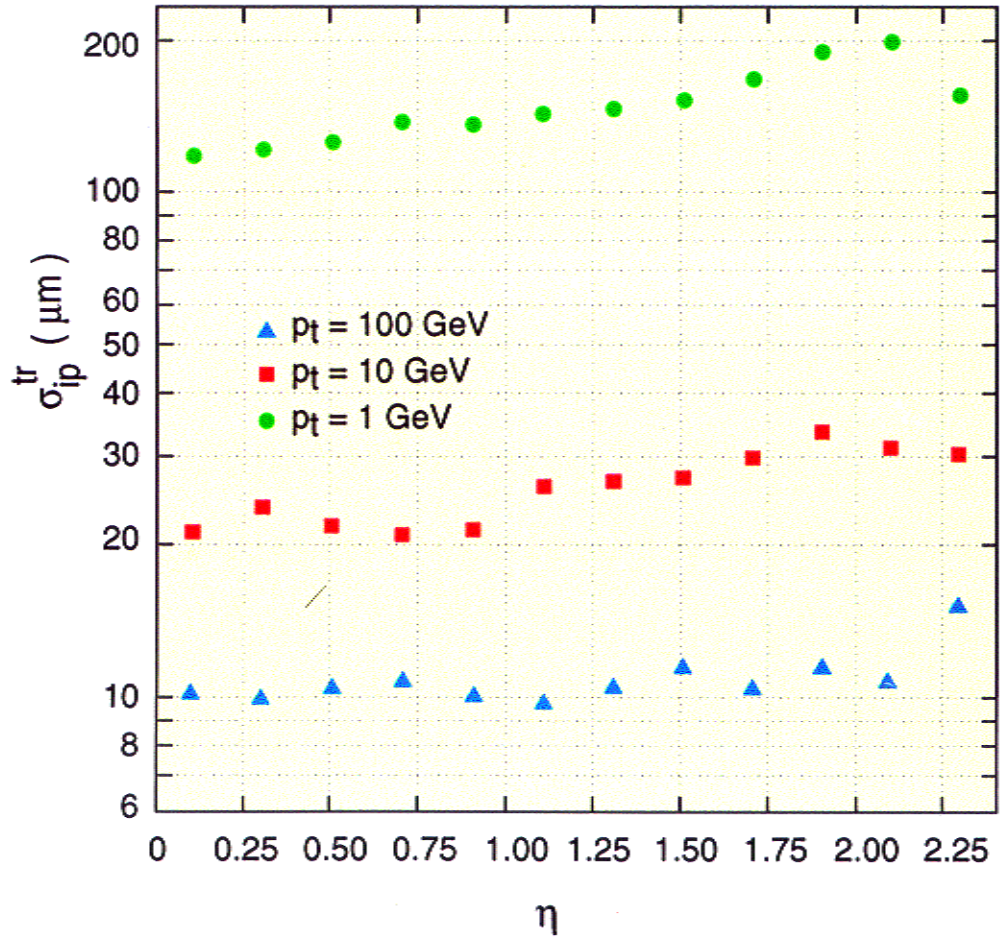
- 16 Tm of bending power in barrel, including return yoke
  best precision for muons connecting tracker and muon system measurements
- outer muon system essential for triggering

Momentum resolution in CMS

Impact parameter resolution in CMS in transverse plane

With full pattern recognition and track reconstruction in low luminosity tracker configuration





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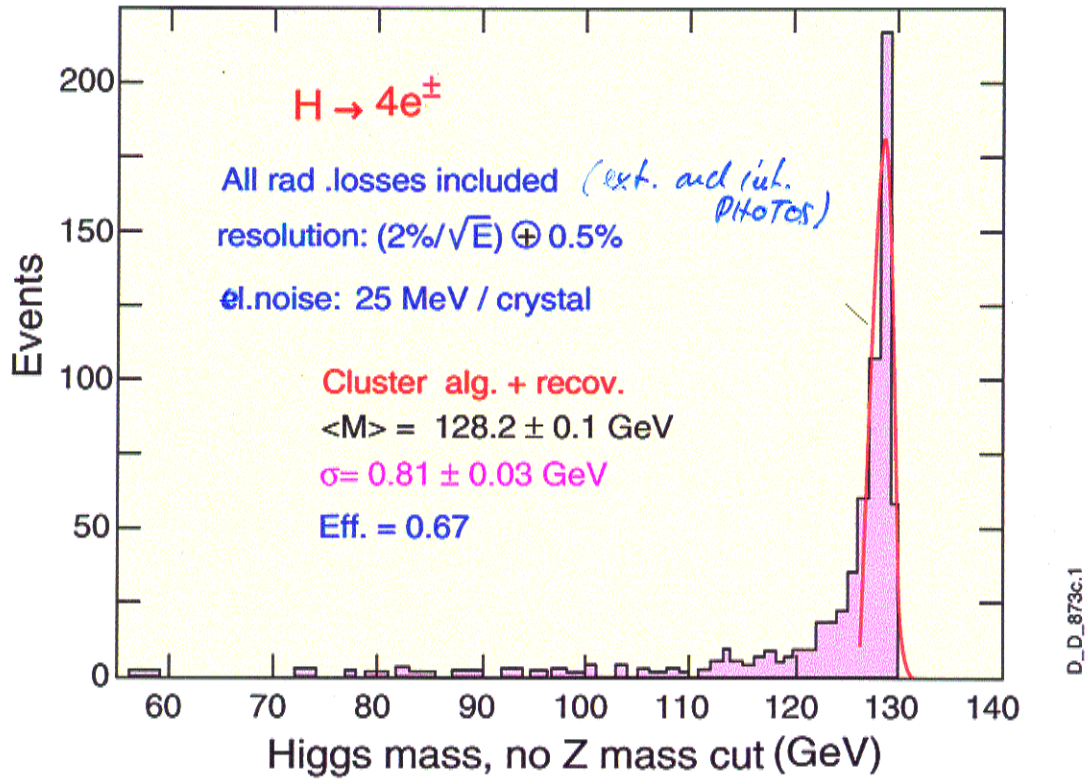
Electron reconstruction in CMS

$H \rightarrow ZZ^* \rightarrow 4e$, $M_H = 130$ GeV,



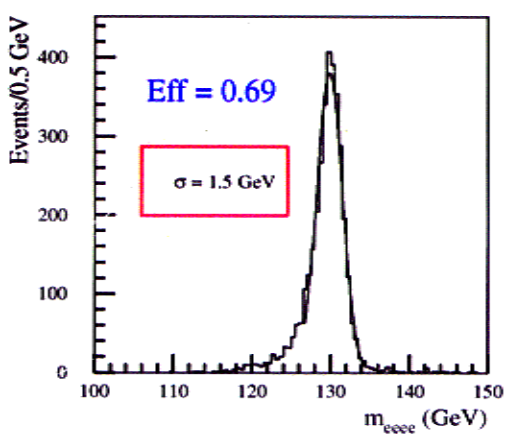
Crystal calorimeter provides excellent resolution

The main difficulty in CMS is electron reconstruction efficiency because of material in the tracker inducing bremsstrahlung, combined with the 4T field

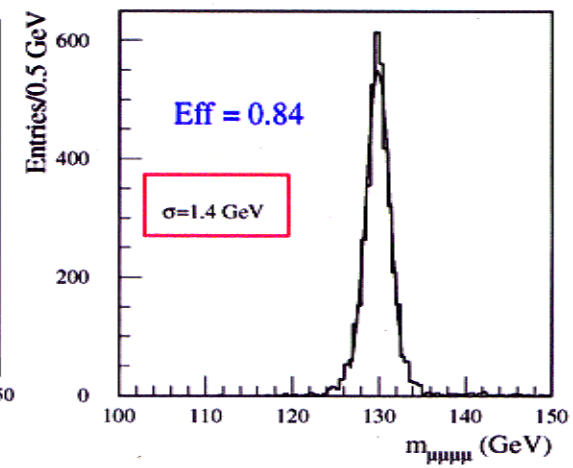
H -> ZZ* -> 4*l* in ATLAS

Higgs-boson mass reconstruction at low luminosity with full detector simulation including internal and external bremstrahlung

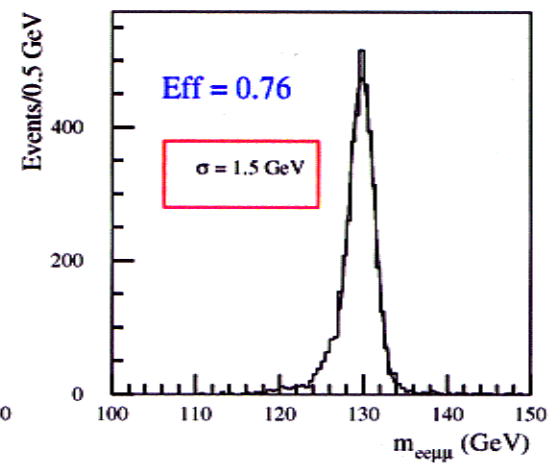
2 leptons, $p_t > 20$ GeV and 2 leptons, $p_t > 7$ GeV, $|\eta| < 2.5$
Z mass constraint for one pair ($\Delta m = 40$ GeV to 12 GeV)
remaining pair with $m > m_{34}$ ($m_{34} = 15$ GeV to 60 GeV)



H -> ZZ* -> eeee



H -> ZZ* -> μμμμ



H -> ZZ* -> eeμμ

Lepton isolation and impact parameter cuts against the reducible tt and $Zb\bar{b}$ backgrounds

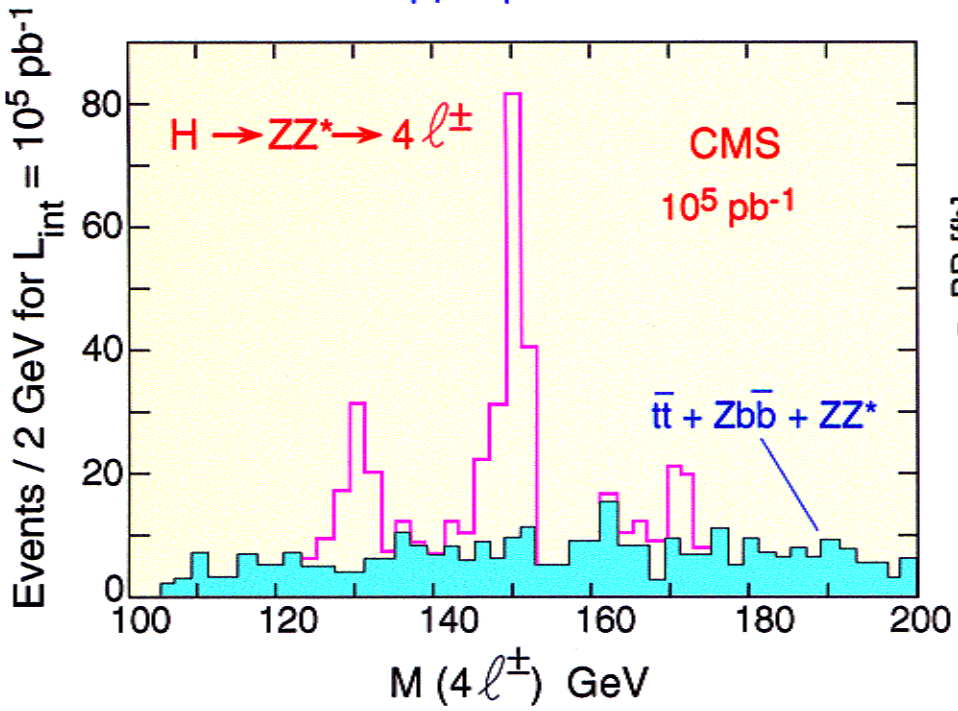
Rejection from isolation cuts: ~110 against $t\bar{t}$, ~ 30 against $Zb\bar{b}$, signal efficiency 90% (75%)

Rejection from impact parameter cuts: ~12 against $t\bar{t}$, ~ 5.5 against $Zb\bar{b}$, signal efficiency 90% (70%)

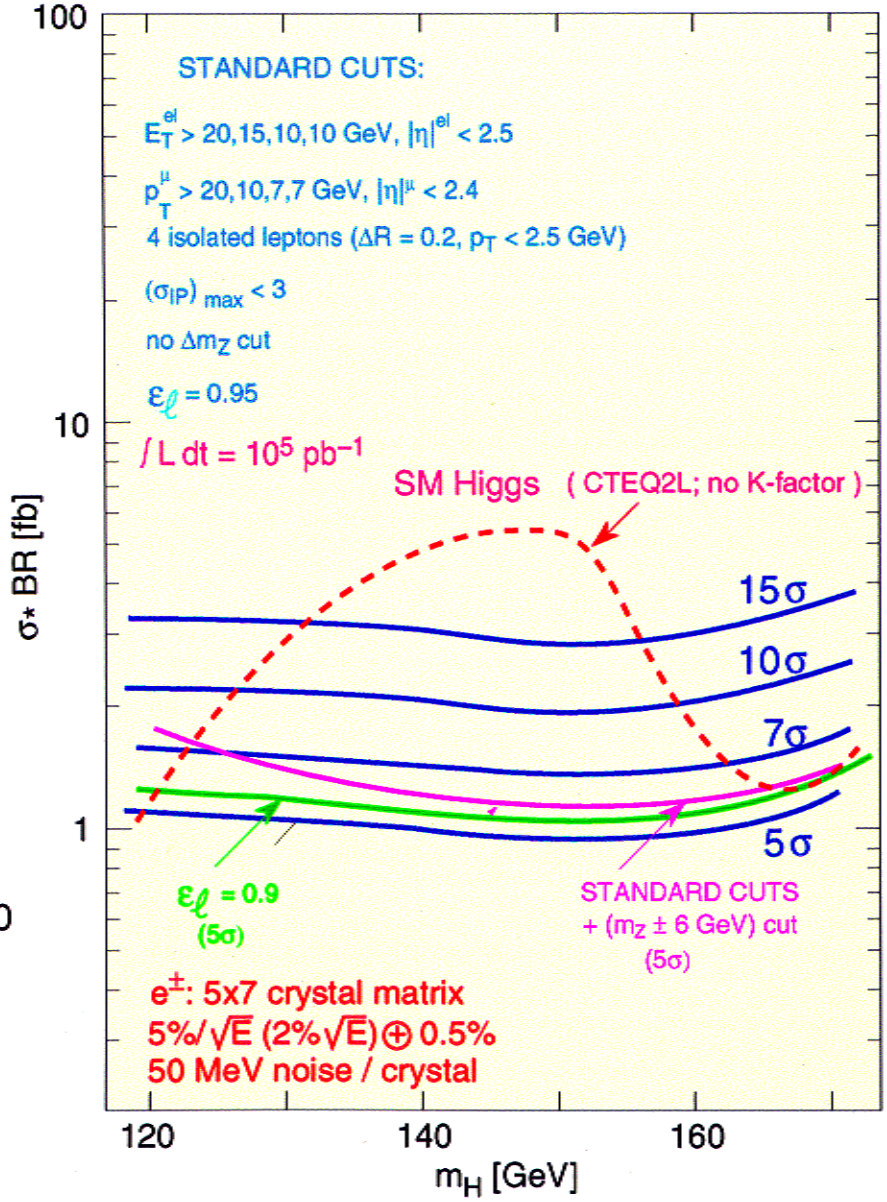
$H \to ZZ^* \to 4\ell^{\pm}$ in CMS

$\sqrt{s}$ = 14 TeV, m_{top} = 174 GeV, CTEQ2L str. func.

E_t^e > 20,15,10,10 GeV; p_t^{μ} > 20,10,5,5 GeV;
$|\eta^{e,\mu}|$ < 2.5, 2.4;



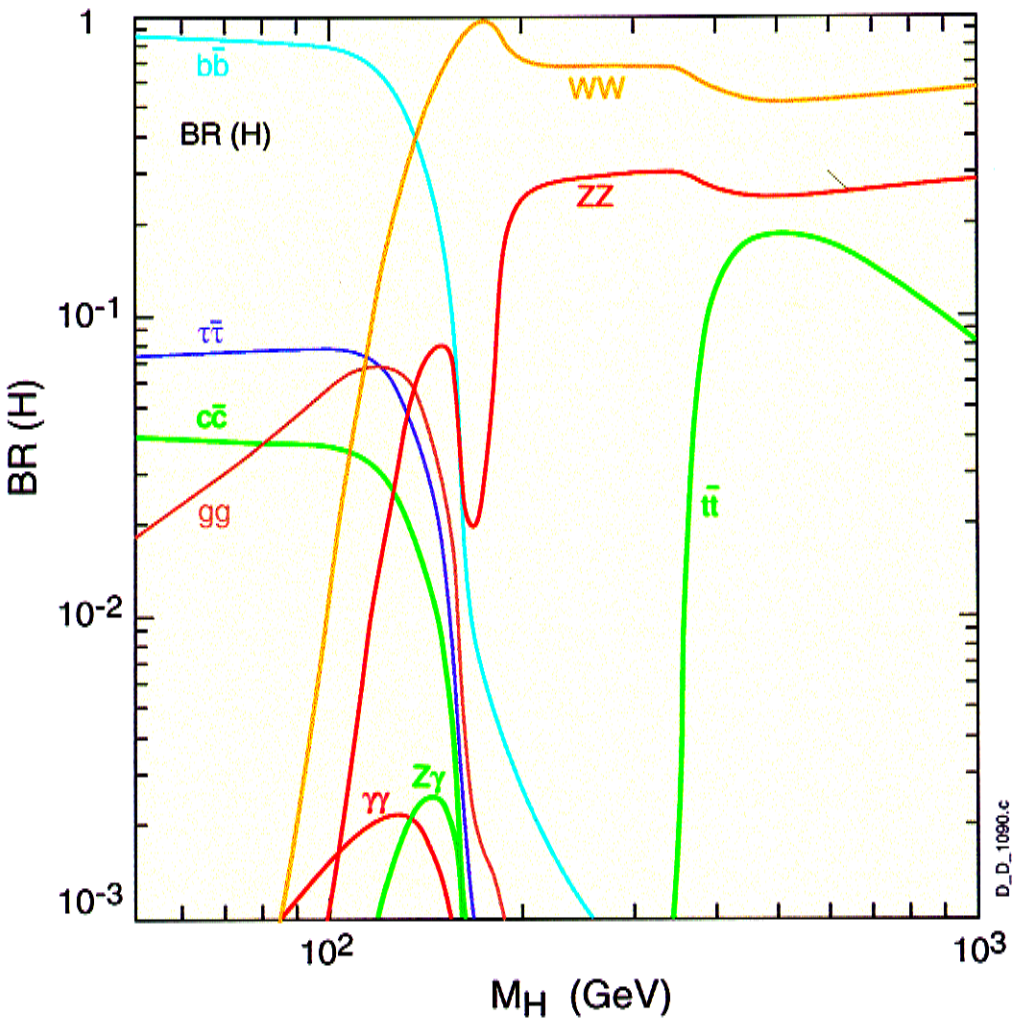
σ*BR required to give specified significance n σ



D.D.802c.1

Higgs Branching Ratios

A. Djouadi, J. Kalinowski, M. Spira



$H_{SM} \rightarrow WW \rightarrow l\nu l\nu$

for $m_H \sim 170$ GeV

D.D92

$H_{SM} \rightarrow WW \rightarrow l\nu l\nu$

for $m_H \sim 170$ GeV

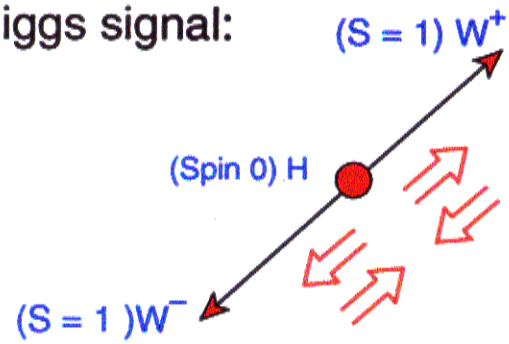
D.D92

$H \to WW \to \ell\nu\,\ell\nu$ for $m_H \simeq 2m_W$

To suppress irreducible WW background
use W^+W^- spin correlations !

a) Spin orientations

Higgs signal:



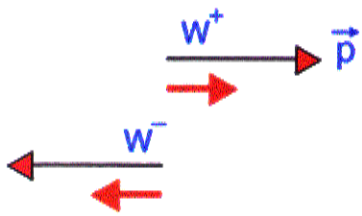
Background:

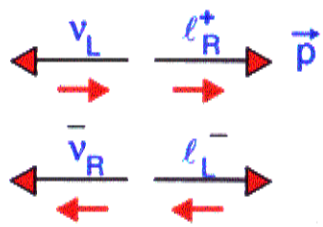
$q\bar{q} \to W^+W^-$

W_tW_L , W_LW_t

W_tW_t , W_LW_L

b) $W^\pm \to \ell^\pm \nu$ decays (V–A)





Higgs signature :
$\ell^+\ell^-$ pair with small opening angle

if $p_t(W) << M_W$
(for $M_H \leq 180$ GeV)

D_D_20721.c

2. Selection: W^+W^- Spin correlations!

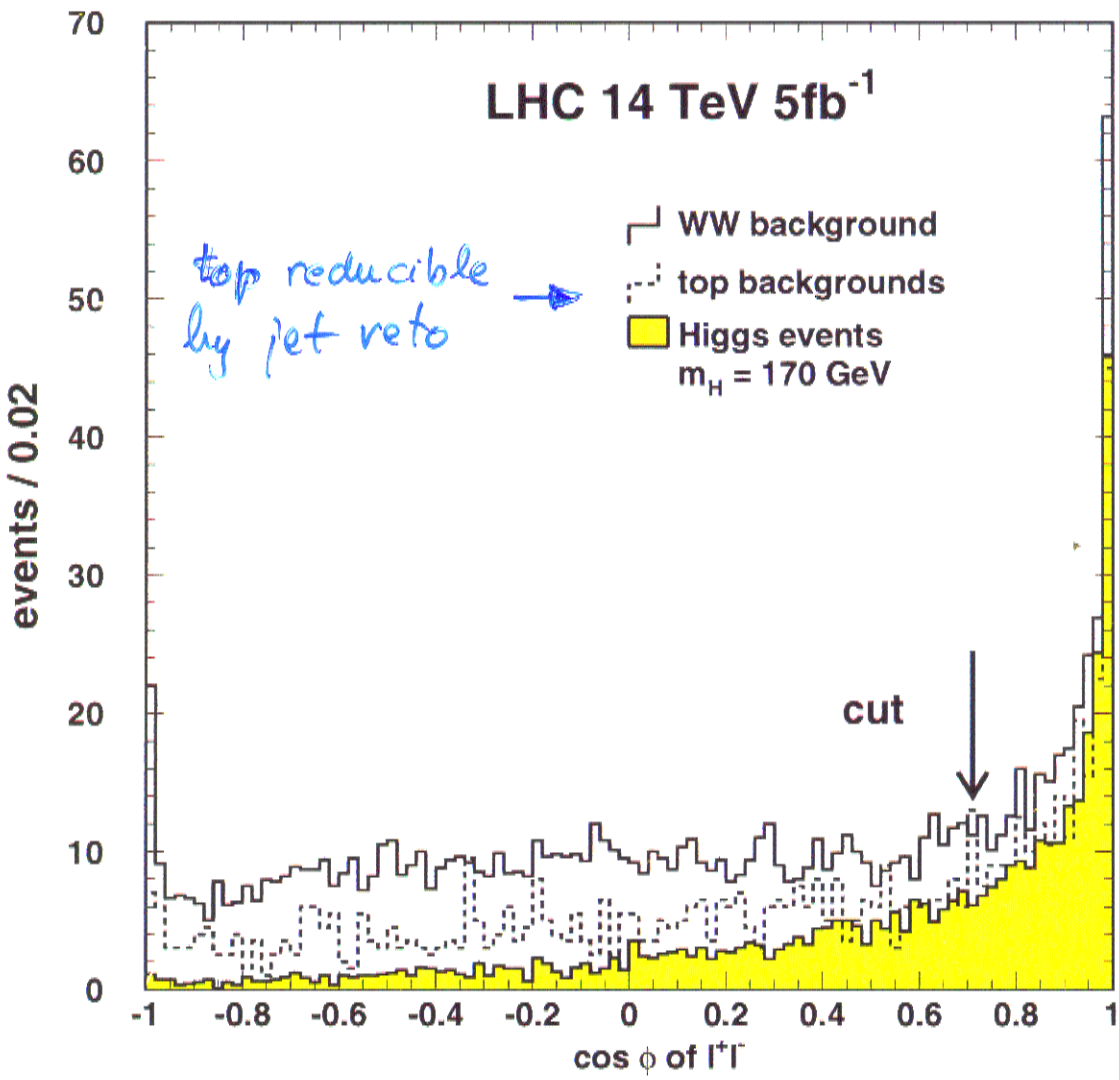
small $\ell^+\ell^-$ opening angle:

$\cos\phi_{plane} > 0.71 (\phi_{plane} = 10° - 45°)$

for 5 fb^{-1} luminosity:

Signal rate: $\approx$ 300 events ($M_H = 170$ GeV)

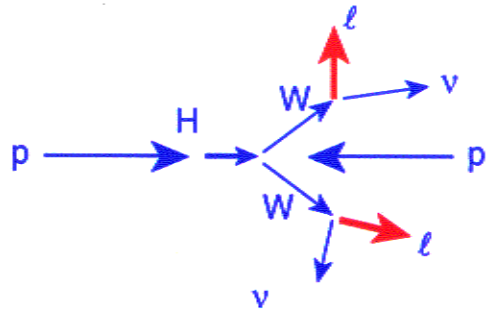
background: $\approx$ 600$\pm$ 25 (stat.) $\pm$ 30-60 (assuming 5–10% syst. error)



$\phi \equiv$ relative azimuthal angle - in transverse plane

Drift mar greiner

$H_{SM} \to WW \to \ell\nu\,\ell\nu$



Signal: $H \to WW \to \ell\nu\ell\nu$

Bkgd: $WW \to \ell\nu\ell\nu$

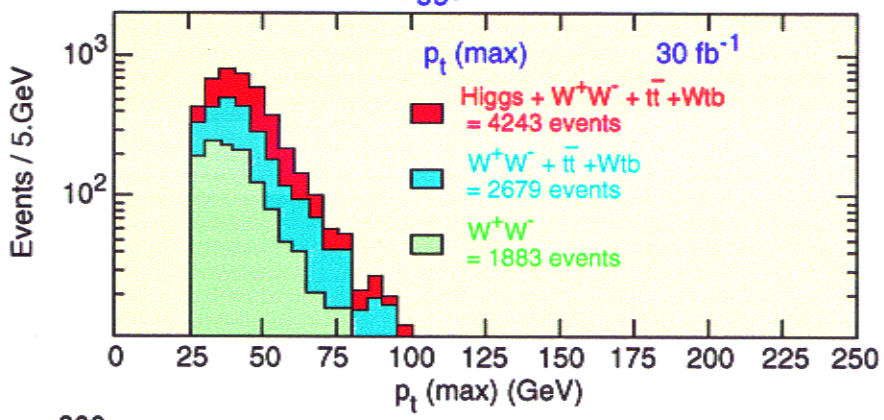
$tt \to Wb\,Wb \to \ell\nu\ell\nu\,bb$

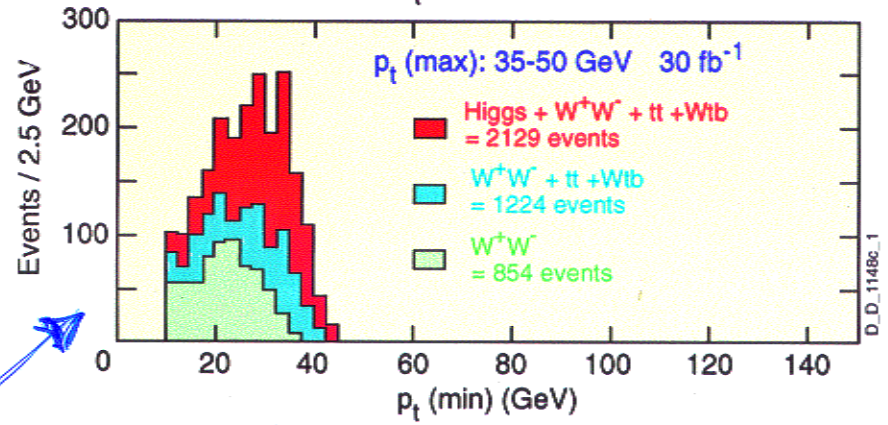
$Wtb \to WWbb \to \ell\nu\ell\nu\,bb$

} reducible by jet veto ($E_T \geq 20$ GeV)

Lepton p_t distributions

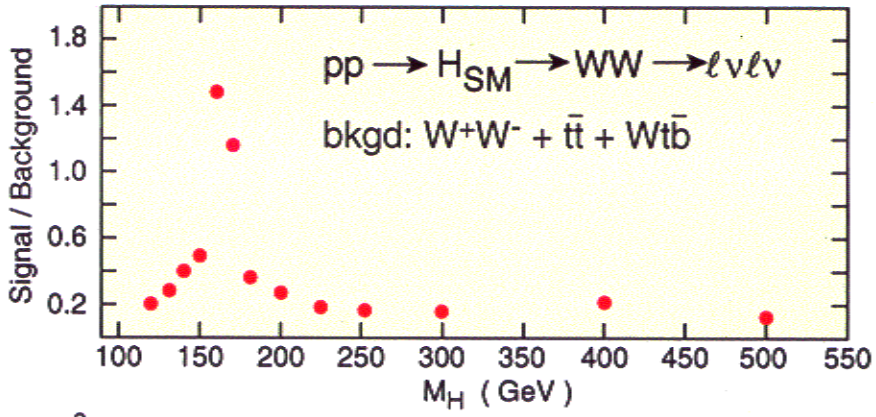
$M_{Higgs} = 170$ GeV

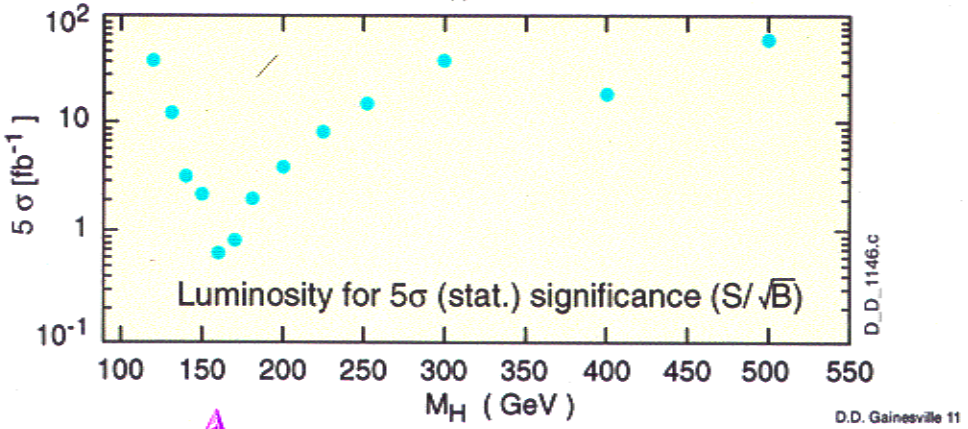




use rate and shape to determine m_H

signal significance





early observation possible, already with ~1 fb^{-1}

$H_{SM} \to WW \to l\nu\, l\nu$

M. Dittmar

LHC 14 TeV and MRSA Structure Function							
M_H	Expected event rate for 30 fb^{-1}					S/B	min. Lumi
[GeV]	Higgs	$\sum B$	W^+W^-	$t\bar{t}$	Wtb		for 5σ [fb^{-1}]
120	93	478	380	35	63	0.19	42.0
130	207	761	582	61	118	0.27	13.3
140	545	1403	1029	113	262	0.39	3.5
150	614	1223	853	126	244	0.50	2.4
160	879	586	376	64	146	1.50	0.6
170	688	586	376	64	146	1.17	0.9
180	1003	2777	1962	559	256	0.36	2.1
200	680	2604	1707	655	242	0.26	4.2
225	467	2604	1707	655	242	0.18	8.9
250	322	2204	1353	714	137	0.15	16.2
300	120	796	421	342	33	0.15	41.0
400	167	796	421	342	33	0.21	21.0
500	96	796	421	342	33	0.12	65.0

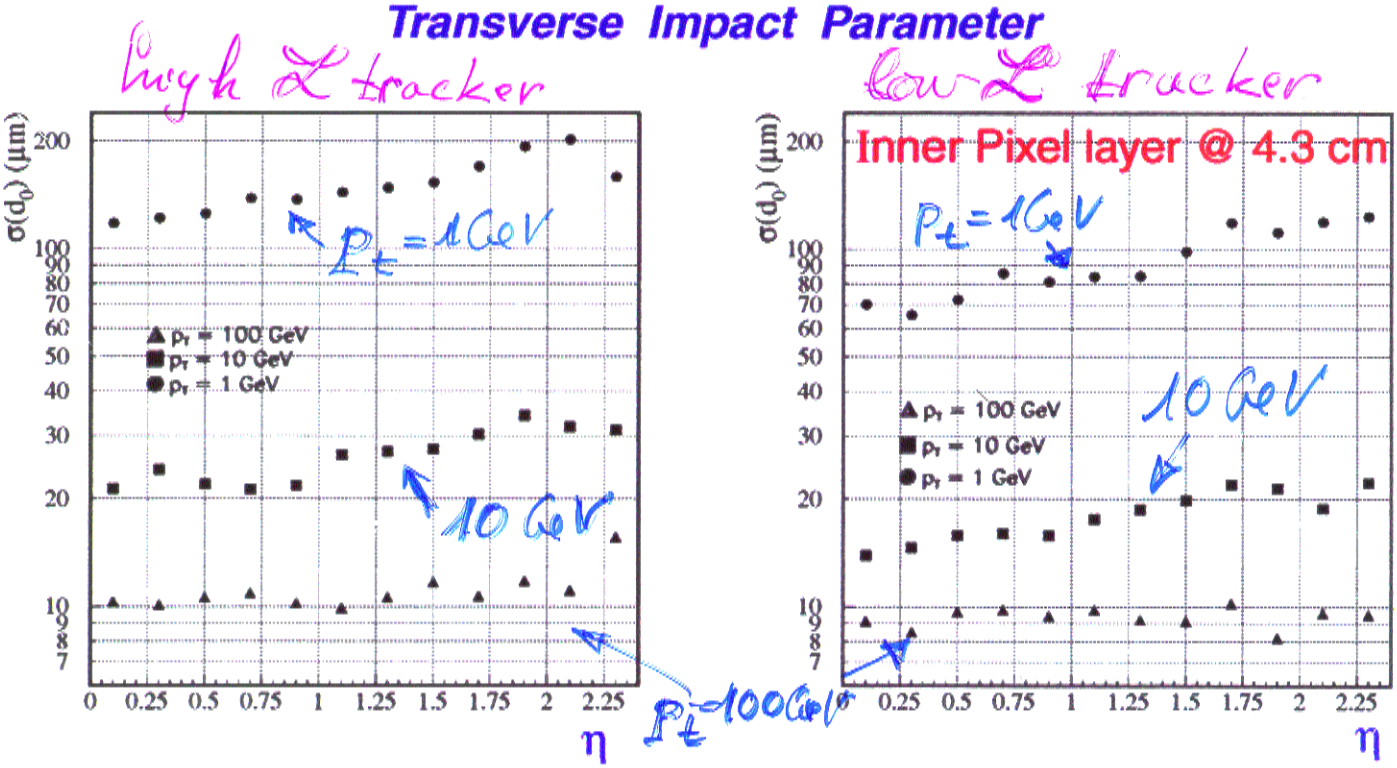
Table 1: Expected event rates for different Higgs masses and backgrounds with adjusted lepton p_t cuts for an integrated luminosity of 30 fb^{-1} using a PYTHIA simulation with MRSA [13]. The signal and background cross sections include NLO K-factors for the Higgs cross section, a K factor of 1.5 is used for the continuum production of W^+W^- pairs [6] and the $t\bar{t}$ rate is normalized to the NLO estimated cross section of 759 pb from [10]. For the Wtb we use a total cross section of $\sigma \times BR^2$ of 6 pb which does not include any K-faktor.

$H_{SM} \rightarrow bb$

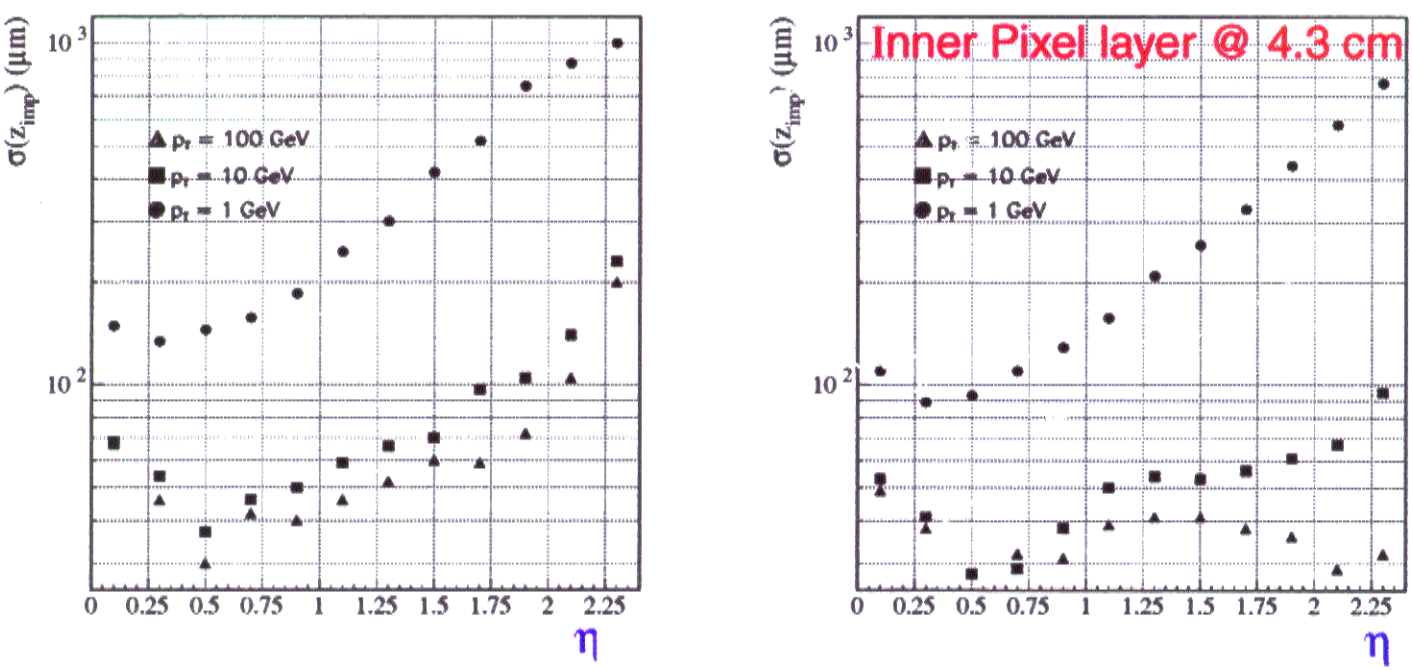
D.D91

Impact Point Resolution

Transverse Impact Parameter

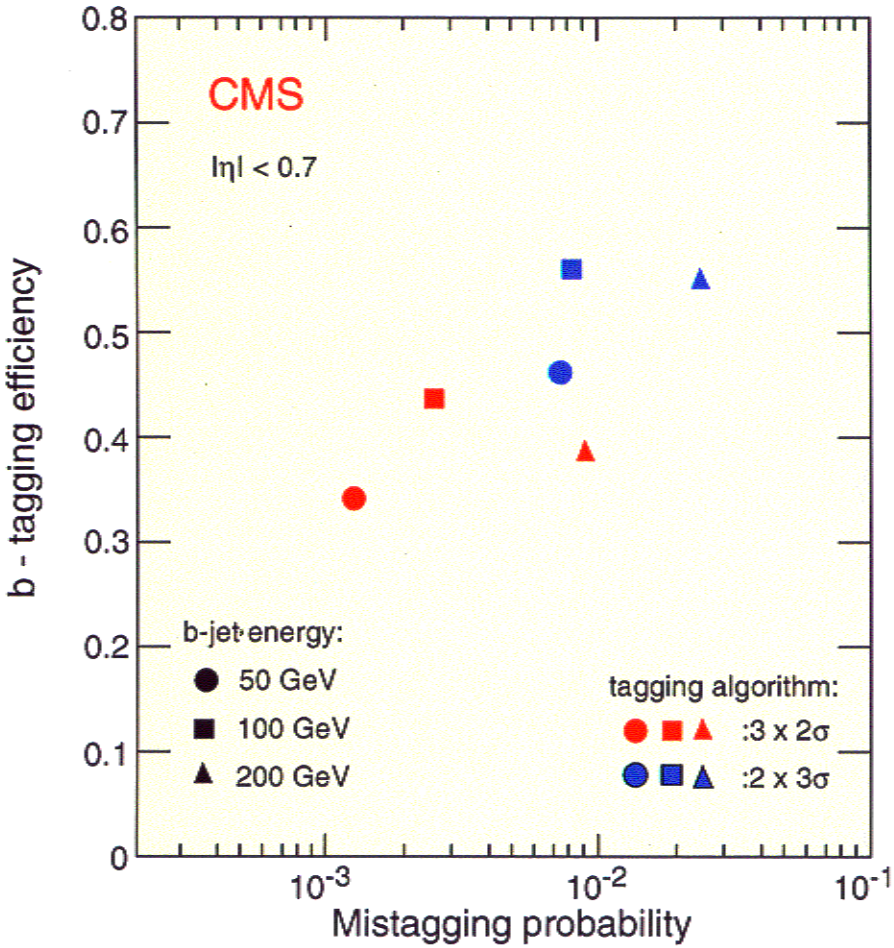


Impact Point z-coordinate

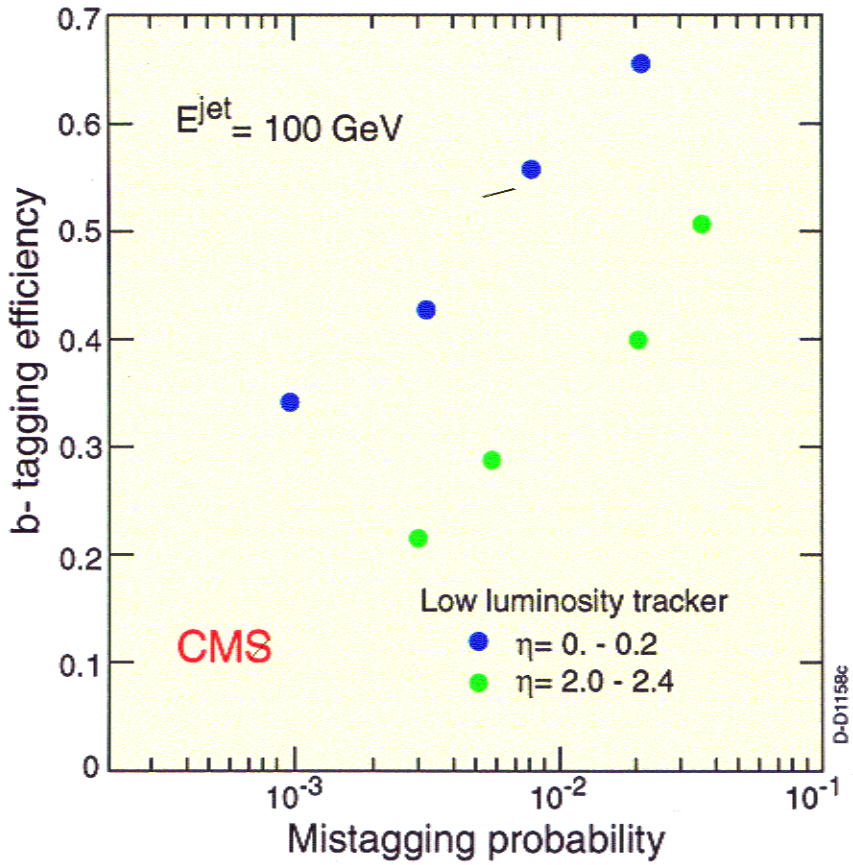


b - tagging performance of CMS

Low luminosity tracker full pattern recognition and track reconstruction

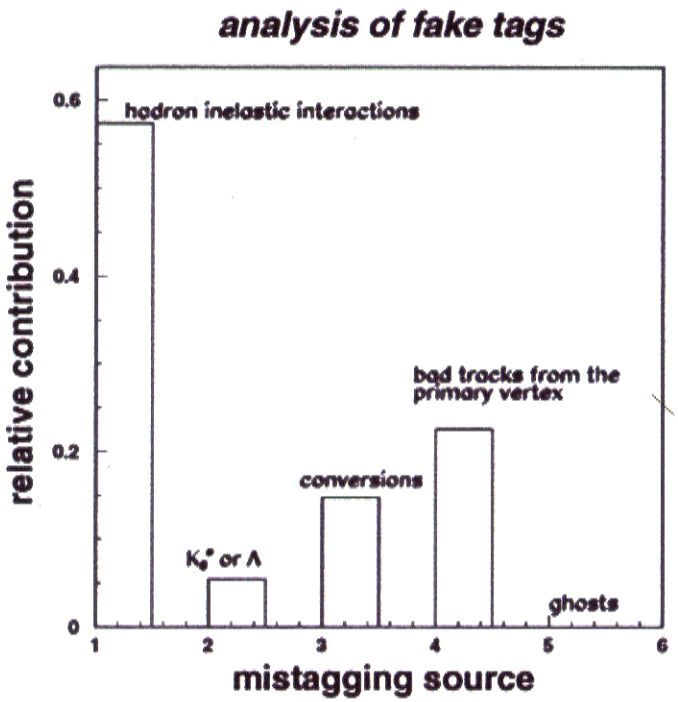


b-tagging performance
for various algorithms



These are tagging efficiencies from impact parameter measurements, can be improved with lepton tags

Tagging b-Jets

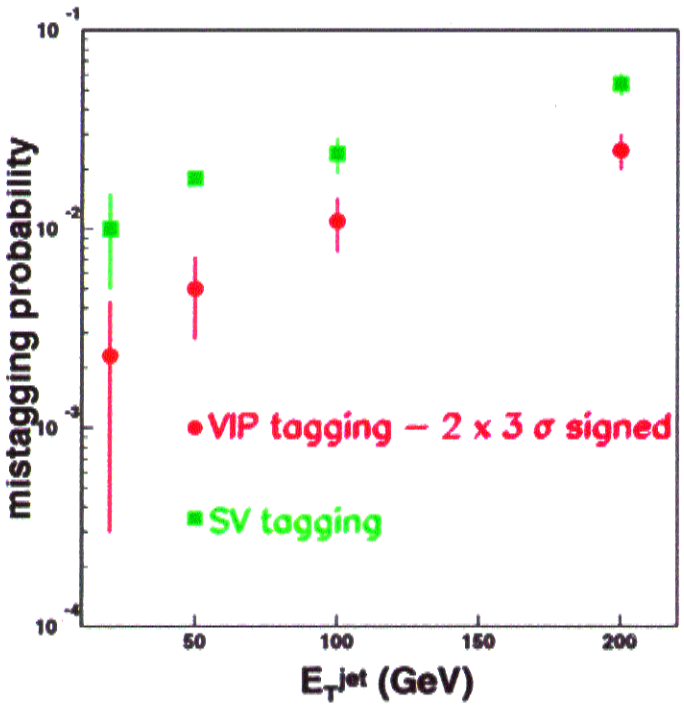


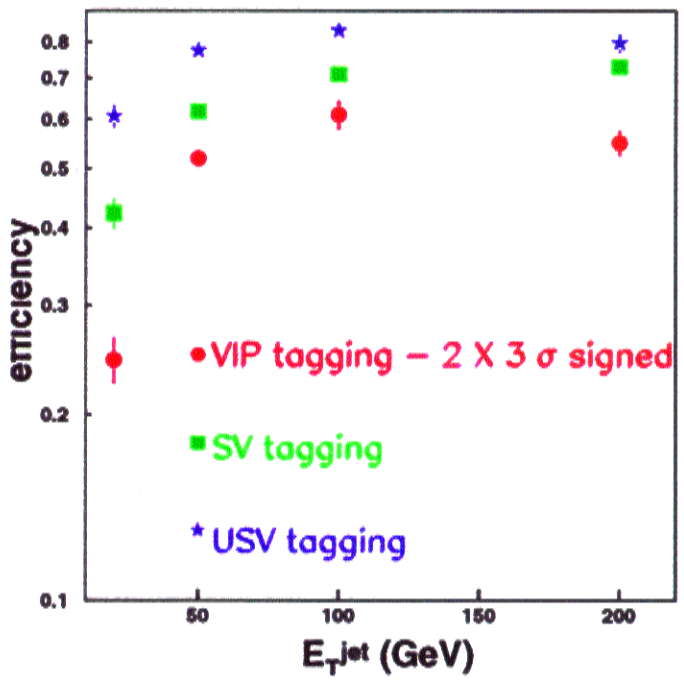
E_T=100 GeV jets

eff. = 62 %

mistag = 1.1 %

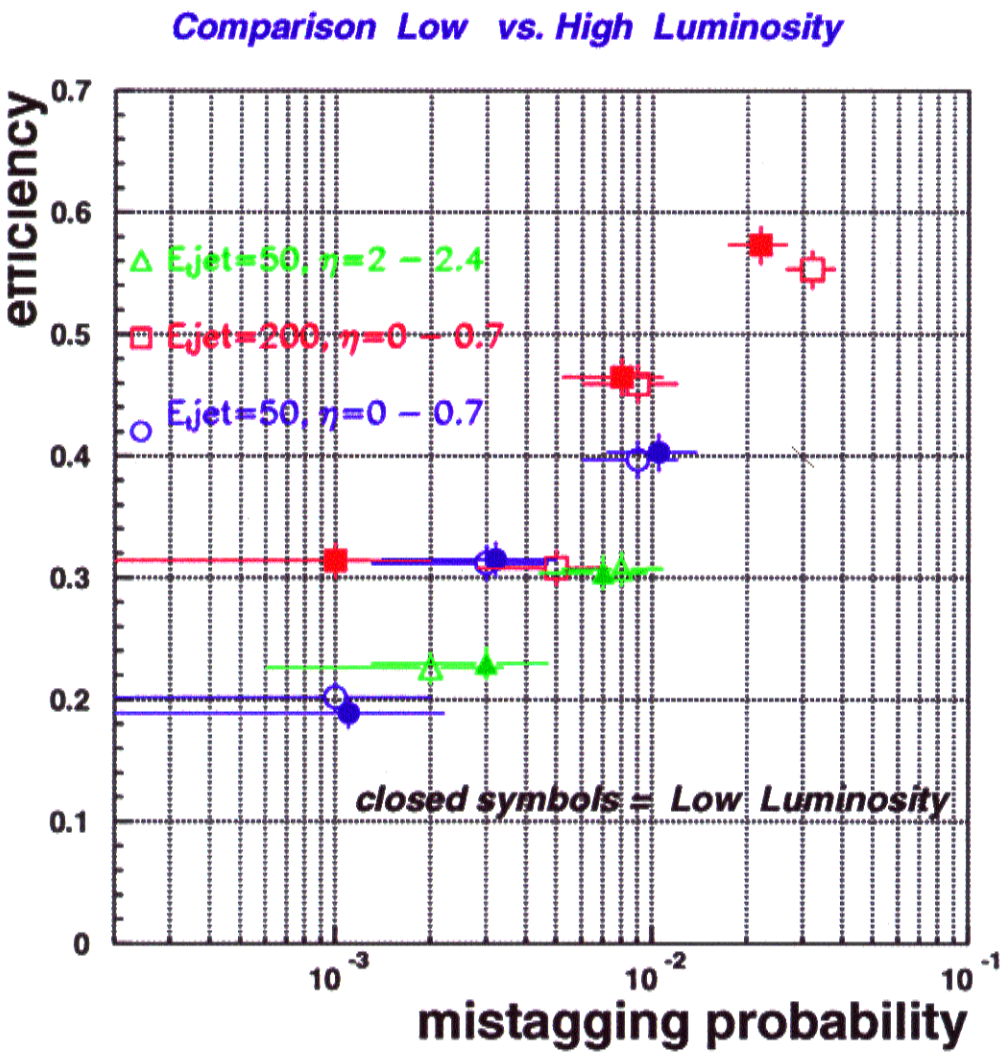
~ 78 % of the mistags is contributed by 'instrumental' background





High b-tagging efficicency achievable with mistag-rate of a ~1%.

Tagging b-jets



Tracks are reconstructed with backward propagation algorithms and requiring at least 8 hits per track.

Tagging algorithms require N tracks with impact parameter significance S, N, S = 2 - 3.

The b-tagging efficiency and the mistagging rate observed at low and high luminosity are consistent.

Track reconstruction efficiency within jets
- various algorithms

CMS

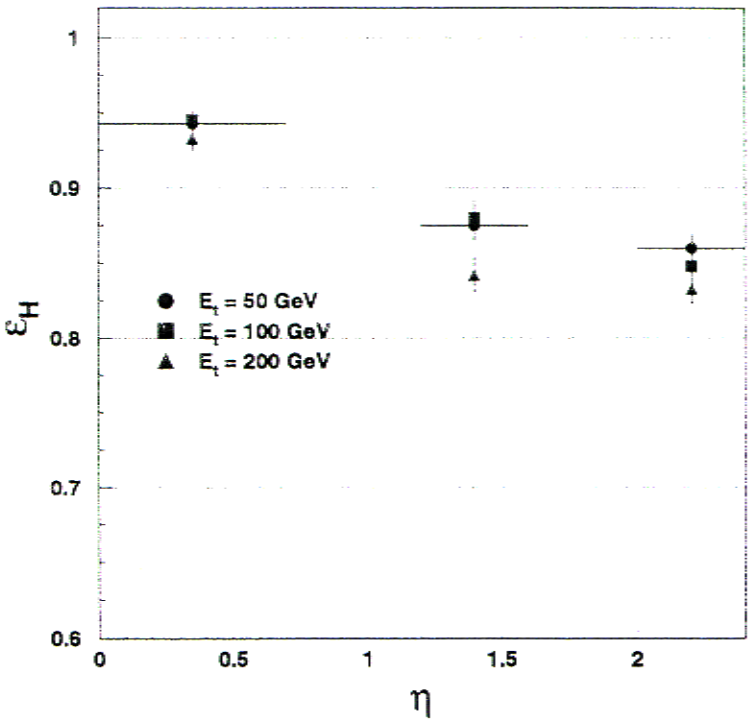


Fig. 9.39: Track reconstruction efficiency within jets as a function of jet pseudorapidity. Tracks are reconstructed with CM-FKF in the Phase I Tracker.

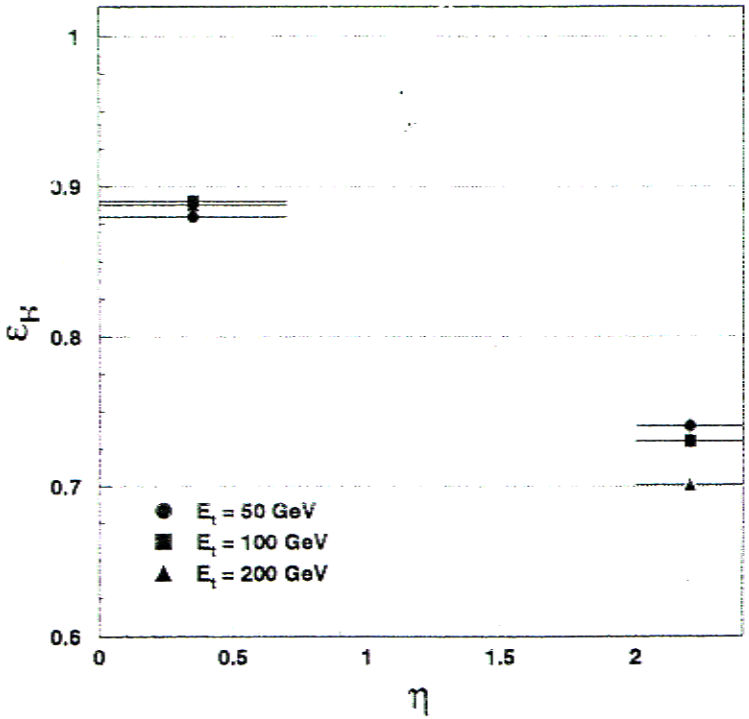
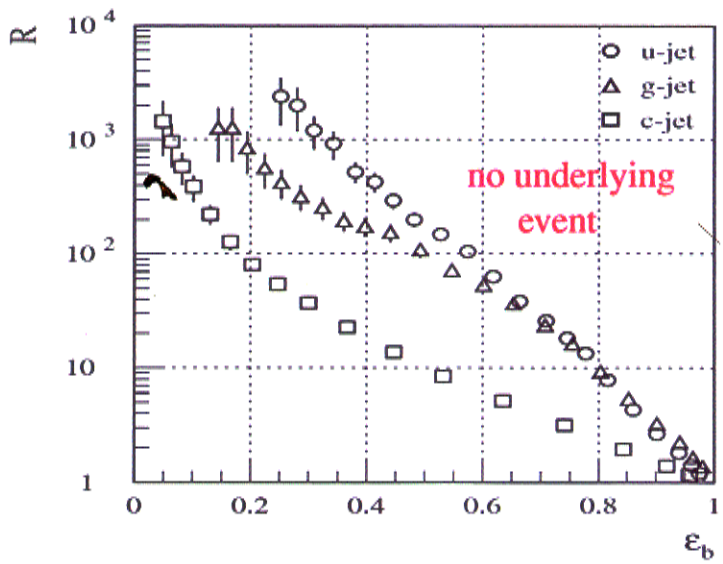
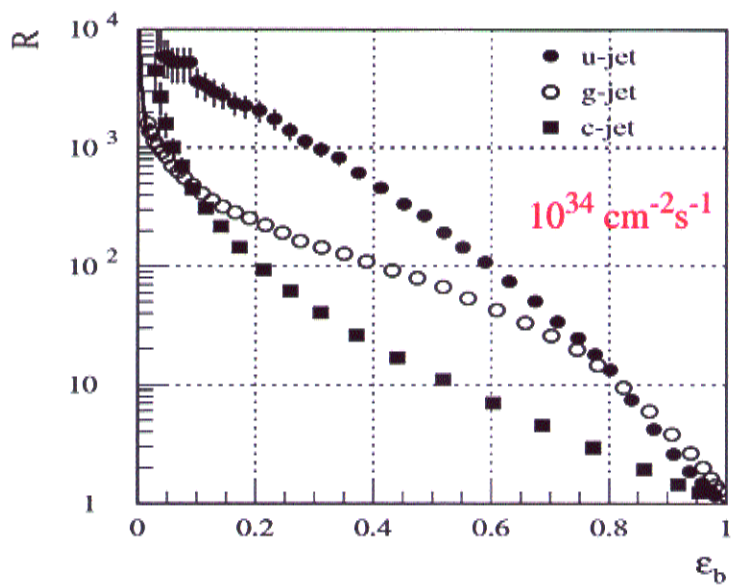


Fig. 9.40: Track reconstruction efficiency within jets as a function of jet pseudorapidity. Tracks are reconstructed with GTF in the Phase I Tracker.

B-tagging performance in ATLAS

Rejection factor for u,g and c jets as a function efficiency for b jets in H -> $b\bar{b}$ with m_H = 100 GeV





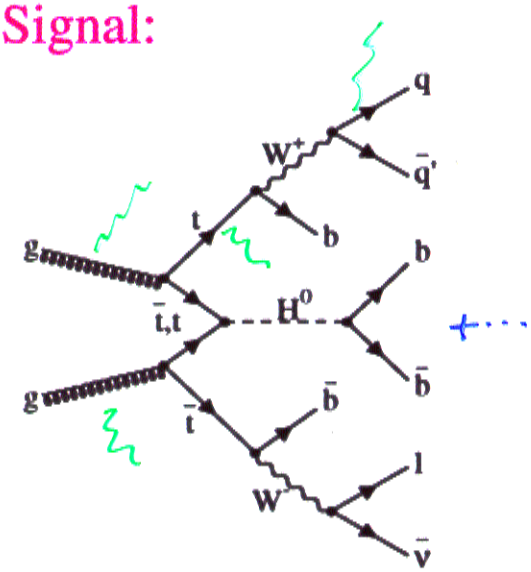
V. Drollinger

CMS-preliminary

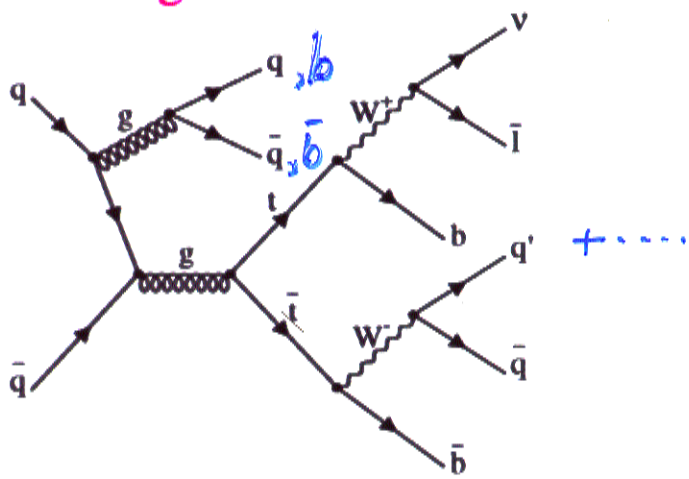
$t\bar{t}H^0$

$\hookrightarrow b\bar{b}$

Signal:



Background:

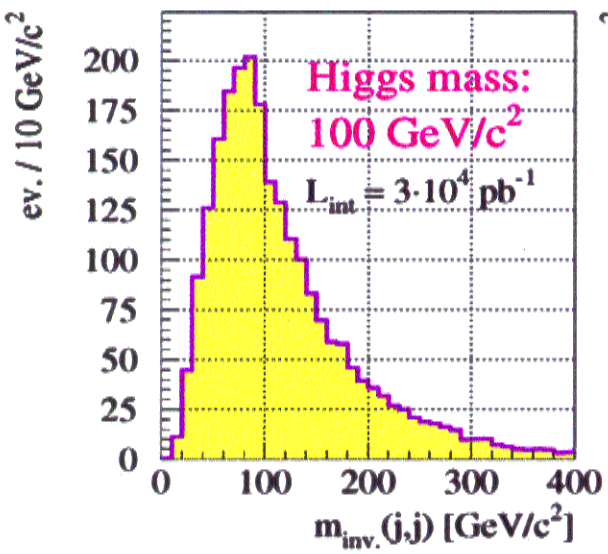


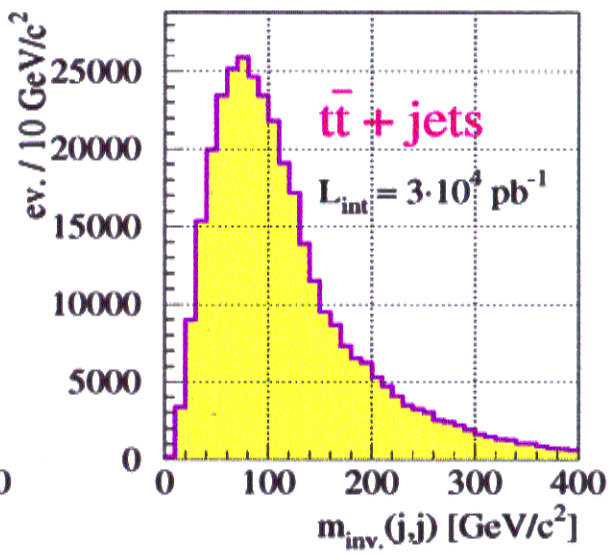
Event Reconstruction:

requirements: one isolated lepton $p_T > 20GeV/c$, at least six jets $|\eta^j| < 4.5$

at least three b-tagged jets with $0.6 < \Delta R_{j,j} < 2.8$

all possible combinations of invariant two jet masses are calculated





$t\bar{t}H$, H -> $b\bar{b}$ in CMS

preliminary results

Event selection for low luminosity ($L \sim 10^{33}$ cm^{-2}s^{-1})

1 isolated lepton, $p_t > 10$ GeV

at least 6 jets, $E_t > 10$ GeV

4 tagged b-jets

reconstruction of m_W, m_{top}(hadronic), m_{top}(leptonic)

calculation of event likelihood for all 6 jet combinations

B-tagging algorithm applied on the reconstructed jets in $t\bar{t}H$ and backround events

Impact parameter errors from full track reconstruction parametrized as a function of p_t and η

Average tagging efficiency/jet:

~ 50 % for b-jets

~ 2 % for light (q,g) jets

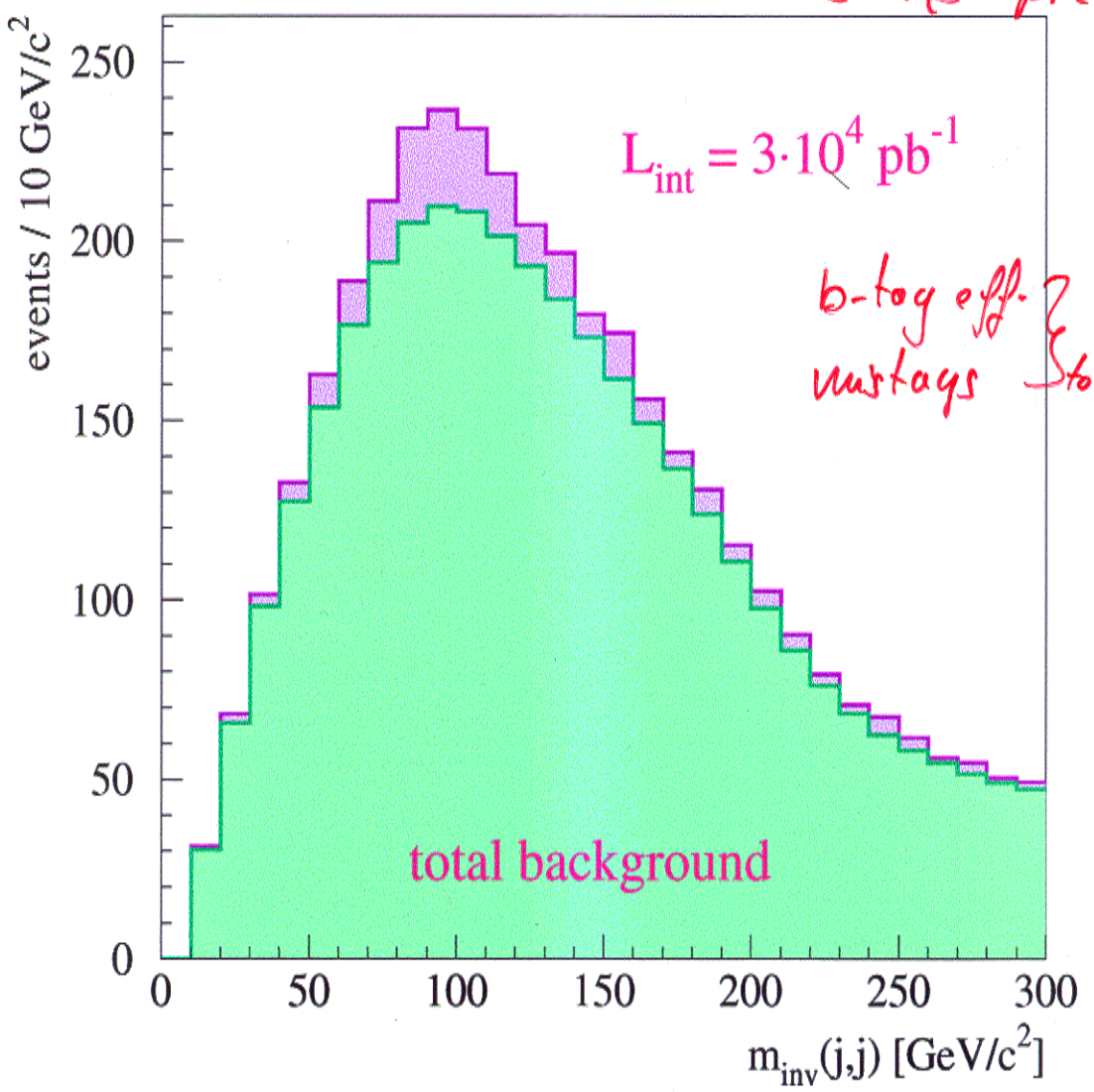
m_H	signal eff.	S / B	$S / \sqrt{B}$
100 GeV	2.4 %	0.12	3.0
120 GeV	3.4 %	0.06	1.9

$S + B$: 100 GeV Higgs

The Cuts:

- likelihood cut = 0.025
- 80 $GeV < m_{inv}$(j,j) < 110 GeV

CMS'-preliminary



b-tag eff. } OK. i.e. ok.
mistags } to full simul.

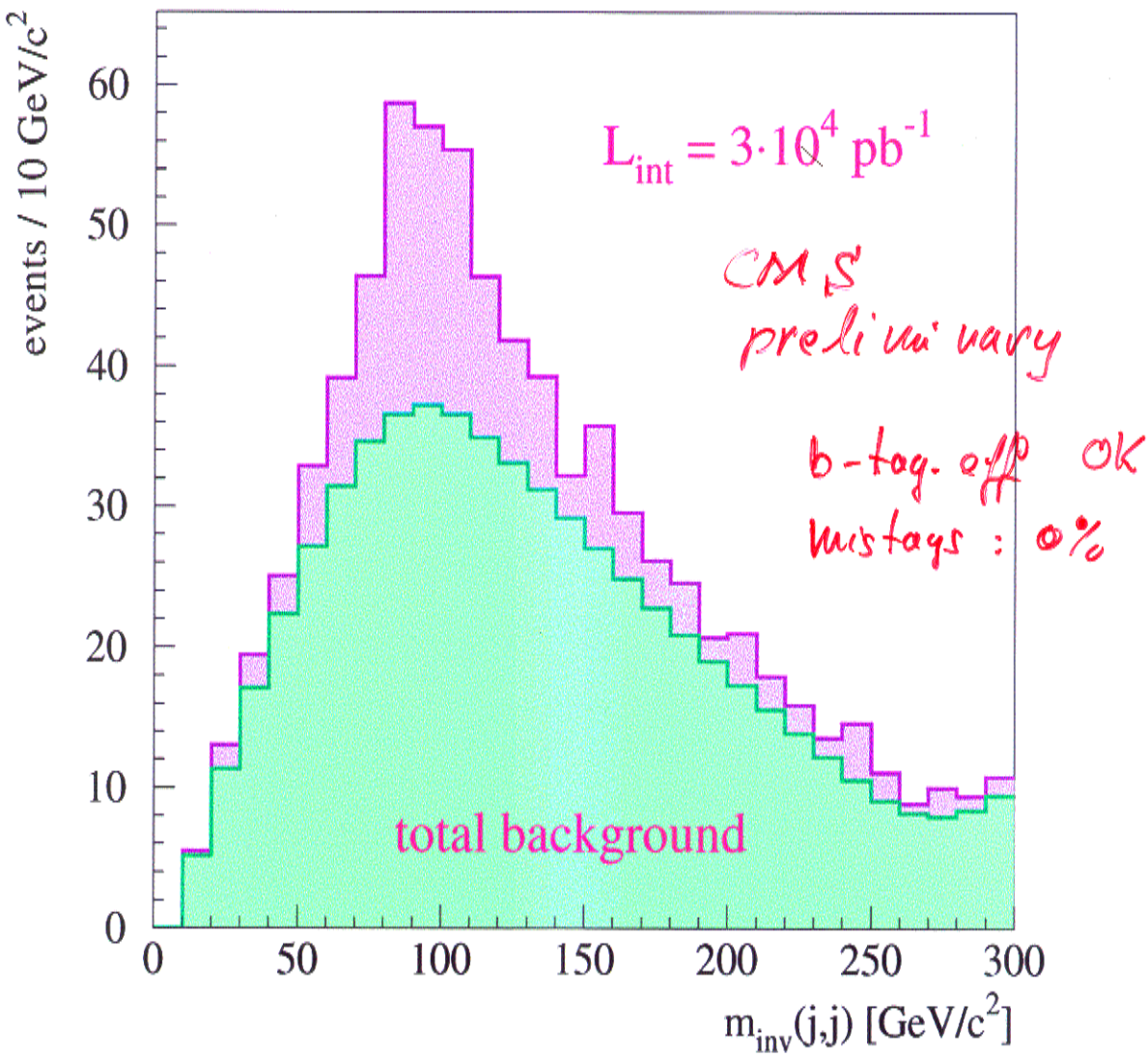
Results:

- signal rec. eff. = 2.4%
- $S/\sqrt{B} = 3.0$

V. Drollinger

$S + B$: 100 GeV Higgs

The Cuts:
- ◇ likelihood cut = 0.025
- ◇ 80 $GeV < m_{inv}$(j,j) $< 110\ GeV$

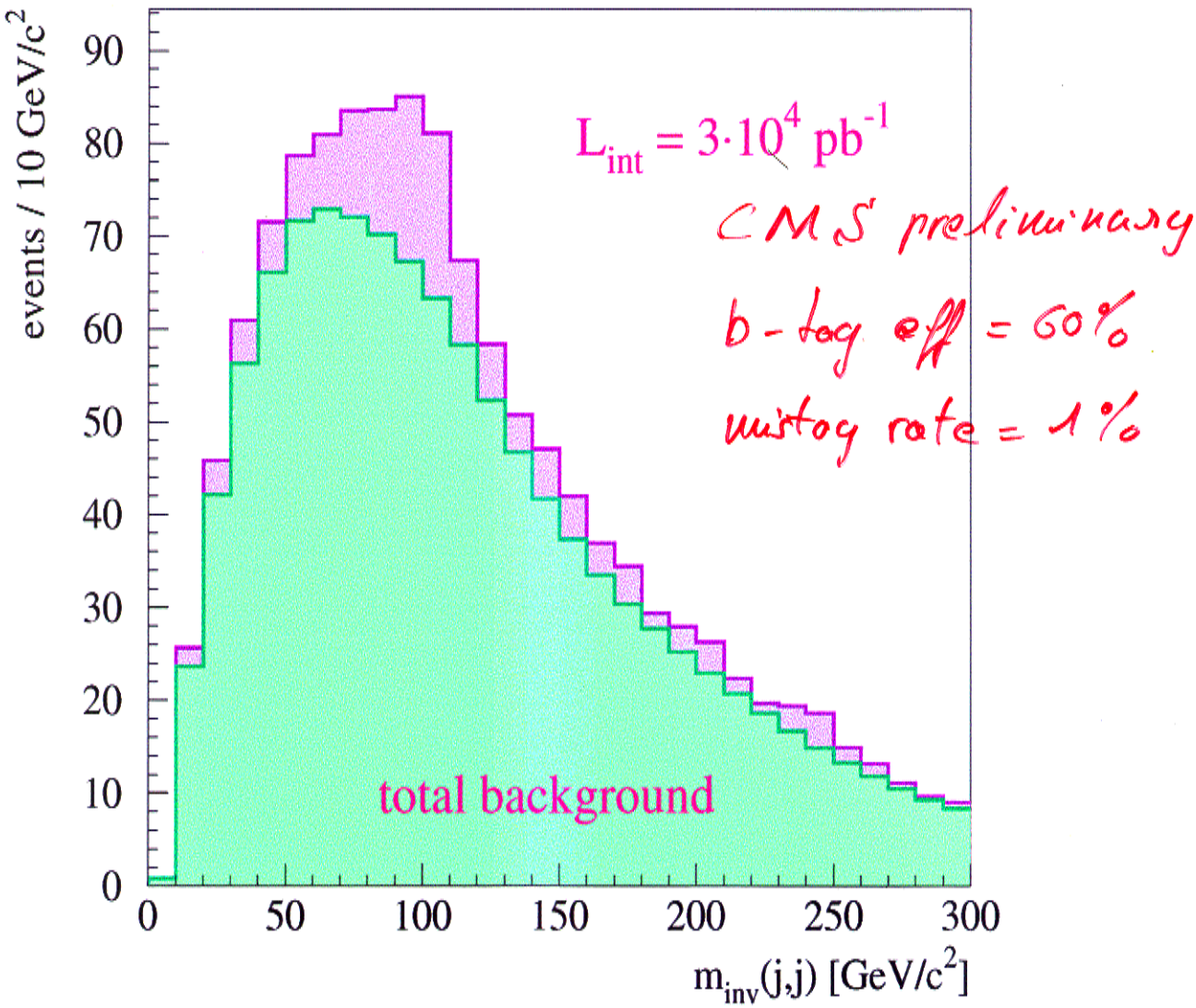


Results:
- ◇ 4 MC b-quarks
- ◇ $S/\sqrt{B} = 4.8$

$E_t^{jet} > 15$ GeV

$S + B$: 100 GeV Higgs

The Cuts:
- ◇ likelihood cut = 0.035 → ≈ 1.5σ
- ◇ 75 GeV < m_{inv}(j,j) < 110 GeV



Results:
- ◇ b-tagging: $\epsilon_b = 60\%$, $\epsilon_c = 10\%$, $\epsilon_q = 1\%$
- ◇ $S/\sqrt{B} = 3.8$

$E_t^{jets} \geq 15$ GeV

ATLAS

H-> $b\bar{b}$ in $t\bar{t}H$ channel with full simulation

Irreducible backgrounds from $t\bar{t}b\bar{b}$, $t\bar{t}Z$

Reducible backgrounds $t\bar{t}jj$, Wjjjjj, WWbbjj,.. with missidentified b jets

Event selection:

One trigger lepton, $p_t^e > 20$ GeV (30 GeV), $p_t^\mu > 6$ GeV(20 GeV)

At least 6 jets, $E_t > 15$ GeV (30 GeV)

Exactly 4 tagged b-jets

B tagging efficiency: 60% (50% for high luminosity)

misstagging rate: 1% for q, g jets, 10% for c-jets

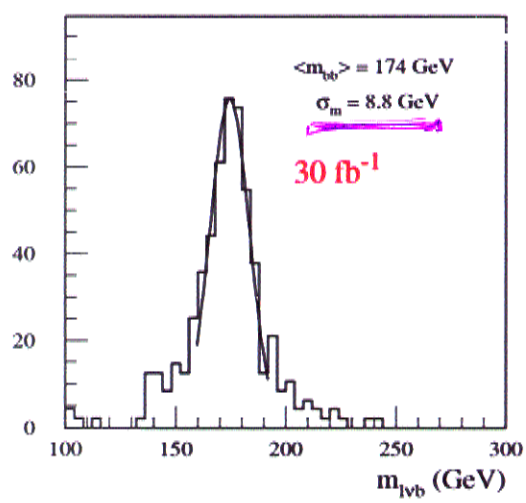
Mass reconstruction with

W mass constraint for construction of ν_L from W -> $l\nu$

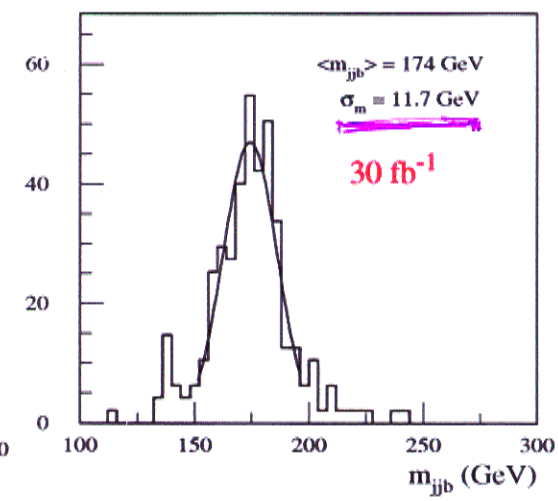
and for rescaling of jet momenta in W -> qq'

Reduction of combinatorial background with minimization of

$\chi^2 = (m_{jjb}-m_t)^2 + (m_{l\nu b}-m_t)^2$



Reconstructed top mass from t->$l\nu$b in $t\bar{t}H$ with m_H= 100 GeV



Reconstructed top mass from t->jjb in $t\bar{t}H$ with m_H= 100 GeV

Efficiency of 66% for both top quarks in the mass window of ± 20 GeV

H -> $b\bar{b}$ in $t\bar{t}H$ with top reconstruction

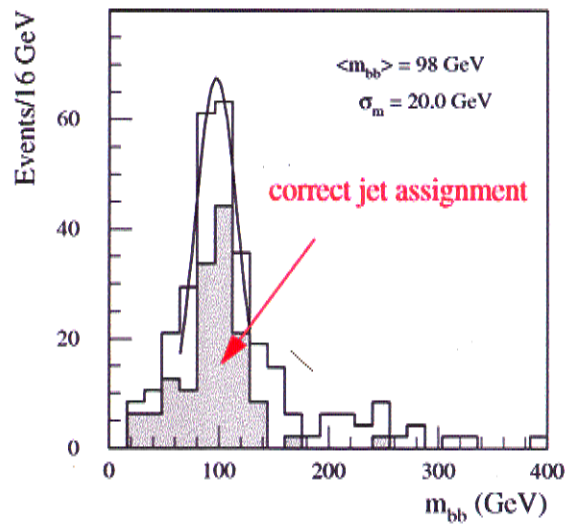
ATLAS

Reconstructed m_{bb} distribution for H -> bb in ttH with

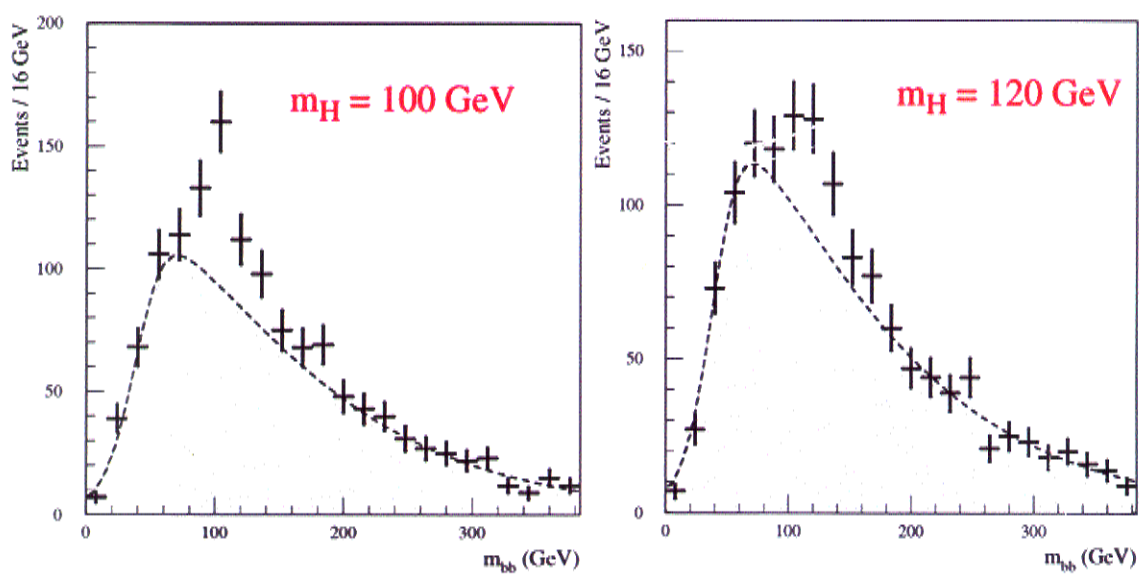
$m_{jjb} = m_t \pm 20$ GeV

$m_{l\nu b} = m_t \pm 20$ GeV

Mass window cut ± 30 GeV with 41% signal efficiency



m_{bb} distribution above the summed background for 100 fb^{-1}



30 fb^{-1} with low luminosity operation and 70 fb^{-1} with high luminosity operation

Total signal acceptance 1.7% at low lum., 0.7% at high lum.

$H_{SM} \rightarrow Z\gamma$

$H \to Z + \gamma$

CMS. first estimations for SM H->Zγ, Z->μμ/ee channel

A. Nikitenko, Saclay/ITEP Moscow

M_H, GeV	140	150	160	170
Br(Zγ) x 10^3*	2.47	2.37	1.19	0.39
σ(gg->H), pb**	25.4	22.6	20.2	18.2
σ(qq->qqH),pb***	3.7	3.4	3.2	3.0
Signal: σ x Br(H->γγ) x Br(Z->2l)x x10^5,pb	488	420	190	56
Bkg.qq->Zγ, σxBr(Z->2l) x10^5,pb****	30000 (51000)	20000 (34000)	14000 (24000)	10000 (17000)

After min. acceptance cuts: p_t^{μ}>10 GeV, $|\eta^{\mu}|$<2.4, p_t^{γ}> 30 GeV, p_t^{e}>15 GeV, $|\eta^{\gamma}|$<2.5, 1.46<$|\eta^{\gamma}|$<1.59 and assuming ε_{rec}^{μ}=0.9, $\varepsilon_{rec}^{\gamma/e}$=0.8 :

exected number of events for L=10^5pb^{-1}

Signal: 2μ/2e	70/48	33/23
Bkg.qq->Zγ, Z->2μ/2e	780/550 (1330/935)	520/365 (880/620)
S/sqrt(B)	3.2 (2.5)	1.9 (1.5)

* HDECAY

** NLO, CTEQ4M, Mt = 175 GeV; from M.Spira HIGLU

*** LO, CTEQ4L ; NLO corrections are about 10 %

**** in Zγ mass bin 2 GeV; PYTHIA 5.7 , CTEQ4M and for K factor 1 and 1.7 (in ())

$H_{SM} \rightarrow WW \rightarrow l\nu jj$

D.D93

ATLAS

Extension of the searches in the H -> WW -> $l\nu jj$ and H -> ZZ -> $ll\nu\nu$ down to masses of 300 GeV

~ 30% of the production with qq -> qqH

Backgrounds from $t\bar{t}$, W + jets, WW

Central cuts for H->WW:

lepton, $p_t > 50$ GeV , $|\eta| < 2$
$E_t^{miss} > 50$ GeV $p_t^{W\to l\nu} > 150$ GeV
2 jets, $E_t > 50$ GeV, $p_t^{W\to jj} > 150$ GeV
$m_{jj} = m_W \pm 2\sigma$

Central cuts for H->ZZ:

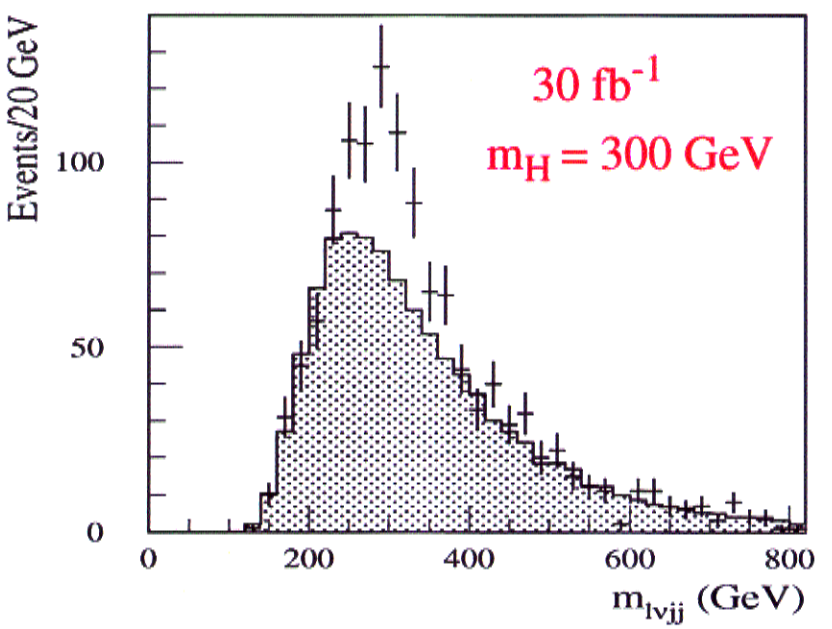
2 eptons, $p_t > 40$ GeV , $|\eta| < 2.5$
$E_t^{miss} > 150$ GeV, $p_t^{Z\to ll} > 150$ GeV
$m_{ll} = m_Z \pm 6$ GeV

Central jet veto: $E_t > 20$ GeV

Signal acceptance 65%, rejection against $t\bar{t}$ ~14

Double jet tag : $E_{tag} > 300$ GeV, $|\eta| > 2$

Signal acceptance 51%, backkground rejection 30 to 300



$qq \rightarrow qqH_{SM}$

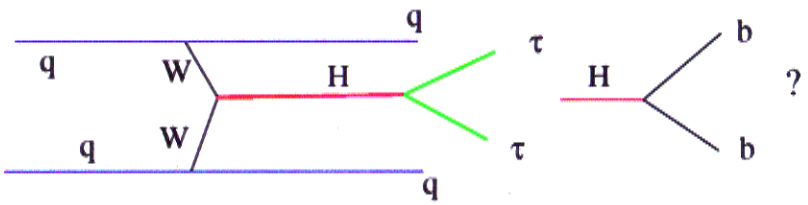
with $H \rightarrow \tau\tau$

D.D94

CMS' preliminary
A. Nikitenko et al.

$H_{SM} \to \tau\tau$ in qqH with $\tau_1 \to l\nu\nu$, $\tau_2 \to h + n\pi^0 + \nu$

possibility to measure the $H\tau\tau$ coupling



Backgrounds from QCD Z+jj, EW Z+2j, Wj+jj, bbjj

Event selection:

1) Isolated lepton, $p_t > 15$ GeV

2) τ jet, $E_t > 30$ GeV

τ identification in tracker and calorimetry with full simulation

τ selection efficiency	30 %
misidentification in W+jet events	1.9×10^{-3}
$b\bar{b}$ events	$< 1 \times 10^{-3}$

3) Forward jet tagging: $E_t^{jet} > 30$ GeV, $\eta_{j1} * \eta_{j2} < 0$, $M_{jj} > 1$ TeV

	σ * BR	Events for 30 fb^{-1} with selection
qqH, $m_H = 135$ GeV	0.17 pb	7.4
QCD Z+jj*	3.94 pb	1.2
EW Z+2j**	33.6 fb	0.76

Colour structure in qqH disfavours jet emission in central region

→ further improvement of S/B possible with minijet veto

Cuts can still be optimized to improve statistics

* $p_t > 30$ GeV, 115 GeV $< m_{Z,\gamma^*} <$ 155 GeV

** $p_t > 20$ GeV, $m_{Z,\gamma^*} > 110$ GeV, $M_{jj} > 500$ GeV

At the time of Les Houches workshop

A. Nikitenko. contribution for Les Houches workshop

τ - jet identification obtained with full simulation of CMS calorimetry

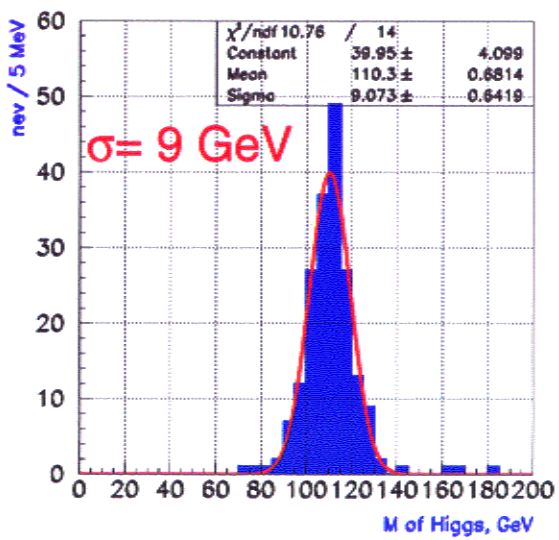
(R. Kinnunen, A. Nikitenko CMS Note 1997/002)

1. electromagnetic collimation: $\Sigma E_t^{cryst}(R<0.13) / \Sigma E_t^{cryst}(R<0.4) > r_{cut}$
2. calorimeter isolation : max $E_t^{ecal+hcal\ cell}(0.13<R<0.40) < E_t^{cut}$
3. one $p_t^{hadr} > 10$ GeV, no tracks $p_t > 2$ GeV in cone 0.4

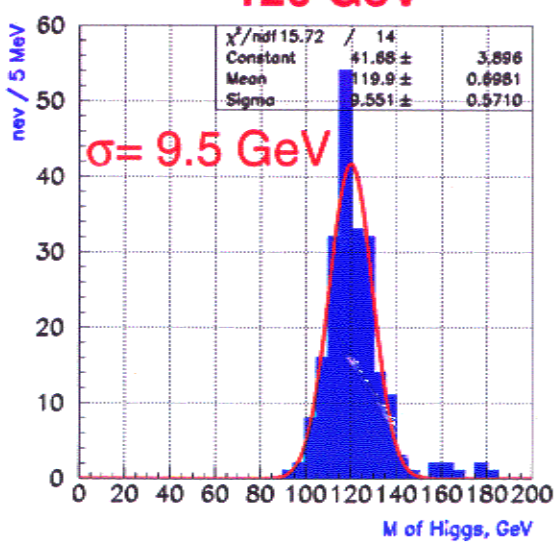
efficiency for τ-jet E_t>40 GeV from Higgs of 140 GeV = 0.32
misidentification for jet from W+jet events = 0.0019; b-jet from bb events < 0.001

Higgs mass reconstruction assuming m_τ=0

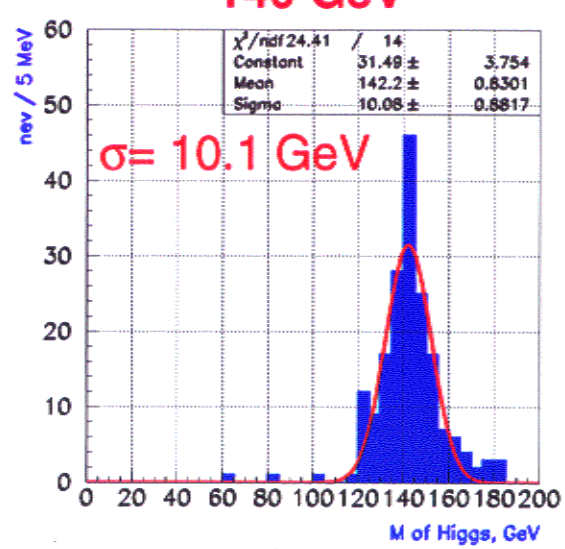
110 GeV



120 GeV



140 GeV



		Signal. M=135 GeV	QCD Z+j j*	EW Z+2j **
	cross-section, pb	3.81	117.3	1.0
	Br H->ττ ; Z -> ττ	0.045	0.0336	0.0336
mc	p_t^l>15 GeV, $p_t^{\tau\text{-jet}}$>30 GeV, $\lvert\eta\rvert$<2.4	0.275	0.169	0.61
fast detector simul. with cmsjet	lepton isolation in the tracker	0.90	0.86	0.99
	lepton isolation in the calorim.	0.91	0.87	0.99
	>= 3 jets of E_t>30 GeV, η < 4.5	0.51	0.24	0.72
	tau-jet association (mc)	0.92	0.85	0.99
	$\eta_{j\,min}+0.7<\eta_{l,\,\tau\text{-jet}}<\eta_{j\,max}-0.7$, $\eta_{j\,min}\eta_{j\,max}<0$	0.57	0.08	0.78
	$\lvert\eta_{j\,max}-\eta_{j\,min}\rvert > 4.4$	0.70	0.36	0.84
	M_{jj} > 1 TeV	0.59	0.32	0.73
	$m_t(l, p_t^{miss})$ < 30 GeV	0.77	0.72	0.60
	$0<x_{\tau\,l}<0.75$, $0<x_{\tau\,h}<1.0$	0.63	0.60	0.77
	$\cos\theta_{l\,\tau\text{-jet}} > -0.9$	0.99	1.0	0.85
	M_H window 40 GeV	0.81	0.74	0.065
Number of events for 3 years at $L=10^{33}cm^{-2}s^{-1}$		7.4	1.2	0.76

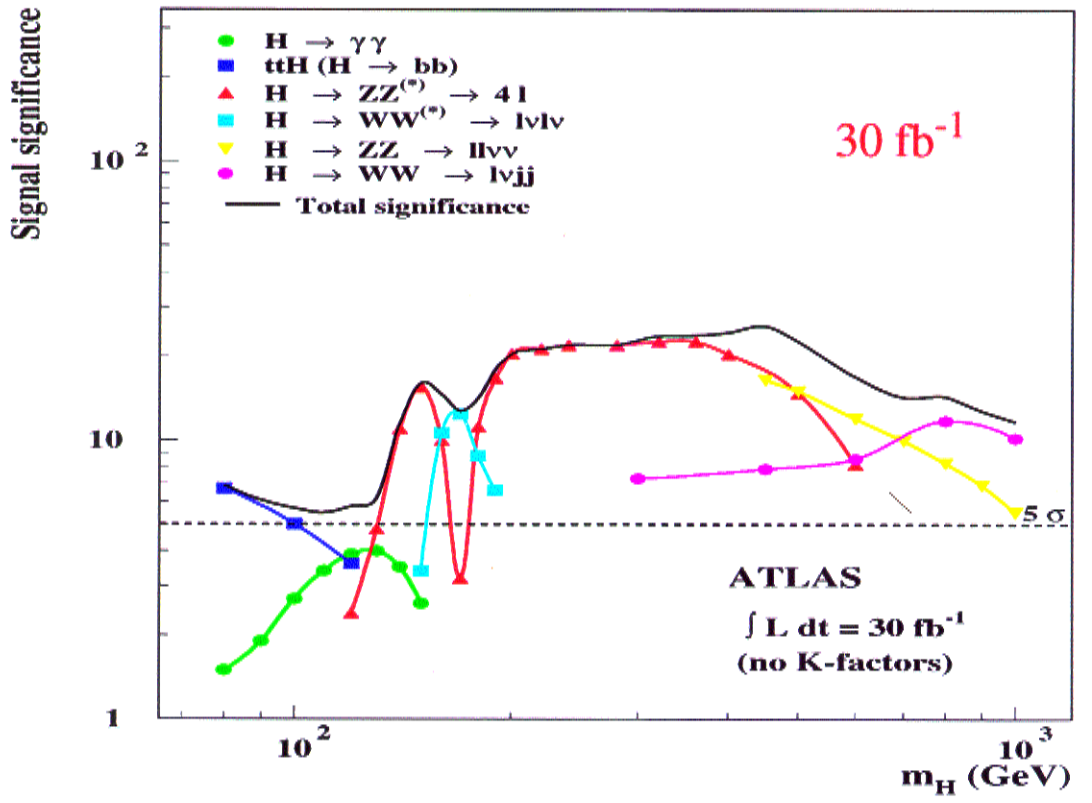
* QCD Z+j - pythia5.7; cteq4l, p_t> 30 GeV, $M_{\gamma^*/Z}$=[115-155] GeV;

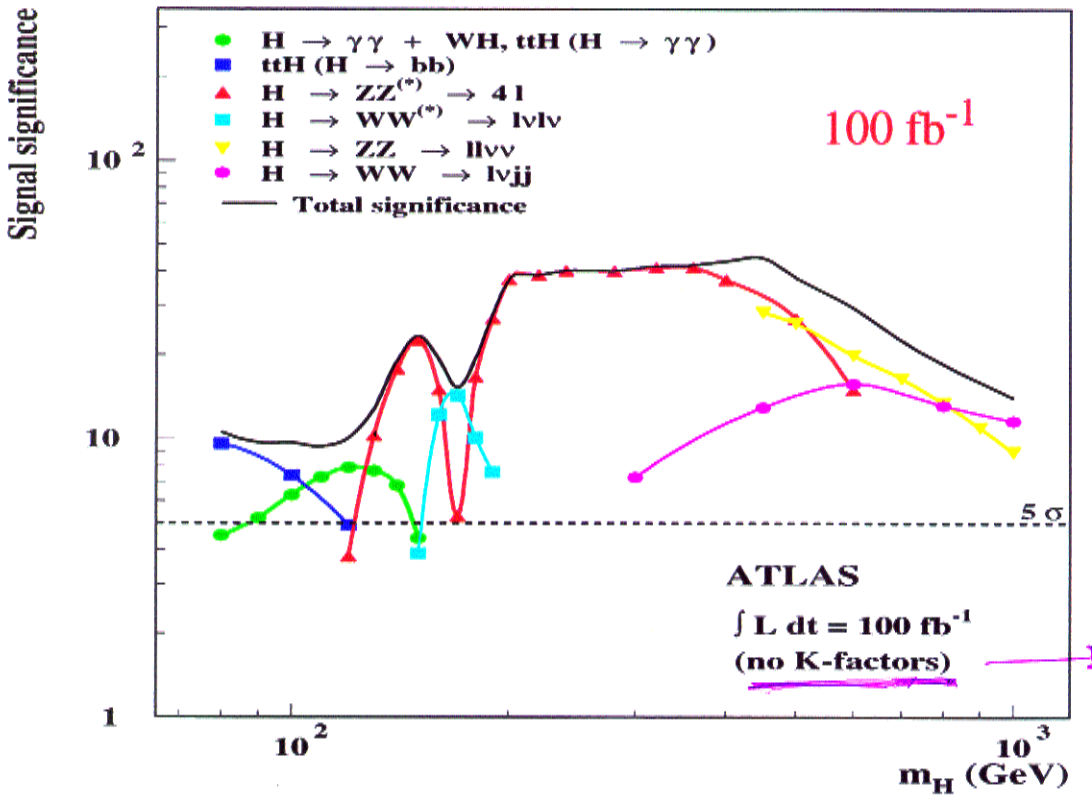
**EW Z+2j - gen. by S.Ilyin with comhep; cteq4m, E_t^j>20 GeV, $\lvert\eta\rvert$ < 5, M_Z>110 GeV, M_{jj}>500 GeV, Q=M_Z; and passed into pythia5.7 ; no ISR and FSR is activated; undependent fragmentation

SM Higgs

mass coverage
signal significance

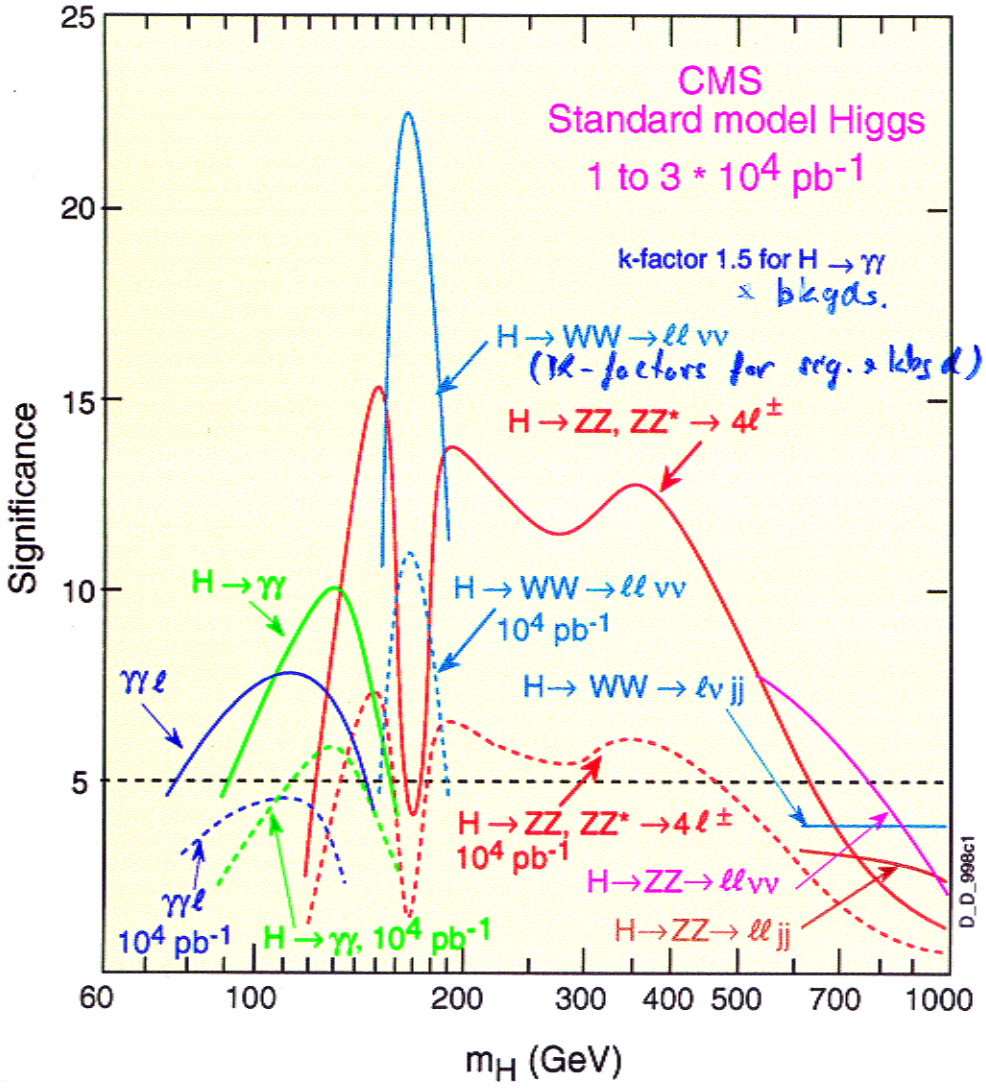
Discovery reach for SM Higgs in ATLAS

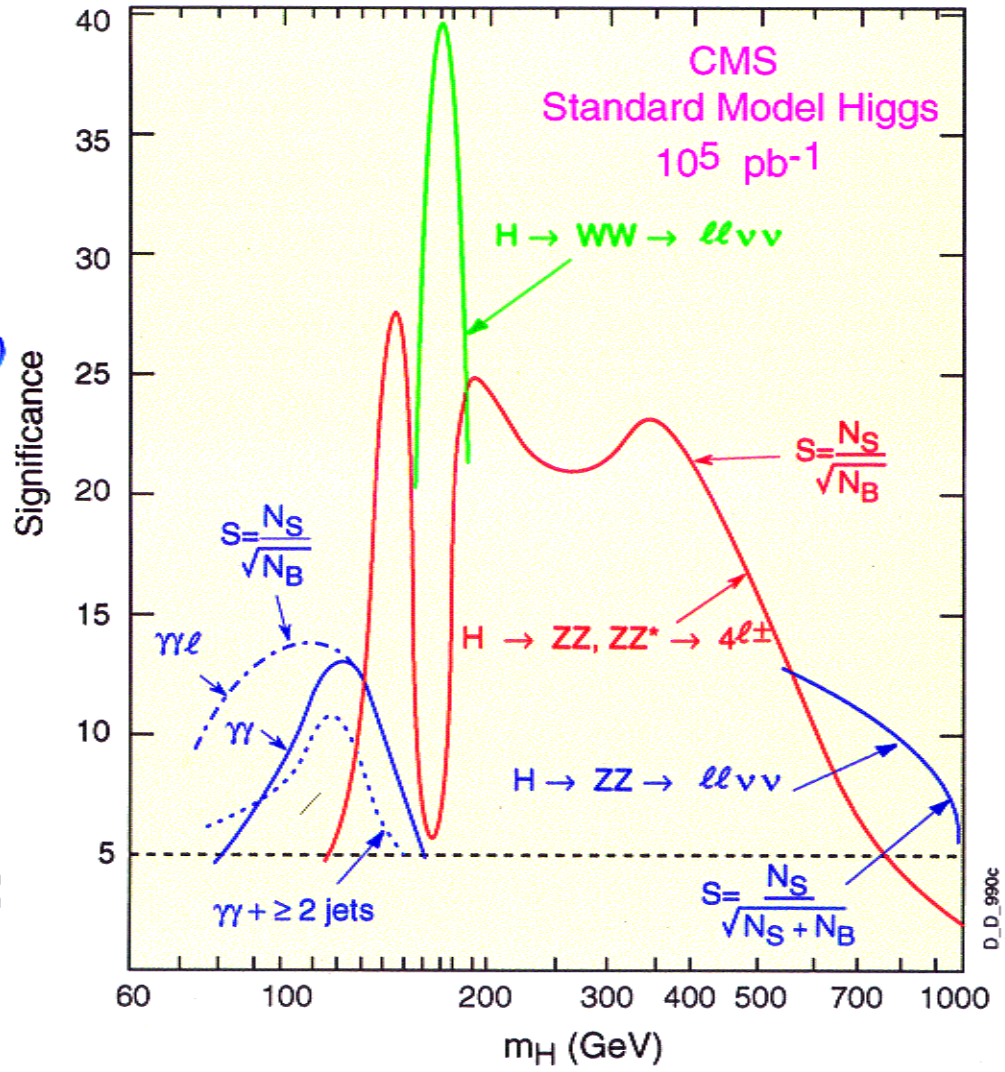




conservative view of things as K-factors for signal ≥ K-factors for bkgd.

Expected observability of Standard Model Higgs in CMS





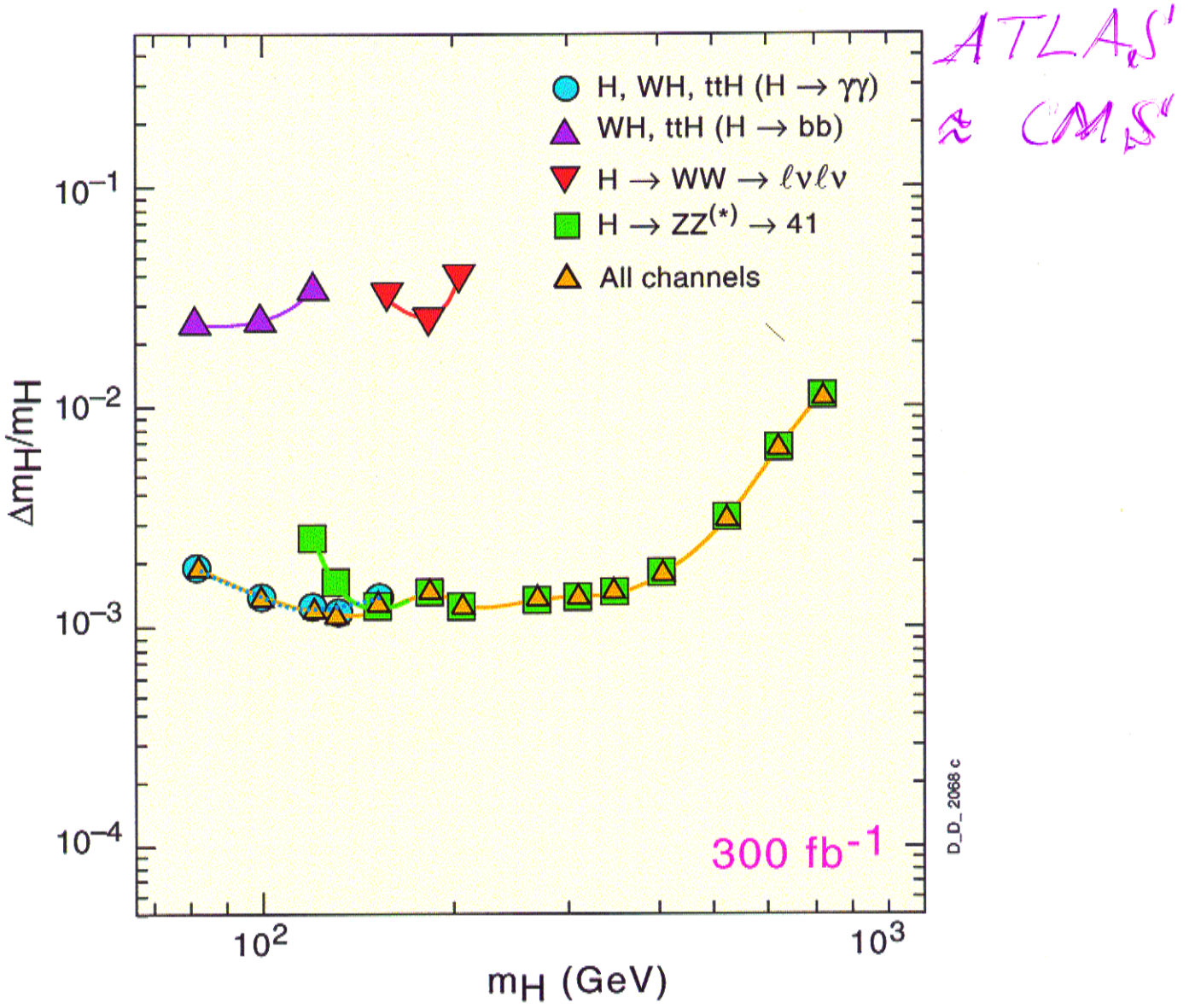
D.D. Gainesville 12

cuts not optimized in ZZ channel!

Precision on SM Higgs parameters

- mass
- width
- σ*BR

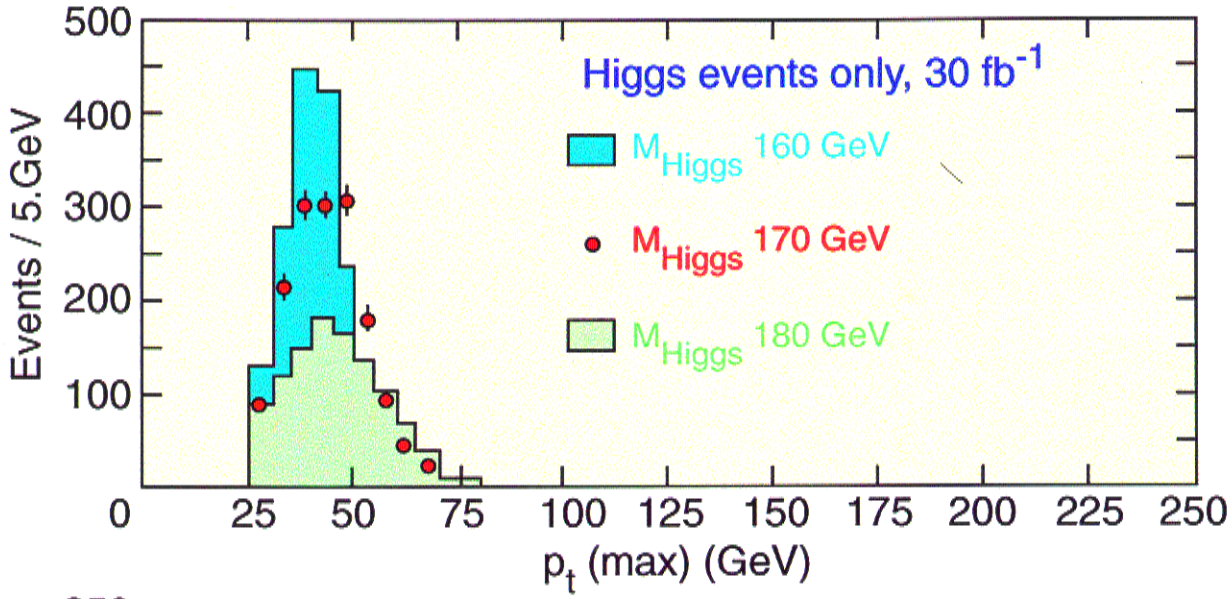
Precision on SM Higgs mass

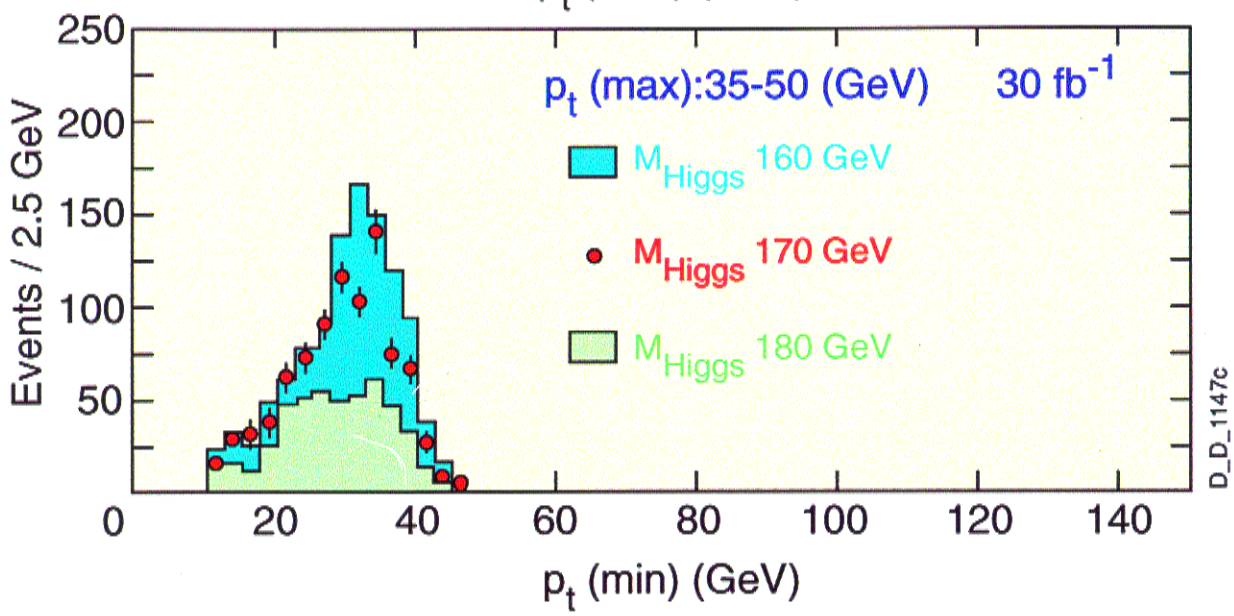


Limiting factor is knowledge of the absolute energy scale
for leptons and photons it is assumed to be known to 0.1% thanks to nearby Z
for jets it is assumed to be 1%

$H_{SM} \rightarrow WW \rightarrow \ell\nu\ \ell\nu$

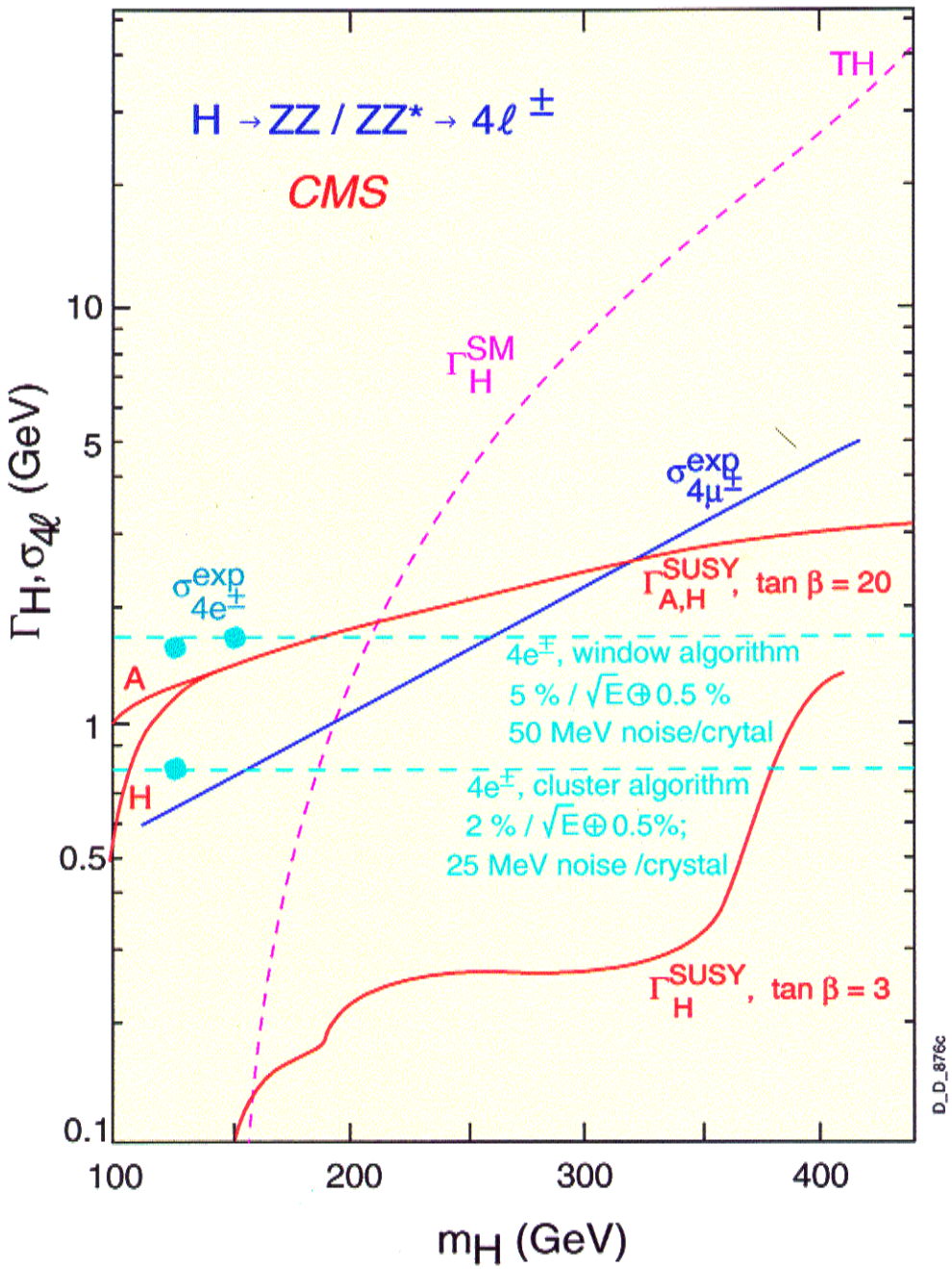
Sensitivity of lepton p_t to m_H – in terms of rate and shape





→ a precision on M_H of ~2-3 GeV could be achieved ultimately

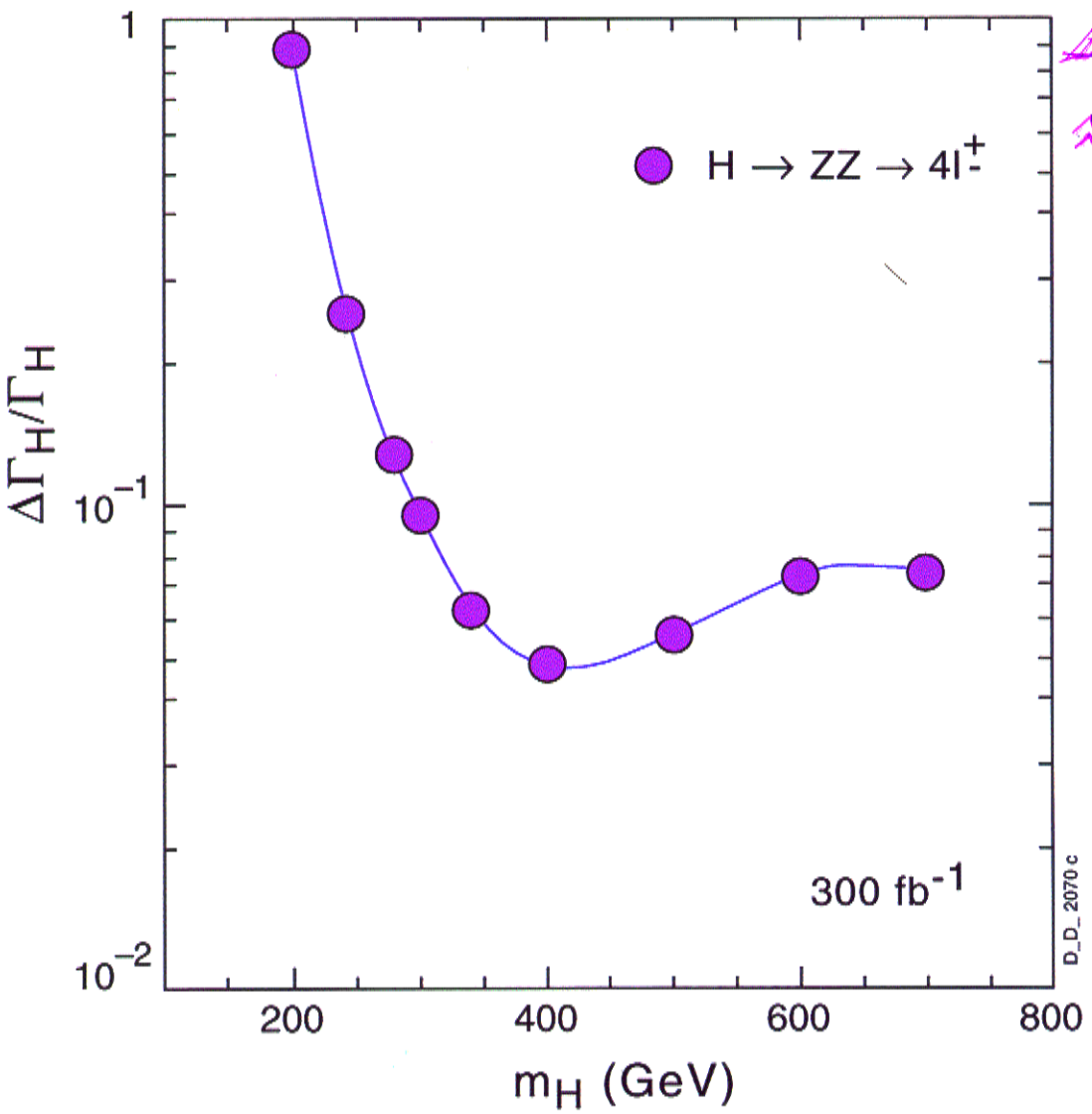
Comparison of intrinsic Higgs widths with expected leptonic mass resolutions in CMS



- SM Higgs width is small (<1GeV) up to m_H ~ 200 GeV
- SUSY Higgs widths are small (< few GeV) for all masses and tanβ

→ best possible 2 and 4-lepton mass resolutions to optimise S/B, ex. in $h,H \to 4l^{+-}$ or $h,H,A \to \mu\mu$

Precision on SM Higgs width

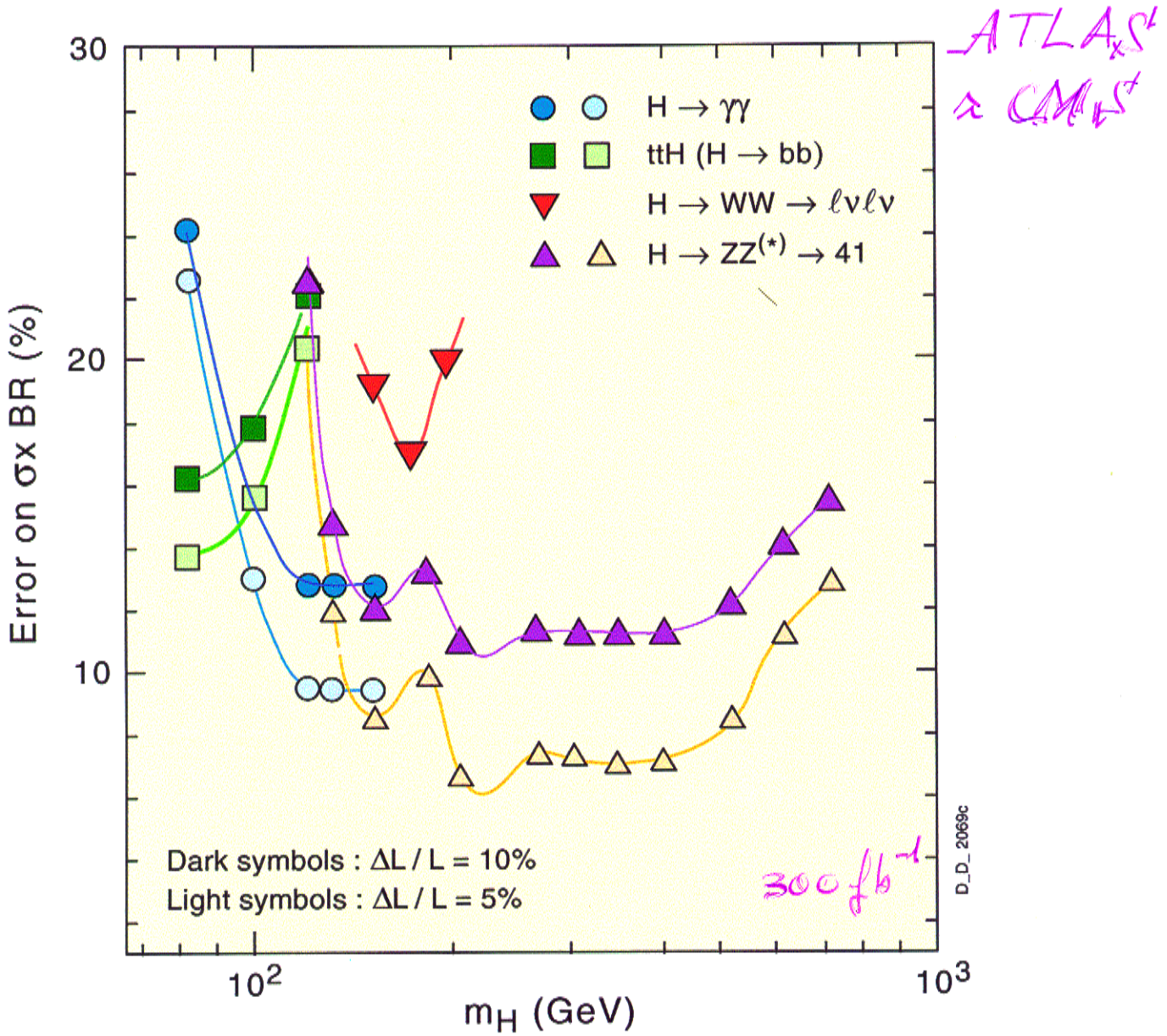


ATLAS ≈ CMS

Limiting factor are radiative decays

systematic uncertainty assumed to be 1.5%

Precision on SM Higgs production rates



- systematic uncertainty of 10% assumed on the background substraction
- Luminosity assumed to be know to 10 or 5%

SM-Higgs, precisions on couplings, BR's

- assuming 300 fb^{-1}
- in ratios luminosity uncertainty largely cancels

$$\frac{\sigma \cdot B(WH \to \gamma\gamma)}{\sigma B(WH \to b\bar{b})} \Rightarrow \frac{BR(H \to \gamma\gamma)}{BR(H \to b\bar{b})}$$

~ known to ~ 30%
stat. limited

only for: $80 \lesssim m_H \lesssim 120$ GeV

$$\frac{\sigma \cdot B(H \to \gamma\gamma)}{\sigma \cdot B(H \to ZZ^*)} \Rightarrow \frac{BR(H \to \gamma\gamma)}{BR(H \to ZZ^*)}$$

known to ~ 15%
~ stat. limited

only for: $125 \lesssim m_H \lesssim 155$ GeV

$$\frac{\sigma \cdot B(t\bar{t}H \to \gamma\gamma/b\bar{b})}{\sigma \cdot B(WH \to \gamma\gamma/b\bar{b})} \Rightarrow \frac{g^2_{Htt}}{g^2_{HWW}}$$

known to ~ 25%
stat. limited

only for: $80 \lesssim m_H \lesssim 130$ GeV

$$\frac{\sigma \cdot B(H \to WW^*/ZZ^*)}{\sigma B(H \to ZZ^*)} \Rightarrow \frac{g^2_{HWW}}{g^2_{HZZ}}$$

known to ~30%
stat (ZZ^*) limited

for $160 \lesssim m_H \lesssim 180$ GeV