A Review of the ATLAS Physics Program at the LHC

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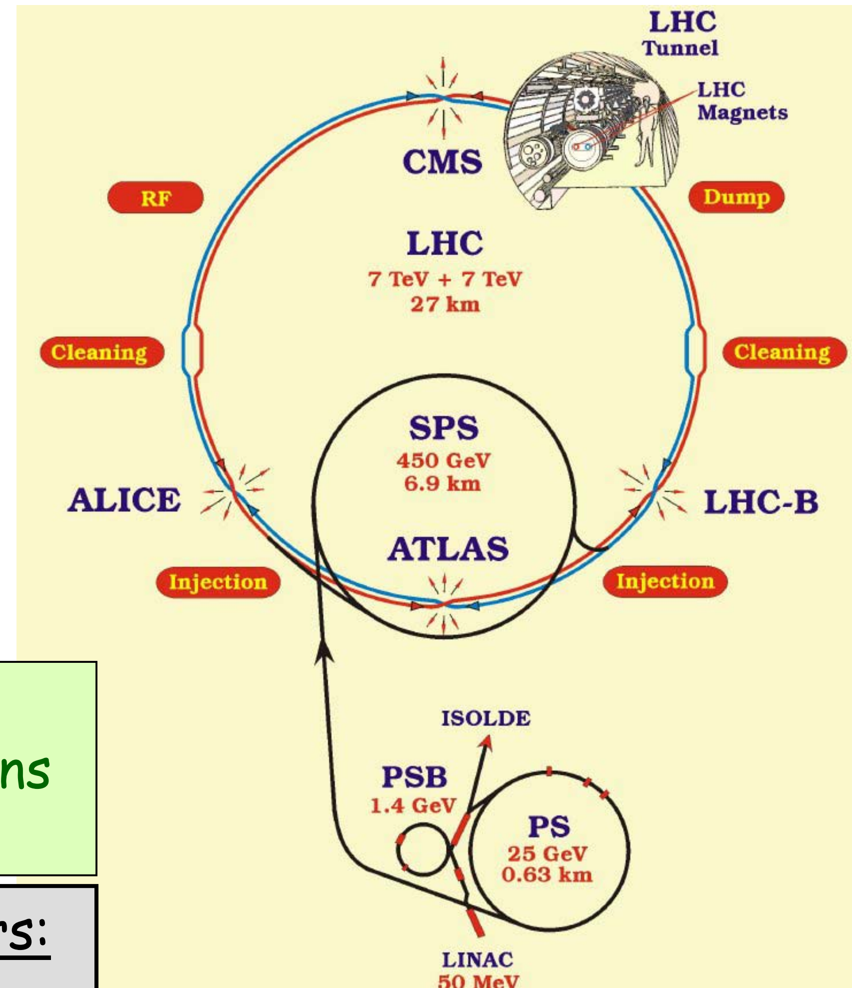
ATLAS Physics Working Groups

- Electro-weak
- B-physics
- Top-quark physics
- Higgs
- Super Symmetry
- Exotic physics
- Monte Carlo Generators
- Heavy Ion

The detector performance, physics prospects, search strategies, etc, are studied in these groups most of which are very advanced and have been around for several years.

Large Hadron Collider (LHC)

Injection Energy	0.45 TeV
Collision Energy	7 TeV
Dipole field at 7 TeV	8.33 T
Design Luminosity	10^{34} cm^{-2} s^{-1}
Luminosity Lifetime	10 h
Protons per bunch	10^{11}
Bunches per beam	2808
Bunch spacing	25 ns
DC Beam Current	0.56 A



- ≈ 1 GHz interaction rate
- ≈ 23 minimum bias interactions per bunch crossing (pile-up)

Extreme demands on detectors:

- high granularity
- high data-taking rate
- high radiation environment

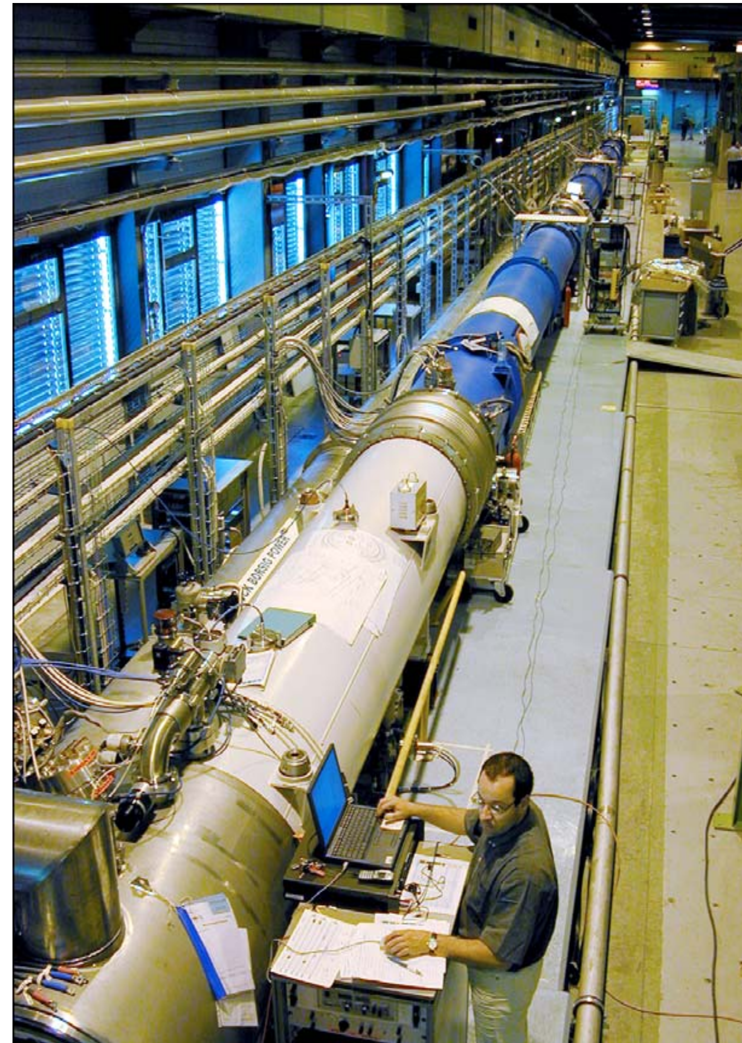
Status of LHC

Status:

- Successful magnet cell test in 2002 (1 cell ~120m long)
- Steady delivery of magnets
- needed:more than 5000 dipoles, quadrupoles, sextupoles….

Current Schedule:

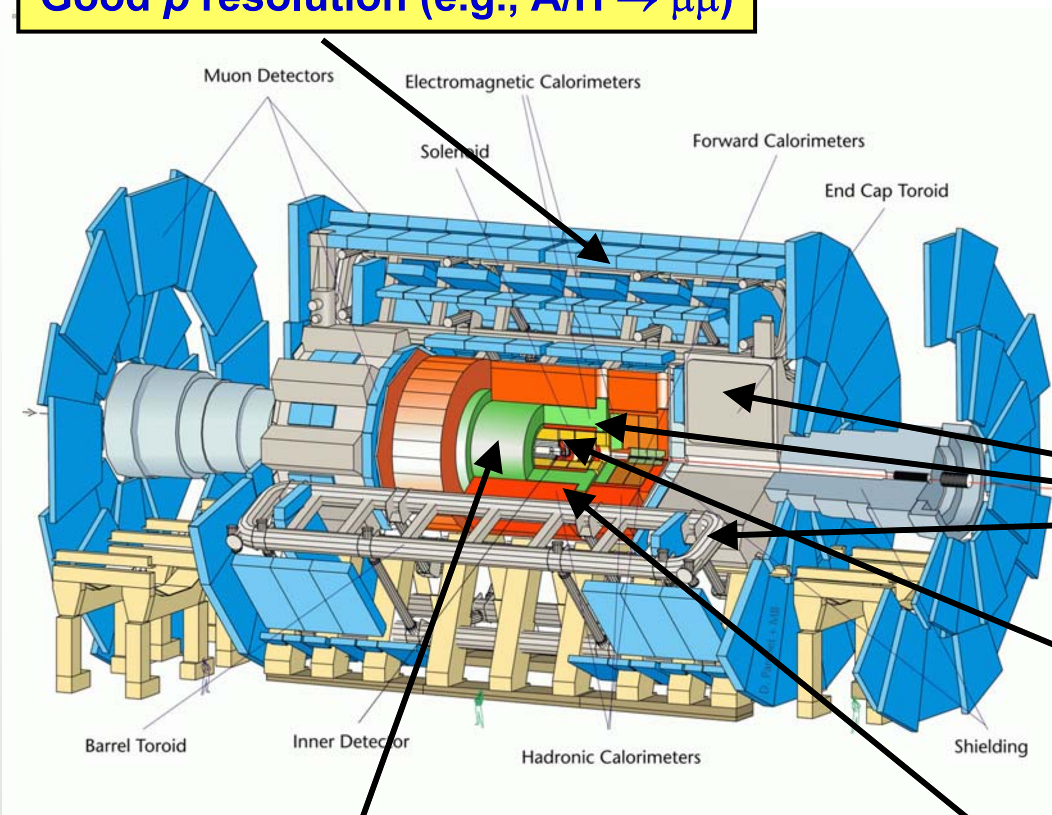
- April 2007: first collisions
- 2007-2008: $L \sim 2 \cdot 10^{33}\ cm^{-2}s^{-1}$, collect $\int Ldt \approx 10\ fb^{-1}$
- For the next years 2-3 years: collect in total $\int Ldt \approx 30\ fb^{-1}$
- afterwards: $L \sim 10^{34}\ cm^{-2}s^{-1}$, $\int Ldt \approx 100\ fb^{-1}$ per year



The ATLAS Detector

ATLAS = A Toroidal LHC ApparatuS

Muon Detectors $|\eta| < 2.7$
Fast response for trigger
Good *p* resolution (e.g., A/H $\rightarrow \mu\mu$)



Length: ~40m
Radius: ~10m
Weight: ~ 7000 t
El. Channels: ~10^8
Cables: ~3000 km

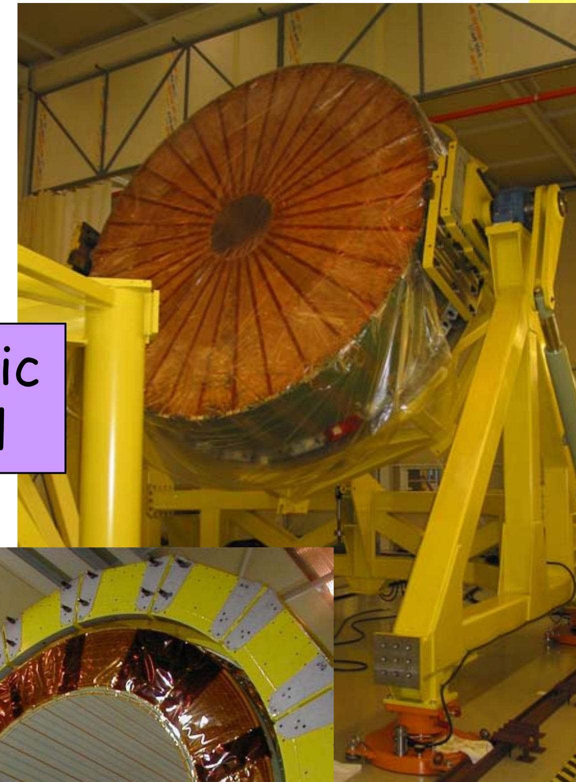
Magnet System
Central Solenoid (2T)
Air core Toroids (4T)

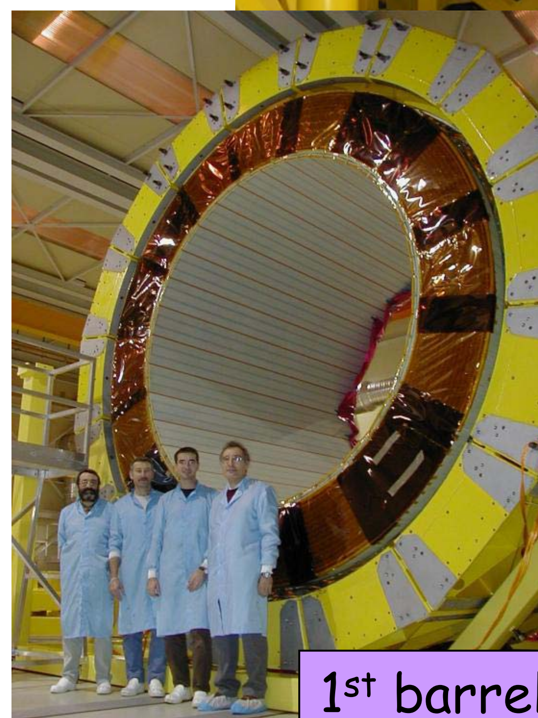
Inner Detector
High efficiency tracking
Good impact parameter res.
(e.g., H $\rightarrow$ bb) $|\eta| < 2.5$

Electromagnetic Calorimeters
excellent electron/photon identification
Good *E* resolution (e.g., H$\rightarrow\gamma\gamma$) $|\eta| < 3.2$

Hadron Calorimeters
Good jet and E_T miss performance
(e.g., H $\rightarrow\tau\tau$) $|\eta| < 4.9$

Detector Construction





QCD at the LHC with ATLAS

- Precision tests & measurements in unexplored kinematic region.
- Jet physics.
- Parton luminosities and p.d.f.'s (high-Q^2 processes at LHC: parton-parton collider).
- Direct photon production ($f_g(x)$, background to $H \rightarrow \gamma\gamma$, parton dynamics).
- Measurement of the α_S at very large scales.
- Background processes: multi-parton interaction, minimum-bias and the underlying event.

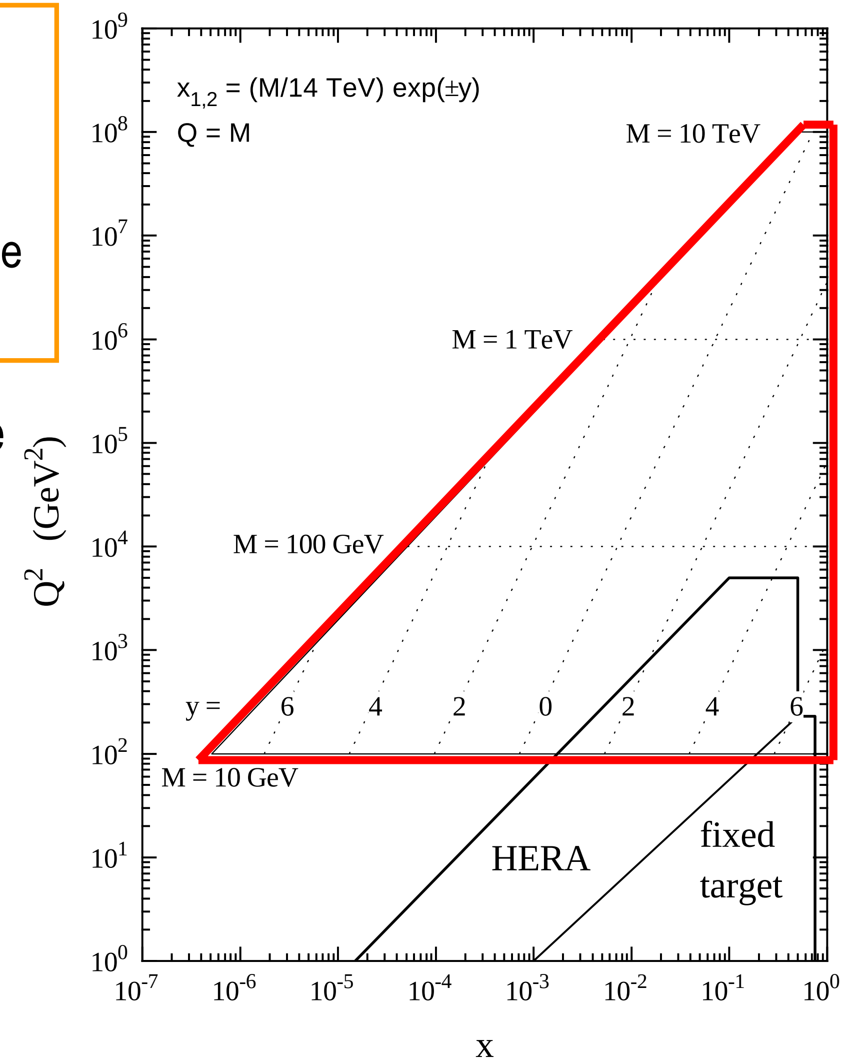
LHC Parton Kinematics

Jet energy scale: precision of 1% (W → jj; Z (*ll*) + jets)

Absolute luminosity: precision ≤ 5% (machine, optical theorem, rate of known processes)

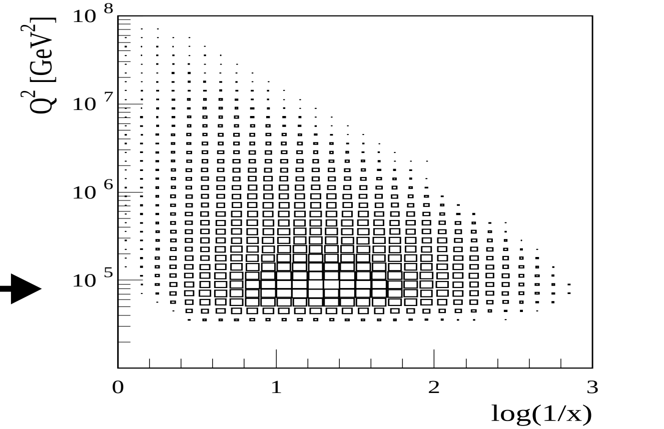
Most of the QCD related measurements are expected to be performed during the "low-luminosity" stage.

- Essentially all physics at LHC are connected to the interactions of quarks and gluons (small & large transferred momentum).
- **This requires a solid understanding of QCD**.
- Accurate measurements of SM cross sections at the LHC will further constrain the pdf's.
  - The kinematic acceptance of the LHC detectors allows a large range of **x** and **Q²** to be probed (LHC coverage: |y| < 5).



Jet physics

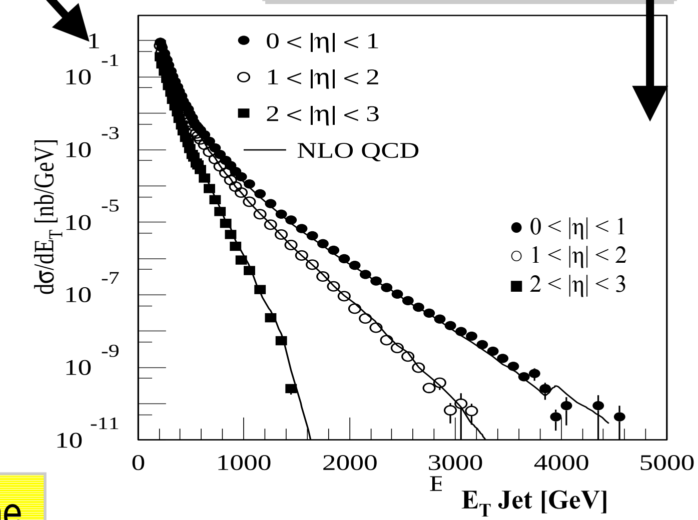
- Test of pQCD in an energy regime never probed!
- The measurement of di-jets and their properties (E_T and $\eta_{1,2}$) can be used to **constrain p.d.f.'s**.



- Inclusive jet cross section: $\boldsymbol{\alpha_S(M_Z)}$ measurement with **10% accuracy**.

$\mathcal{L}$ = 30 fb^{-1}

Jet E_T	N_{events}
> 1 TeV	4×10^5
> 2 TeV	3×10^3
> 3 TeV	40



- Multi-jet production is important for several physics studies:
  a) tt production with hadronic final states
  b) Higgs production in association with tt and bb
  c) Search for R-parity violating SUSY (8 – 12 jets).
- **Systematic errors**:
  - ➢ jet algorithm,
  - ➢ calorimeter response (jet energy scale),
  - ➢ jet trigger efficiency,
  - ➢ luminosity (dominant uncertainty 5% -10%),
  - ➢ the underlying event.

At the LHC the **statistical** uncertainties on the jet cross-section will be **small**.

Measuring parton luminosities and p.d.f.'s

$$N_{events}(pp \to X) = L_{p-p} \times pdf(x_1, x_2, Q^2) \times \sigma_{theory}(q, \bar{q}, g \to X)$$

Uncertainties in **p-p luminosity (±5%)** and **p.d.f.'s (±5%)** will limit measurement uncertainties to ±5% (at best).

- For **high Q^2** processes LHC should be considered as a **parton-parton collider** instead of a p-p collider.
  - Using only **relative cross section measurements, might lead eventually to accuracies of ±1%**.

$q\bar{q}$ (u,d) (high-mass DY lepton pairs and other processes dominated by $q\bar{q}$)	**W± and Z** leptonic decays	▪ precise measurements of mass and couplings; ▪ huge cross-sections (~nb); ▪ small background. ▪ x-range: 0.0003 – 0.1 ▪ ± 1%
g (high-Q^2 reactions involving gluons)	**γ-jet**, Z-jet, W±-jet	▪ γ-jet studies: γ p_T > 40 GeV ▪ x-range: 0.0005 – 0.2 ▪ γ-jet events: γ p_T ~ 10-20 GeV ▪ low-x: ~ 0.0001 ▪ ±1%
s, c, b	**γc, γb, sg→Wc**	▪ quark flavour tagged γ-jet final states; ▪ use inclusive high-p_T μ and b-jet identification (lifetime tagging) for c and b; ▪ use μ to tag c-jets; ▪ 5-10% uncertainty for x-range: 0.0005 – 0.2

Direct photon production

Understanding photon production:

- Higgs signals **($H \to \gamma\gamma$)** & background;
- direct photon production: constraints on parton distribution (e.g., gluon density inside the proton)
- Soft gluon emission effects can be studied in direct $\gamma\gamma$ production

Production mechanism:

$$qg \to \gamma q$$

$$q\bar{q} \to \gamma g$$

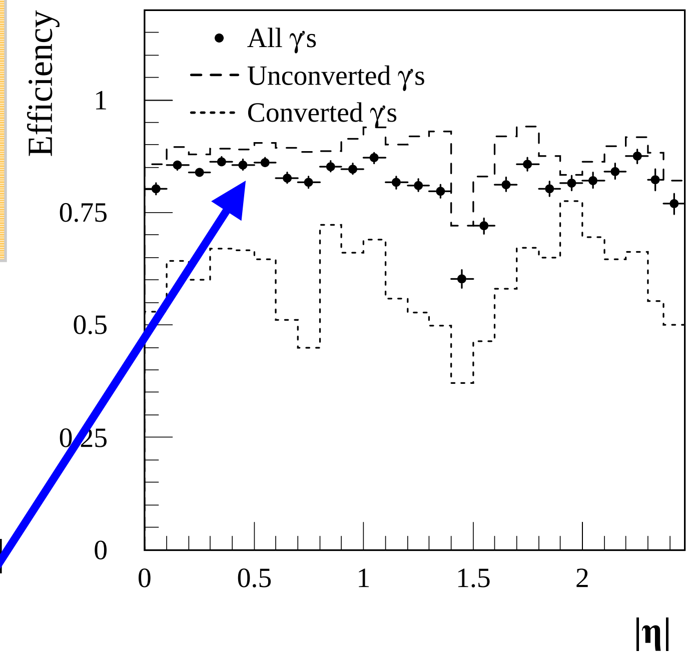
$$gg/q\bar{q} \to \gamma\,\gamma$$

Background: mainly related to jet fragmentation into a leading π^0 or η

Isolation cut: reduces background from fragmentation (π^0)
(cone isolation)

ATLAS: high granularity calorimeters ($|\eta| < 3.2$) allow good background rejection.

Low luminosity run: the photon efficiency is more than **80%** (jet rejection > 1000.



Determination of α_S: scale dependence

- Verification of the running of α_S : check of QCD at the **smallest distance scales yet uncovered (but difficult task as running slows down at large scales)**:
  - α_S= 0.118 at 100 GeV
  - α_S~ 0.082 at 4 TeV

- However, measurements of $\boldsymbol{\alpha_S(M_Z)}$ will not be able to compete with precision measurements from e^+e^- and DIS (gluon distribution).

- Differential cross-section for inclusive jet production (NLO)

$$\frac{d\sigma}{dE_T} \sim \alpha_S^{\,2}(\mu_R)A(E_T) + \alpha_S^{\,3}(\mu_R)B(E_T)$$

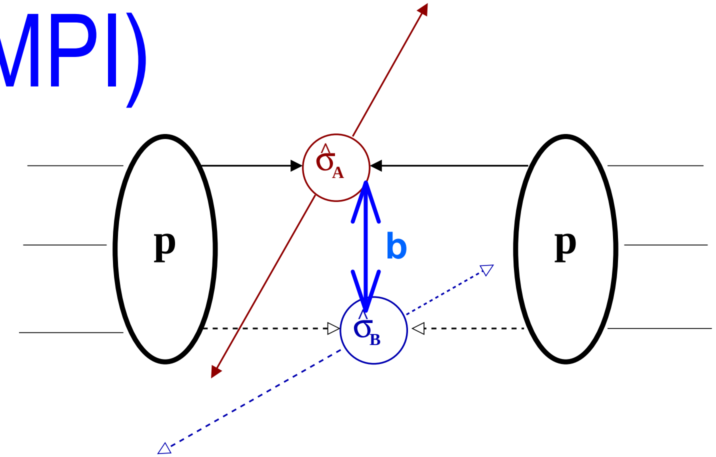
- A and B are calculated at NLO with input p.d.f.'s.

- **Systematic uncertainties**:
  - **p.d.f. set (±3%),**
  - **parametrization of A and B,**
  - **renormalization and factorization scale (±7%).**

- Fitting this expression to the measured inclusive cross-section gives for each E_T bin a value of $\alpha_S(E_T)$ which should show the running of the coupling constant

Multiple parton interactions (MPI)

Given the large parton density and the small longitudinal momenta in the proton, the possibility exist for 2 or more hard interactions in the same collision!



- AFS, UA2 and more recently CDF, have measured **double parton** interactions.

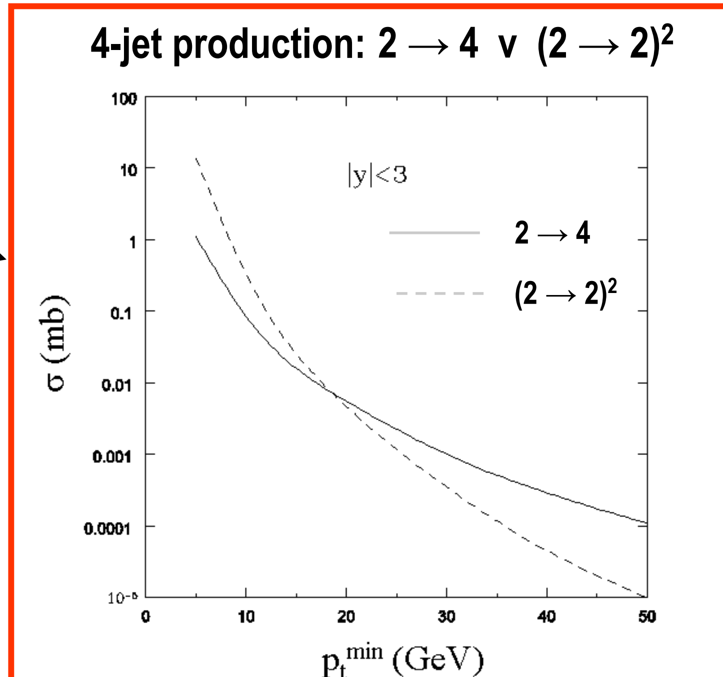
$$\sigma_D = m\frac{\sigma_A \sigma_B}{2\sigma_{eff}}$$

$\sigma_{eff} = 14.5 \pm 1.7$ mb

σ_{eff} contains information about the spatial distribution of partons in the proton; it is energy and cut-off independent.

- σ_D decreases as $\mathbf{p_T} \rightarrow \infty$ and grows as $\mathbf{p_T} \rightarrow \mathbf{0}$.

- σ_D increases faster with **s** as compared to σ_S.



- **Source of background**:
  - **WH+X→ (lν) bb+X,**
  - **Zbb→ (lν) bb+X,**
  - **W + jets, Wb + jets and Wbb + jets,**
  - **tt → llbb,**
  - **final states with many jets p_T^{min} ~ 20 – 30 GeV.**

Challenge at the LHC:
Selection of events
With mini-jets

Minimum-bias and the underlying event

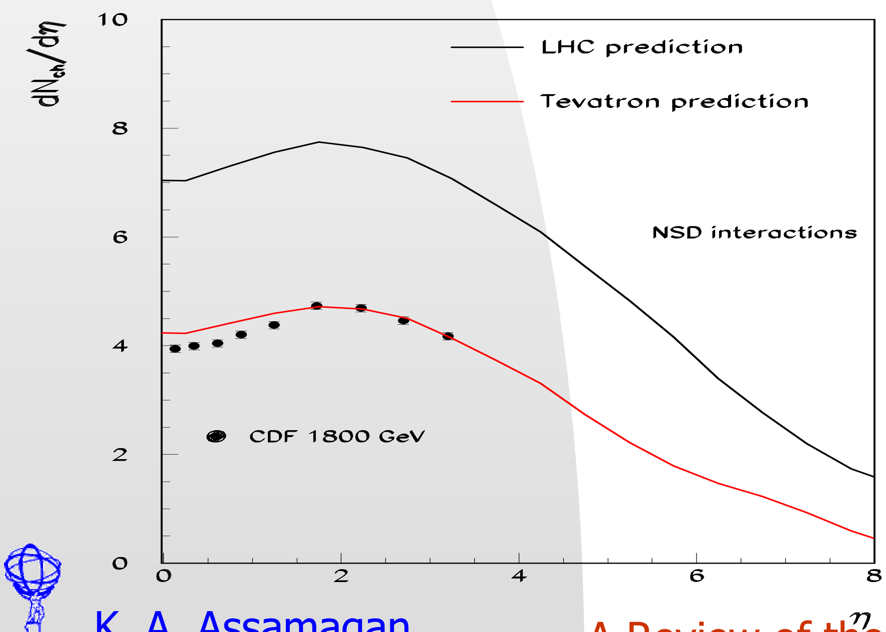
Minimum bias events

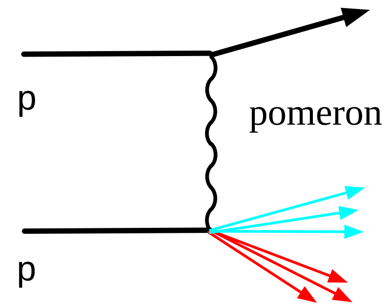
Experimental definition: depends on the experiment **trigger**! "Minimum bias" is usually associated to **non-diffractive events** (NSD), e.g. ISR, UA5, E735, CDF.

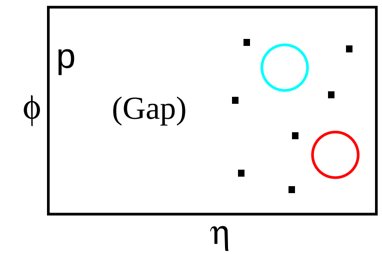
$$\sigma_{tot} = \sigma_{elas} + \sigma_{s.dif} + \sigma_{d.dif} + \sigma_{n.dif}$$

$\sigma_{tot} \sim$ **102 - 118 mb**
(PYTHIA) (PHOJET)

$\sigma_{n.dif} \sim$ **55 - 65mb**
(PYTHIA) (PHOJET)







Single diffraction process

Underlying events

It is not only minimum bias event!

In a hard scattering process, the underlying event has a **hard component** (initial + final-state radiation and particles from the outgoing hard scattered partons) and a **soft component** (beam-beam remnants).

A detailed knowledge of the structure of minimum bias and underlying events is required to understand their contributions the measured quantities from the hard scattering events of interest

Electroweak Physics at the LHC

- **W mass** measurement
- Improvements in the measurements of the mass of the top quark (**m_t**).
- A_{FB} asymmetry in dilepton production: **$\sin^2\theta_{eff}^{lept}(M_Z^2)$**.
- EW single top quark production: direct measurement of **V_{tb}**.
- Triple gauge boson couplings (TGC).

W mass measurement

- W mass is one of the fundamental parameters of the SM (α_{QED}, G_F, $\sin\theta_W$)

$$M_W = \sqrt{\frac{\pi\alpha}{G_F\sqrt{2}}}\frac{1}{\sin\theta_W(1-\Delta R)}$$

M_W = **80.446 ± 0.040 GeV** (LEP2 – PDG)

- Precise measurements will constrain the mass of the SM Higgs or the h boson of the MSSM;

- At the time of the LHC start-up the W mass will be known with a precision of about **30 MeV** (LEP2 + Tevatron)

  - Equal weights in a χ^2 test: $\Delta M_W \approx 0.7\times10^{-2}\,\Delta m_t$

At the LHC Δm_t ~ 2 GeV ⇒ M_W should be known with a precision of about **15 MeV** (combining e/μ and CMS data).

- **constrains M_H to ~25% .**

W mass measurement

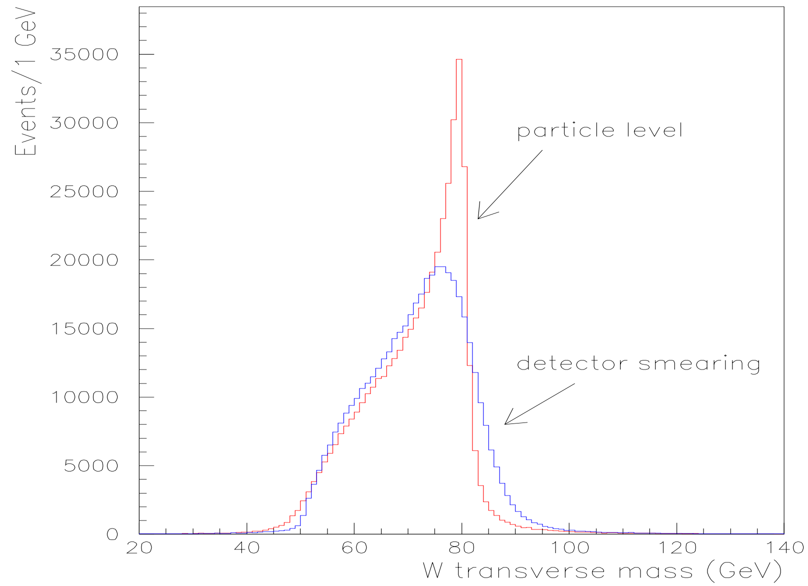
Sources of uncertainty:

• **Statistical uncertainty**: **< 2 MeV** for $\mathcal{L} \approx 10$ fb^{-1}

$$pp \rightarrow W + X$$
$$W \rightarrow l\nu_l$$

σ = 30 nb (l=e,μ)

3x10^8 events ($\mathcal{L} \approx 10$ fb^{-1})



➢ **Detector resolution + pile-up** will smear significantly the transverse mass distribution.
(method limited to the low-luminosity phase!)

• **Systematic error**

a) physics: W p_t spectrum, structure functions, W width, radiative decays and background.

b) detector performance: lepton scale, energy/ momentum resolution and response to recoil.

• Lepton energy and momentum scale:
~0.1% at Tevatron
~0.02% at LHC – ATLAS (tuned to $Z \rightarrow l^+l^-$, l=e, μ)

• p.d.f.'s & radiative corrections: improve theoretical calculations!

Other methods to measure m_W:
- Jacobian peak at $p_T^l \sim m_W$
- Ratio of p_T^W to p_T^Z

Measuring m_W to 20 MeV will be challenging

Top mass

SM dominant decay

$t\bar{t}$ leptonic decays ($t\to bW$)	
single lepton: $W\to l\nu$, $W\to jj$	29.6% (2.5 x 10^6 events)
di-lepton: $W\to l\nu$, $W\to l\nu$	4.9% (400,000 events)

$\mathcal{L} \approx 10\ fb^{-1}$

- Together with M_W, m_t helps to **constrain the SM Higgs mass.**

  m_t = 175.3 ± 4.4 GeV (global fit – PDG)

- $t\bar{t}$ production is expected to be the main background to new physics processes: production and decay of **Higgs bosons** and **SUSY particles**.
- Precision measurements in the top sector are important to get more clues on the origin of the fermion mass hierarchy.

- Top events will be used to **calibrate the calorimeter jet scale** ($W\to jj$ from $t\to bW$).

$\sigma_{NLO}(pp \to t\bar{t})$ = **833 pb** at LHC → **> 8x10^6 events** at ($\mathcal{L} \approx 10\ fb^{-1}$)

$gg \to t\bar{t}$ (~ 90%)   (~7 pb at Tevatron)

$q\bar{q} \to t\bar{t}$ (~ 10%)

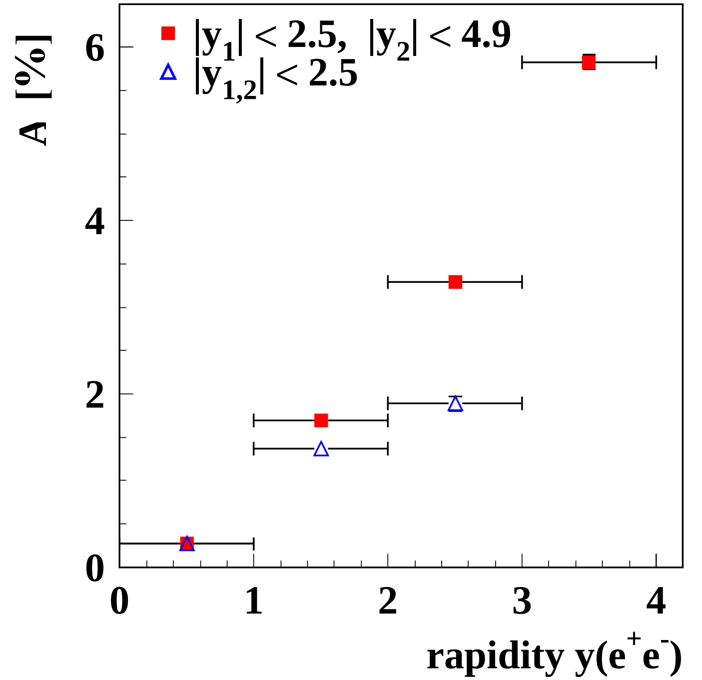
Best channel for **m_t measurement** will be $t\bar{t}\to WWb\bar{b}\to(l\nu)(jj)b\bar{b}$ ($m_t = m_{jjb}$)

Δm_t ~ 2 GeV

Δm_t at LHC will be dominated by systematic errors!

- Jet energy scale:
  ~3% at Tevatron
  ~1% at LHC – ATLAS (including $W\to jj$ from $t\to bW$)
- Final state gluon radiation (~1%)

Determination of $\sin^2\theta_{eff}^{lept}(M_Z^2)$



- $\sin^2\theta_{eff}^{lept}$ is one of the **fundamental parameters of the SM!**
- precise determination will **constrain the Higgs mass** and check **consistency of the SM**.
- $\sin^2\theta_{eff}^{lept}$ will be determined at the LHC by measuring **A_{FB} in dilepton production** near the Z pole: $Z \rightarrow l^+l^-$.

$$A_{FB} = b\,\{\,a - \sin^2\theta_{eff}^{lept}(\,M_Z^2\,)\,\}$$

a and **b** calculated to **NLO** in QED and QCD.

$\sigma\,(\,Z \rightarrow l^+l^-\,) \sim 1.5$ nb (for either e or μ)

y cuts – e^+e^- ($\lvert y(Z) \rvert > 1$)	ΔA_{FB} (statistical)	$\Delta\sin^2\theta_{eff}^{lept}$ (statistical)
$\lvert y(l_{1,2}) \rvert < 2.5$	3.03×10^{-4}	4.0×10^{-4}
$\lvert y(l_1) \rvert < 2.5$; $\lvert y(l_2) \rvert < 4.9$	2.29×10^{-4}	1.41×10^{-4}

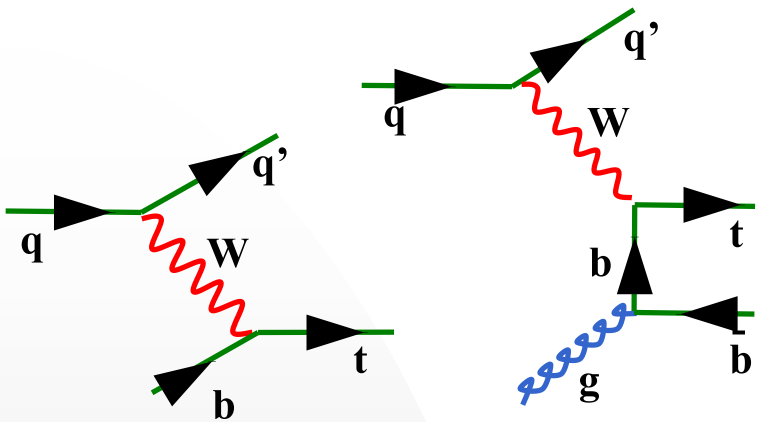
$\mathcal{L} = 100\ \text{fb}^{-1}$

- Main systematic effect: **uncertainty on the p.d.f.'s**, lepton acceptance (~0.1%), radiative correction calculations.

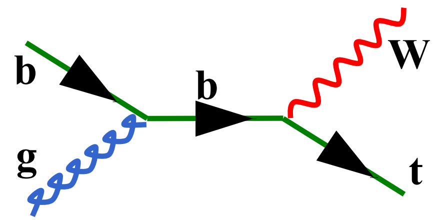
$\sin^2\theta_{eff}^{lept}(\,M_Z^2\,) = 0.23126 \pm 1.7 \times 10^{-4}$ (global fit PDG)

Can be further improved:
combine channels/experiments.

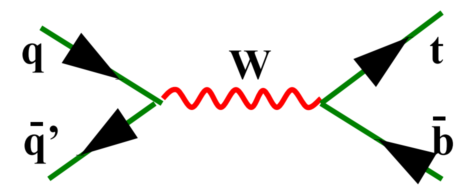
EW single top quark production (not yet observed!)



W-gluon fusion
$\sigma_{Wg} \sim 250$ pb



Wt process
$\sigma_{Wt} \sim 60$ pb



W* process
$\sigma_{W^*} \sim 10$ pb
(lower theoretical uncertainties!)

for each process: $\sigma \propto |V_{tb}|^2$

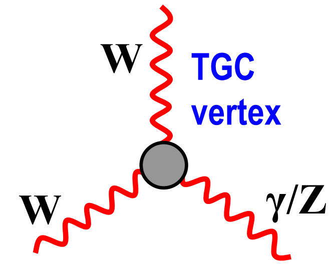
- Probe the **t-W-b vertex**
- **Direct measurement** (only) of the CKM matrix element V_{tb} at ATLAS
- **New physics**: heavy vector boson W'
- Source of **high polarized tops!**
- Background: **$t\bar{t}$, $Wb\bar{b}$, Wjj**

Process	S/B	S/√B	$\Delta V_{tb}/V_{tb}$ – statistical	$\Delta V_{tb}/V_{tb}$ – theory
W-gluon	4.9	239	0.51%	7.5%
Wt	0.24	25	2.2%	9.5%
*W**	0.55	22	2.8%	3.8%

$\mathcal{L} = 30$ fb^{-1}

Systematic errors: b-jet tagging, luminosity ($\Delta\mathcal{L} \sim 5 - 10\%$), **theoretical (dominate V_{tb} measurements!).**

Triple gauge boson couplings



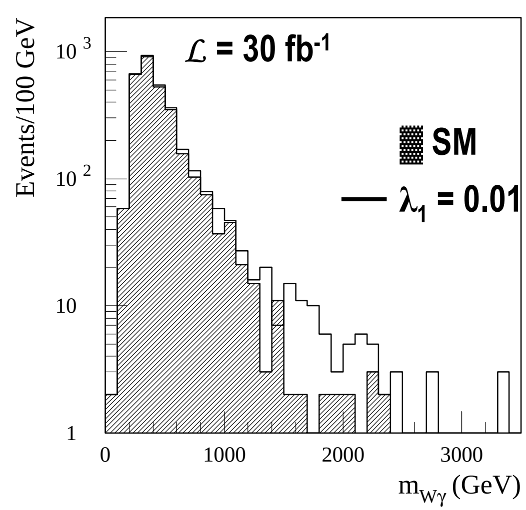
- TGC of the type **WWγ** or **WWZ** provides a direct test of the non-Abelian structure of the SM (EW symmetry breaking).

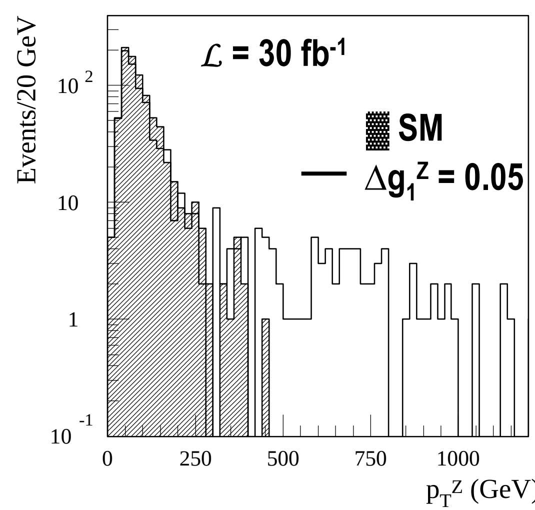
- It may also indicate hints of **new physics**: new processes are expected to give anomalous contributions to the TGC.

- New physics could show up as deviations of these parameters from their SM values.

- This sector of the SM is often described by 5 parameters: g_1^Z, κ_γ, κ_Z, λ_γ and λ_γ, (SM values are equal to $g_1^Z = \kappa_\gamma = \kappa_Z = 1$ and $\lambda_\gamma = \lambda_\gamma = 0$, at the tree level).

Gauge, C and P invariance





- Anomalous contribution to TGC is **enhanced at high** $\sqrt{s}$ (increase of production cross-section).

• Variables:

Wγ: ($m_{W\gamma}$, $|\eta_\gamma^*|$) and (p_T^γ, θ^*)

WZ: (m_{WZ} , $|\eta_Z^*|$) and (p_T^Z, θ^*)

sensitive to **high-energy behaviour:** m_{WV}, p_T^V

sensitive to **angular information:** $|\eta_V^*|$, θ^*

Parameters	Statistical (at 95% C.L.)	Systematic (at 95% C.L.)
Δg_1^Z	- 0.0064 + 0.010	±0.0058
$\Delta\kappa_Z$	- 0.10 + 0.12	±0.024
λ_Z	- 0.0065 + 0.0066	- 0.0032 + 0.0031
$\Delta\kappa_\gamma$	- 0.073 + 0.076	- 0.015 + 0.0076
λ_γ	±0.0033	±0.0012

$\mathcal{L}$ = 30 fb^{-1}

Using max-Likelihood fit to distributions of variables

• SM: vanishing helicity at low $|\eta|$
Non-standard TGC: partially eliminates `zero radiation'

Systematic uncertainties:

• At the LHC, sensitivity to TGC is a combination of the very high energy and high luminosity.

• Uncertainties arising from low p_T background will be quite small: anomalous TGC signature will be found at high p_T.

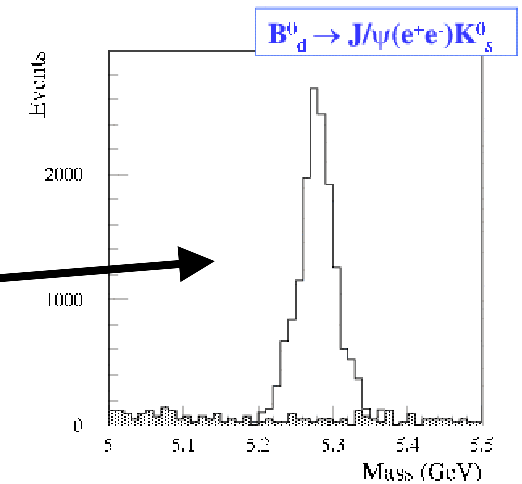
• Theoretical uncertainties: p.d.f.'s & higher order corrections

CP violation in B-system

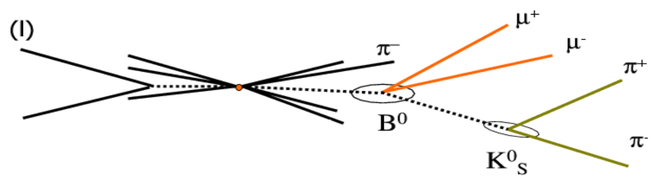
SM prediction of CP-violation A(t) in $B^0_d \to J/\psi K_s^0$:

$$A(t) = \sin 2\beta \sin(\Delta m_d t)$$

$B^0_d \to J/\psi\,(\to l^+l^-)\, K_s(\to \pi^+\pi^-)$



- CP violations studies need determination of B flavor at creation time; in ATLAS used:
  - opposite side lepton
  - same side jet
  - B-π correlation



σ_m = 22 MeV
σ_R = 64 μm

- Most effective flavor tag performance:
  - $J/\psi \to e^+e^-$ (lepton tag):
    100% efficiency relative to triggered event, 22% mistag probability
  - $J/\psi \to \mu^+\mu^-$ (B–π tag):
    82% efficiency relative to triggered event, 42% mistag probability
- For asymmetry studies after 1 year of low luminosity (10 fb-1):

	$J/\psi\to\mu^+\mu^-$	$J/\psi\to e^+e^-$
$N(B^0\to J/\psi K^0_s)$	160 000 S/B ~ 30	4 800 S/B ~ 15
δ(sin2β)	0.022	0.031

Uncertainty will be dominated statistics. Systematics from false asymmetries will be measured using channels with 0 CP-asymmetry:

$B^+ \to J/\psi\, K^+$

Combined δ(sin2β) at 10 fb^{-1} 0.017 (statistical) : comparable to LHCb

B_s^0- $\bar{B}_s^0$ Oscillation & Rare Decays

- $B^0_S \to D^-_S\pi^+/a^+_1$ with $D^-_S \to \phi\ (\to KK)\ \pi^-$ **can be used to measure the B^0_S mixing oscillation frequency Δm_s**
- trigger + flavor tag with other side μ at $p_T > 6$ GeV
- proper time resolution: $\sigma_1 = 52$ fs (60%), $\sigma_2 \sim 100$ fs (40%)

Δm_s reach ⇨ **22.5 ps^{-1} (> 5 σ discovery limit)**
(95% Confidence Exclusion Limit up to 36.0 ps^{-1})

- Allowed range from Standard Model fit is covered.

.. and rare decays

⇒ **$B^0_s \to \mu^+\mu^-$ X (BR SM ~ 4×10^{-9})** , **$B^0_d \to \mu^+\mu^-$ X (BR SM ~ 1×10^{-10})**
(Tevatron experimental limit < 10^{-6})

⇒ tiny SM branching ratios: ideal place to search for new physics at LHC

⇒ self-triggering: can be looked for at high luminosity as well

⇒ reconstruction uses vertex and isolation

$BR(B^0_s \to \mu^+\mu^-\rho^0)$ / $BR(B^0_s \to \mu^+\mu^-K^{0*}) = k_d\,|V_{td}/V_{ts}|^2$
could be determined to 15% after 30 fb^{-1}

FCNC in the top sector

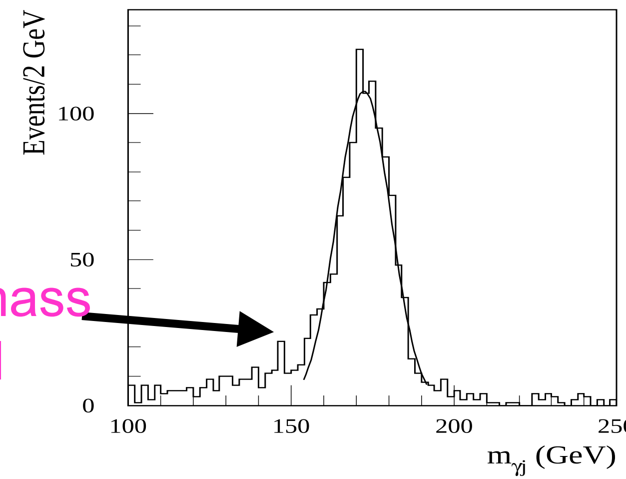
- FCNC decay of top-quark in SM highly suppressed $\Rightarrow$ any observation of FCNC top decay would be an indication of new physics

FCNC Decay	BR in SM	BR in MSSM
$t \to Zq$	$\approx 10^{-12}$	$\approx 10^{-8}$
$t \to \gamma q$	$\approx 10^{-12}$	$\approx 10^{-6}$
$t \to gq$	$\approx 10^{-10}$	$\approx 10^{-6}$

- Enhancements in MSSM still to small to be observable
- Other models predict BR ~ 10^{-3} – 10^{-2} while satisfying stringent bound bounds on light quark FCNC decays

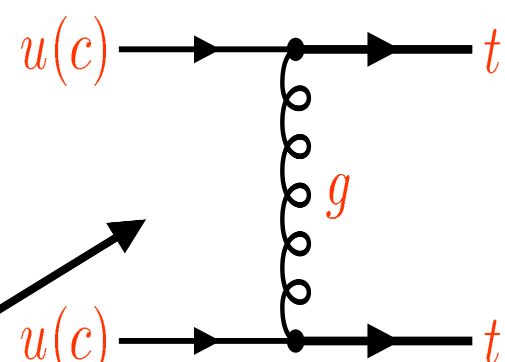
FCNC in the top Sector

- tt-bar $\rightarrow$ (Wb)(Zq) : W $\rightarrow$ lν or W $\rightarrow$ jj
  backgrounds: Z+jets, WZ, QCD
  BR limits (5σ, 100 fb^{-1}) : 2.3×10^{-4}
- tt-bar $\rightarrow$ (Wb)(γq) : q=u,c ; W $\rightarrow$ lν
  reconstruct t $\rightarrow$lνb, search for signal in $m_{\gamma q}$ distribution
  BR limit : 1×10^{-4}



γq invariant mass
For the signal

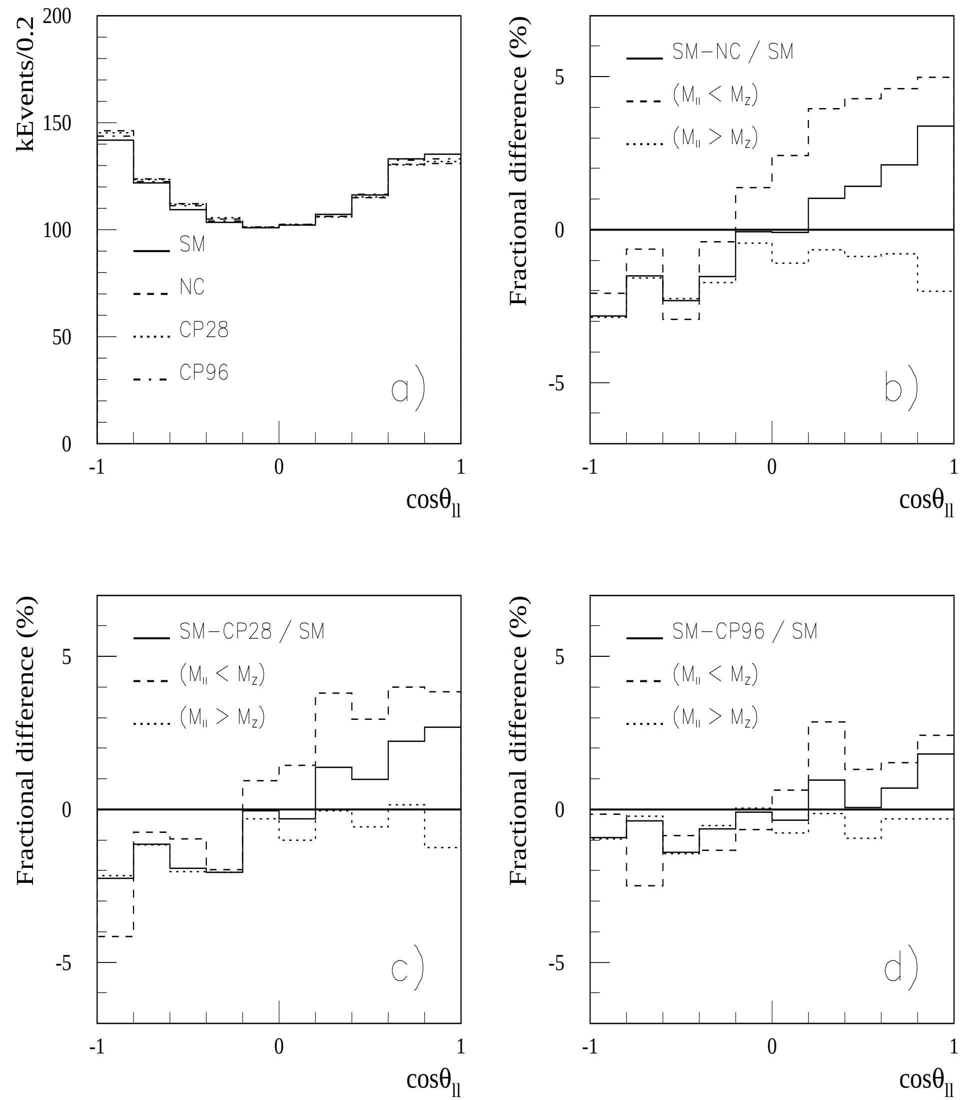
- t $\rightarrow$ gq overwhelmed by QCD bgds
  use sign-like top pair production:
  pp $\rightarrow$ttX [t-bar t-bar X]. Search for 2 isolated sign-like leptons
  BR limit: 7.4×10^{-4}



Sign-like tt production
Through FCNC tgq coupling

CP violation in the top sector

- The top-quark has a short life time compared to its hadronization time ⇒
  - Top would decay before hadronizing
  - Spin would be preserved in decays
- gg (qq-bar) → tt-bar unpolarized but t and t-bar are spin-correlated
- CP violation in top sector could alter spin correlations predicted by the SM
- Di-lepton opening angle in tt-bar → (lνb)(lνb) is one way to investigate spin correlation and is sensitive to CP violation



Further studies needed to fully explore sensitivity to CP violation

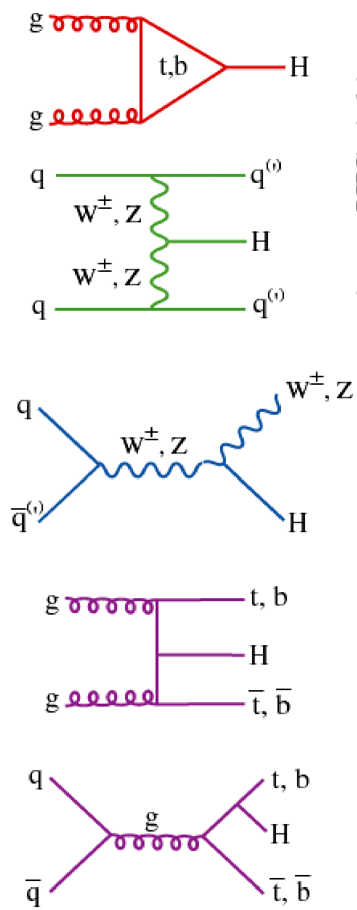
SM Higgs Production @ LHC

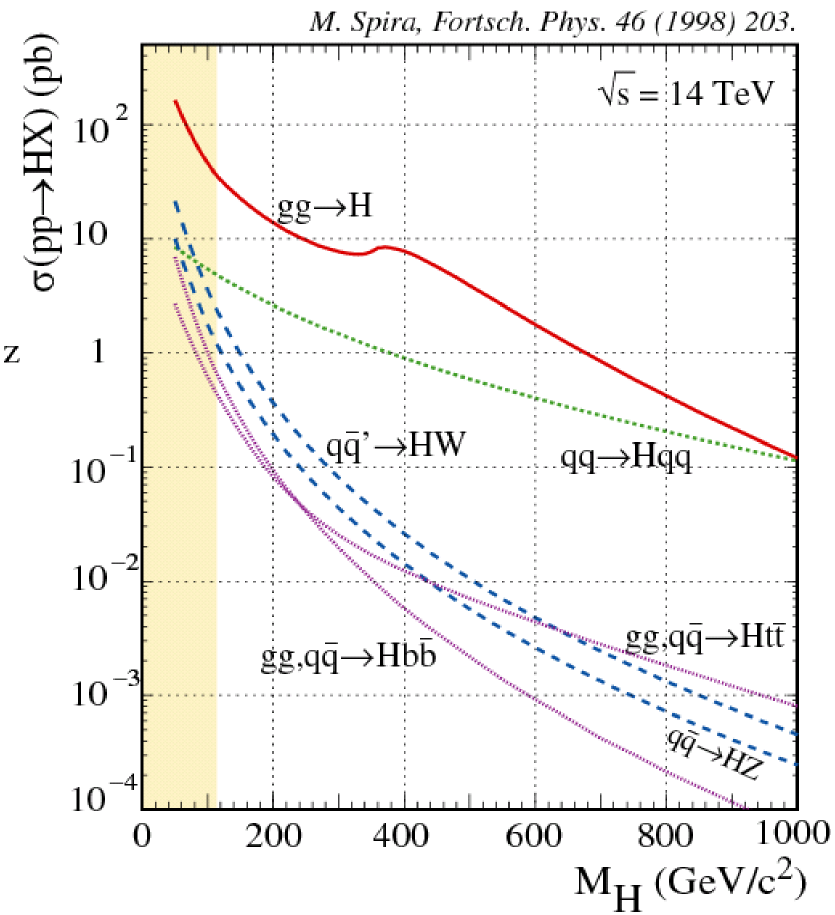
Gluon Fusion
- dominant process

Vector Boson Fusion
- 20% of gg @ 120GeV

Associated Production
- W or Z (1-10% of gg)

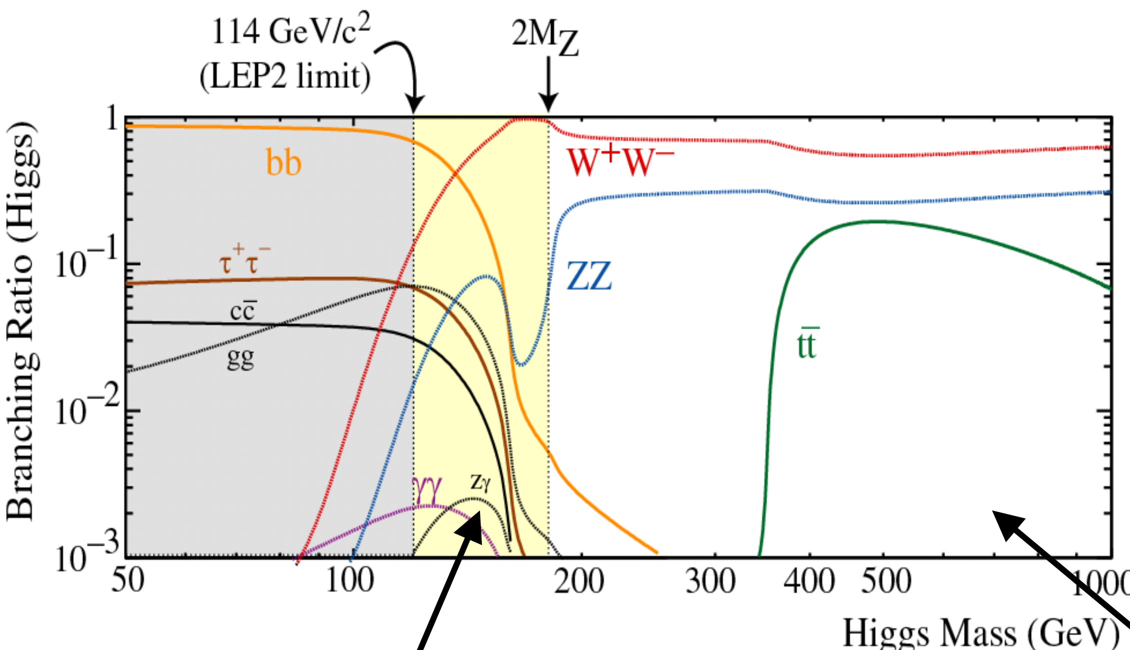
Associated Production
- $t\bar{t}$ or $b\bar{b}$ (1-5% of gg)





4 production mechanism ➡ key to measure H-boson parameters

Main Discovery Channels



Dominant BR for $m_H < 2m_Z$:
$\sigma(H \to b\bar{b}) \approx 20$ pb;
$\sigma(b\bar{b}) \approx 500\ \mu$b
for m(H) = 120 GeV
→ no hope to trigger or extract fully had. final states
→ look for final states with ℓ, γ (ℓ = e, μ)

Low mass region: m(H) < 2 m_Z :

- $H \to \gamma\gamma$: small BR, but best resolution
- $H \to bb$: good BR, poor resolution ➔ $t\bar{t}H$, WH
- $H \to \tau\tau$: via VBF
- $H \to ZZ^* \to 4\ell$
- $H \to WW^* \to \ell\nu\ell\nu$ or $\ell\nu jj$: via VBF

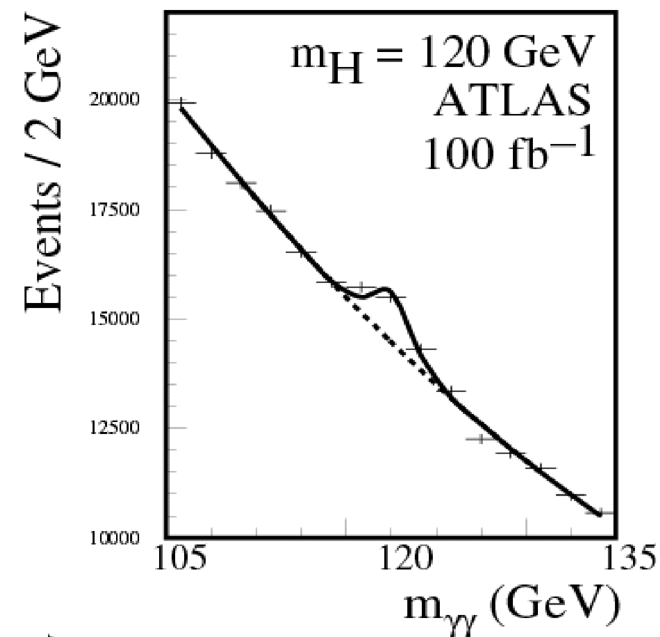
m(H) > 2 m_Z :

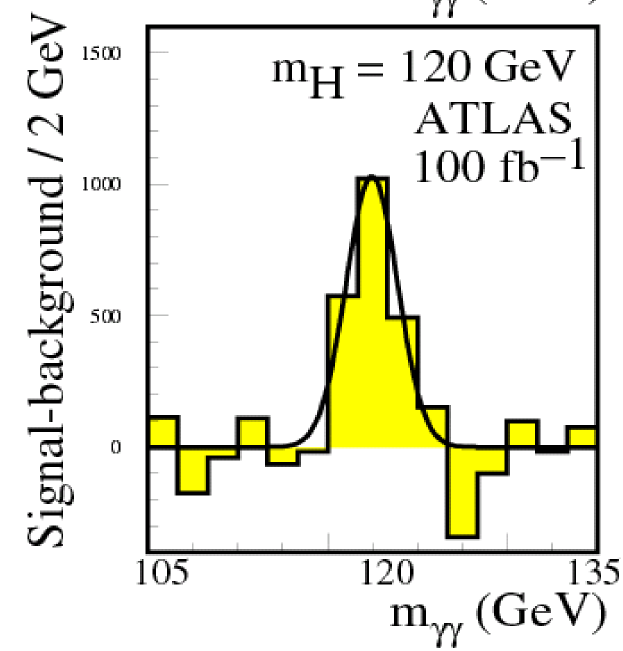
- $H \to ZZ \to 4\ell$
- $qqH \to ZZ \to \ell\ell\,\nu\nu$ *
- $qqH \to ZZ \to \ell\ell\,jj$ *
- $qqH \to WW \to \ell\nu jj$ *

* for m_H > 300 GeV forward jet tag

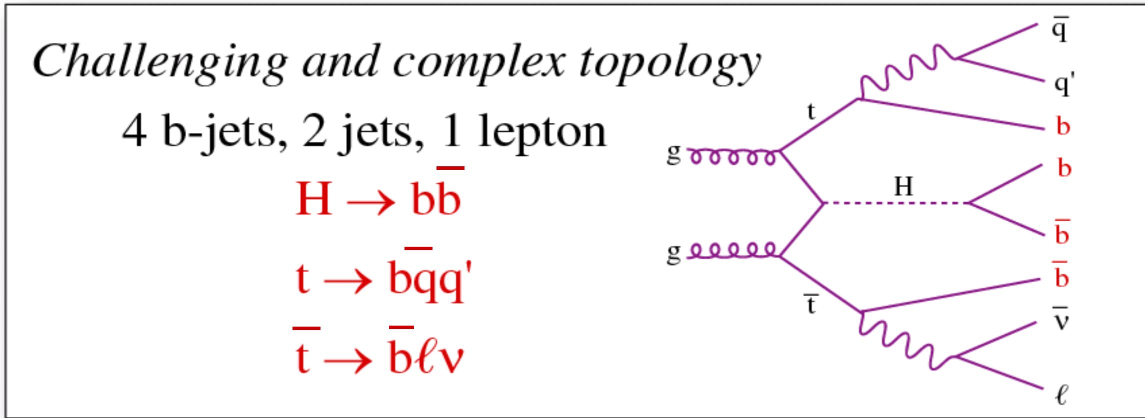
$H \rightarrow \gamma\gamma$

- Rare decay mode accessible for
  - $100 < m_H < 150$ GeV
- Places severe requirements on EM Calorimetry to achieve ≈1% resolution on m_H
- Production mechanisms:
  - Gluon Fusion
  - Associated production (WH, ZH, ttH)
- Background:
  - dominated by smooth continuum of $\gamma\gamma$ pairs
  - Excellent γ/jet separation needed to keep bkgd from γj and jj pairs with mis-identified γ's low
  - determine from sidebands and subtract
- Signal significance: 2.8 to 4.3σ for 100 fb^{-1}



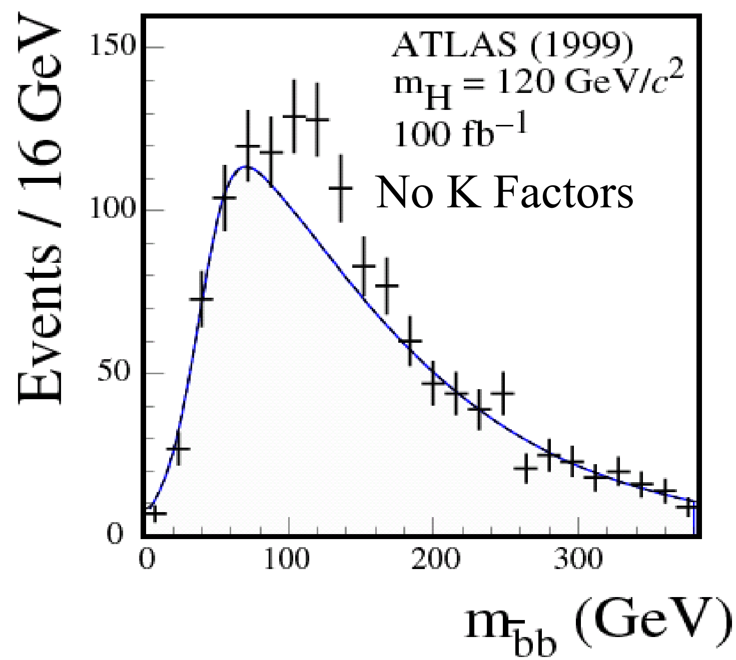


Light Higgs: ttH → ttbb



$\sigma \times BR \approx 300$ fb

- Complementary to $H \to \gamma\gamma$
- Fully reconstructed final state (except ν)
- Requires good b-tagging
  - $\varepsilon_b \approx 60\%$, $R_{uds} \approx 100\%$
- Backgrounds:
  - Combinatorial from signal
  - Irreducible ttbb (ttjb, ttjj)
- Signal significance (5σ) :
  - $m_H < 120$ GeV needs 100 fb^{-1}
  - $m_H < 130$ GeV needs 300 fb^{-1}



Light Higgs Search: VBF

Motivation

- Strong discovery potential for m_H < 150 GeV
- Determine Higgs parameters
- Also good for Invisible Higgs

Production

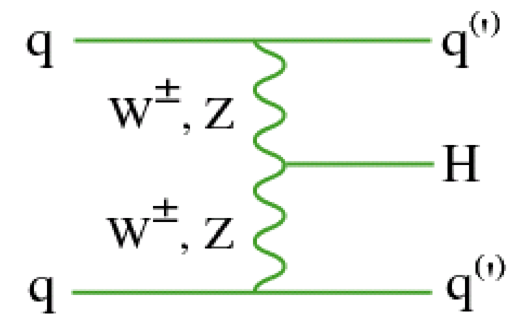
- σ = 4 pb = 20% of total σ (m_H = 120 GeV)

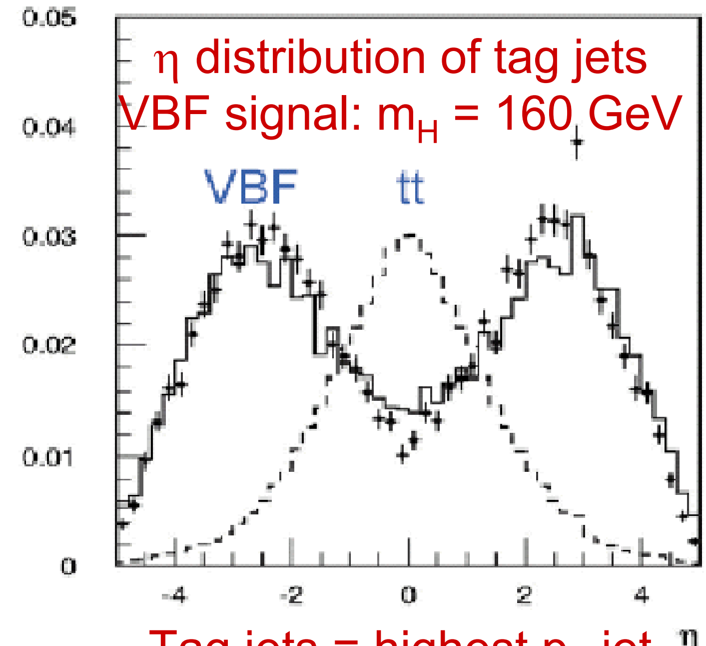
Decays

- $H \rightarrow WW^* \rightarrow \ell\nu\ell\nu,\ \ell\nu qq'$
- $H \rightarrow \tau\tau \rightarrow \ell\nu\nu\ell\nu\nu,\ \ell\nu\nu j$

Distinct Final States

- Fragmentation of q which emitted W,Z
  - ➔ Two high p_T jets with large $\Delta\eta$ (opposite hemispheres)
- Lack of colour exchange in initial state
  - ➔ Little jet activity in central region
  - ➔ central jet veto



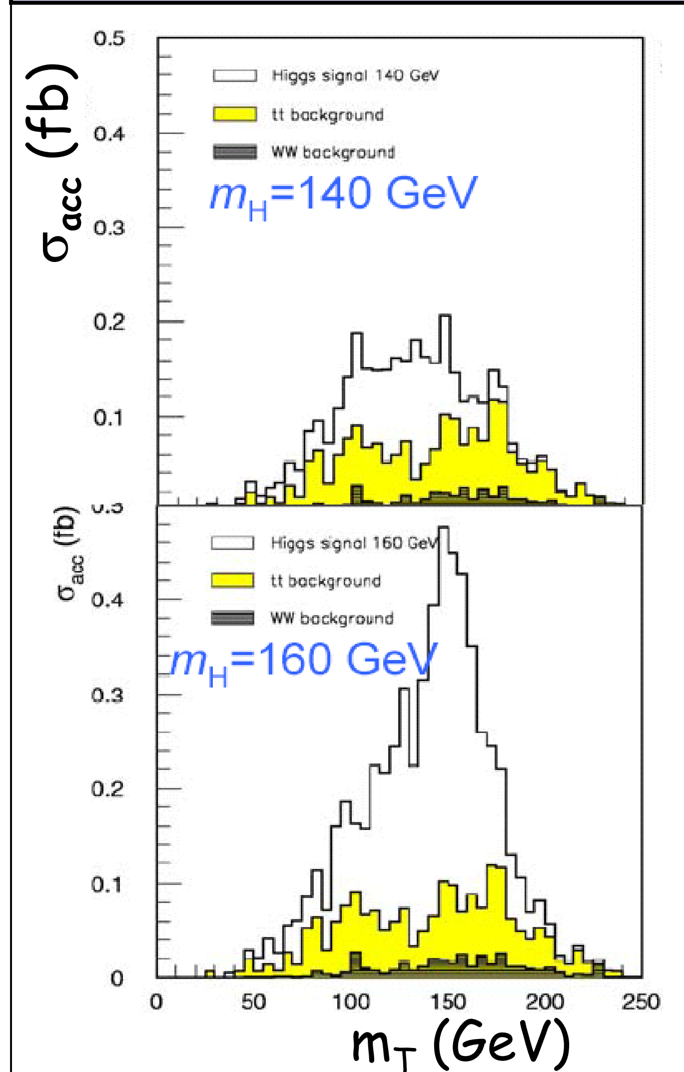


Tag jets = highest p_T jet in each η-hemisphere

VBF: $H \rightarrow WW^* \rightarrow \ell\nu\ell\nu$

- Two isolated leptons:
  - p_T> (20 GeV, 15 GeV)
- Two forward tag jets:
  - p_T > (40 GeV, 20 GeV); $\Delta\eta$>3.8
    (e ≈ 50% with fake ≈ 1% @ 10^{34})
- Central jet veto: p_T<20 GeV
- lepton angular correlations **(anti-correlation of W spins from H decay)**
  - $\delta\phi_{\ell\ell}$, $\cos\theta_{\ell\ell}$, $m_{\ell\ell}$

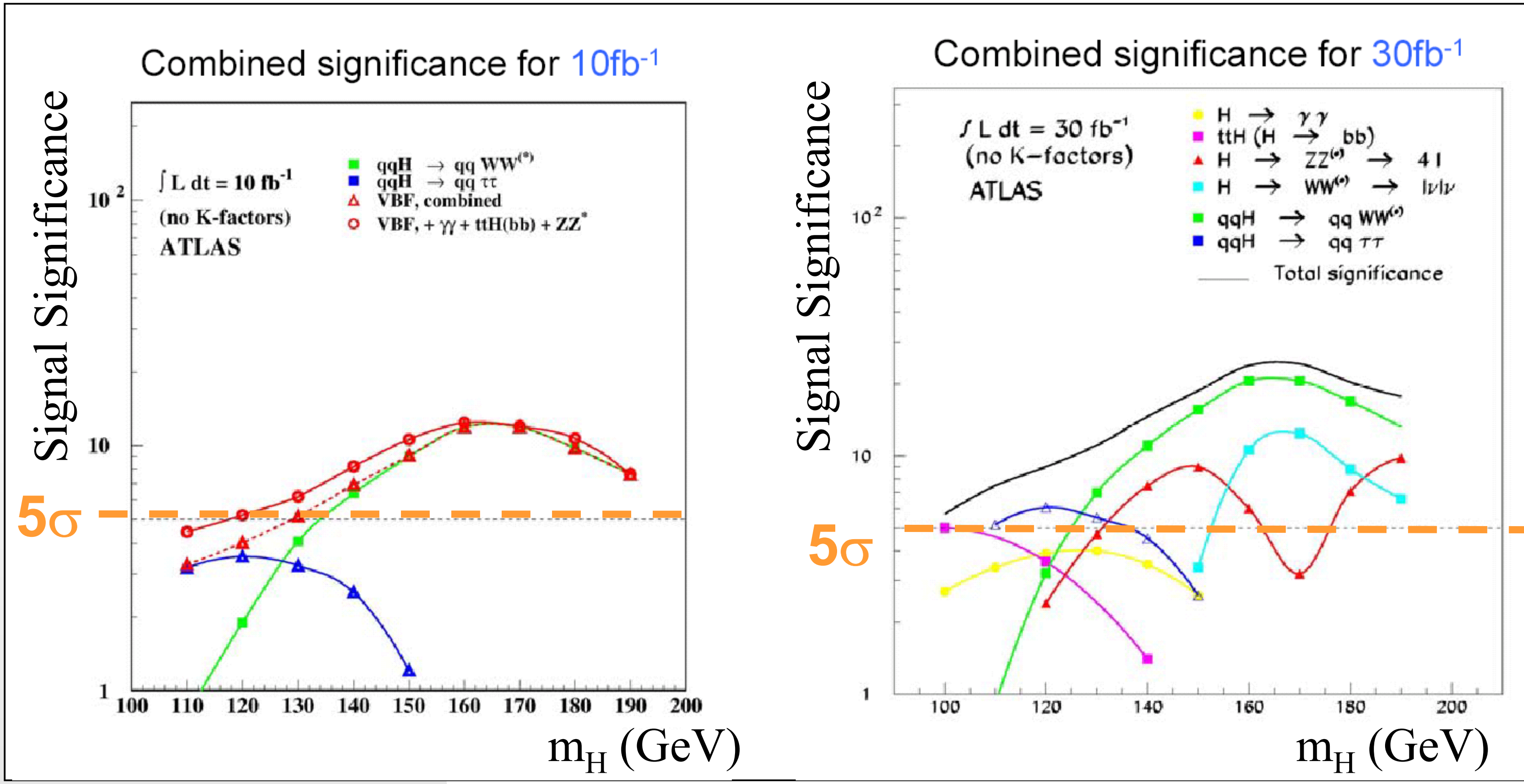
$$m_T = \sqrt{2 p_T^{\ell\ell} E_T^{miss}(1-\cos\phi)}$$



Results for 5 fb^{-1}, 5% background syst.

m_H (GeV)	130	150	170	190
Signal	5	13	22	14
Background	3	4	5	7
Significance	2.1	4.7	6.5	4.2

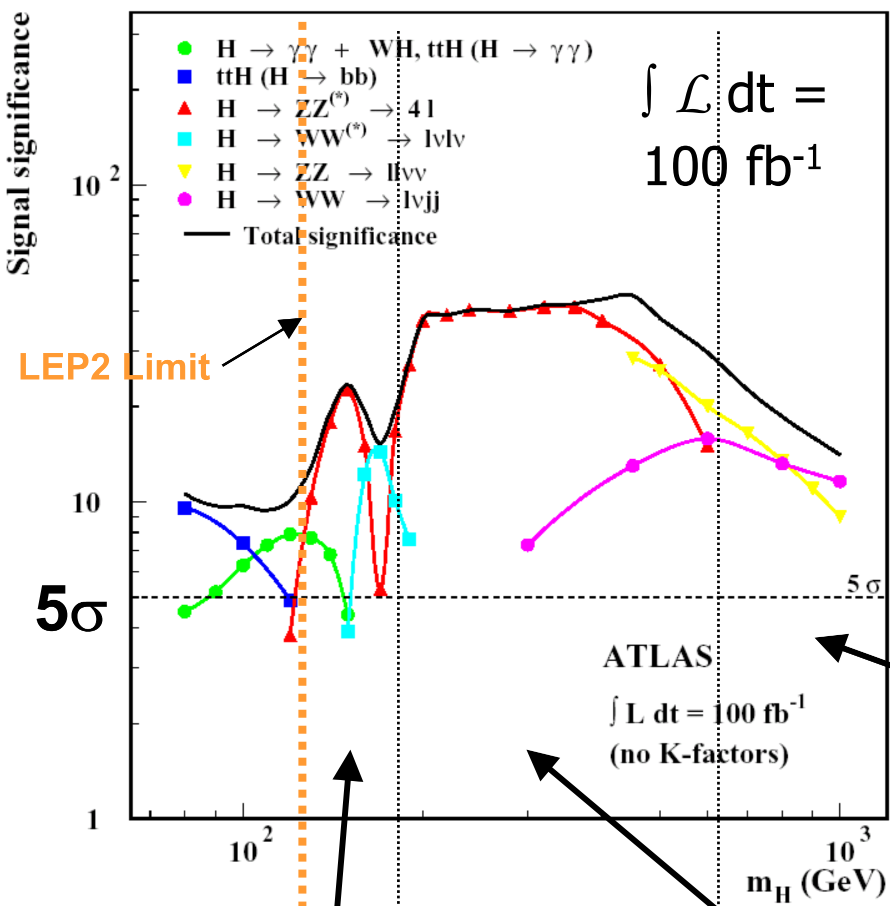
Discovery for $m_H < 2 \cdot m_Z$ for $\mathcal{L}$ = 10, 30 fb^{-1}



5σ significance for
120 < m_H < 190 GeV,
VBF channels will most likely be discovery channels

Several channels available over the full mass range

Overall Higgs Significance for $\mathcal{L}$ = 100 fb^{-1}



VBF channels at low mass not yet included in the plot! Low mass will improve!

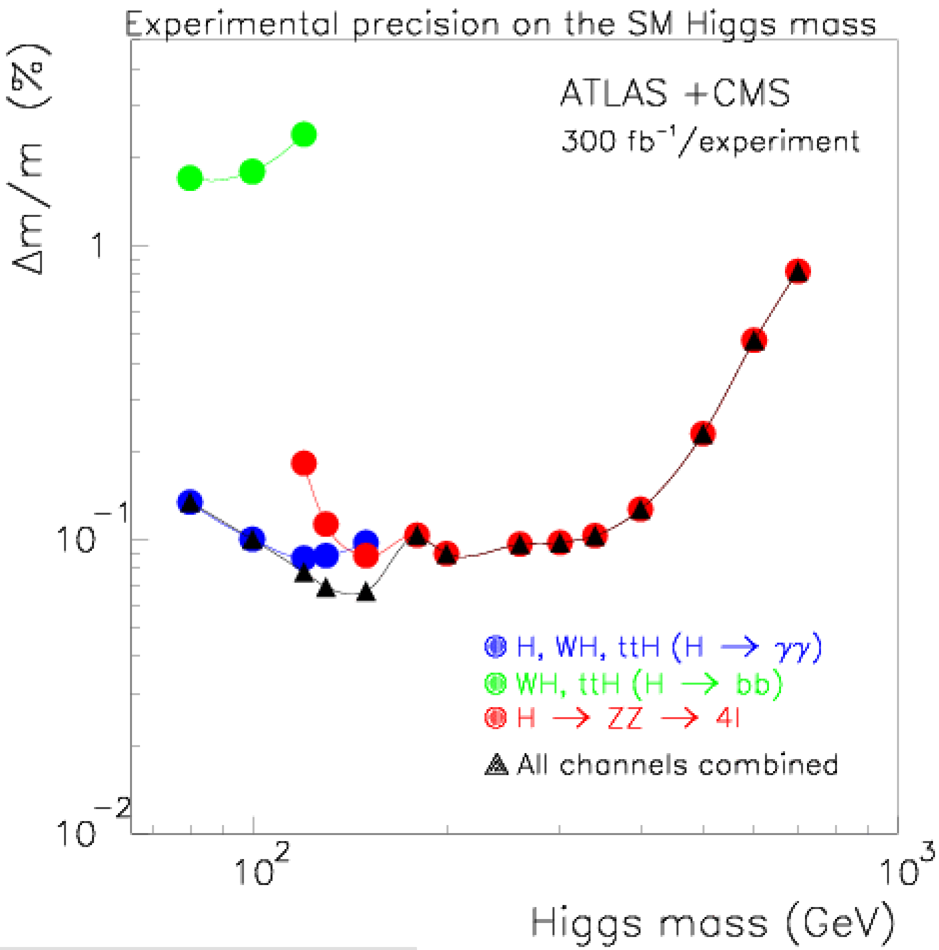
700 GeV < m_H < 1 TeV:
need $H \rightarrow ZZ \rightarrow \ell\ell\nu\nu, \ell\ell jj$
$H \rightarrow WW \rightarrow \ell\nu jj$

190 GeV < m_H < 700 GeV:
easy with $H \rightarrow ZZ \rightarrow 4\ell$

114 GeV < m_H < 190 GeV:
several complementary channels

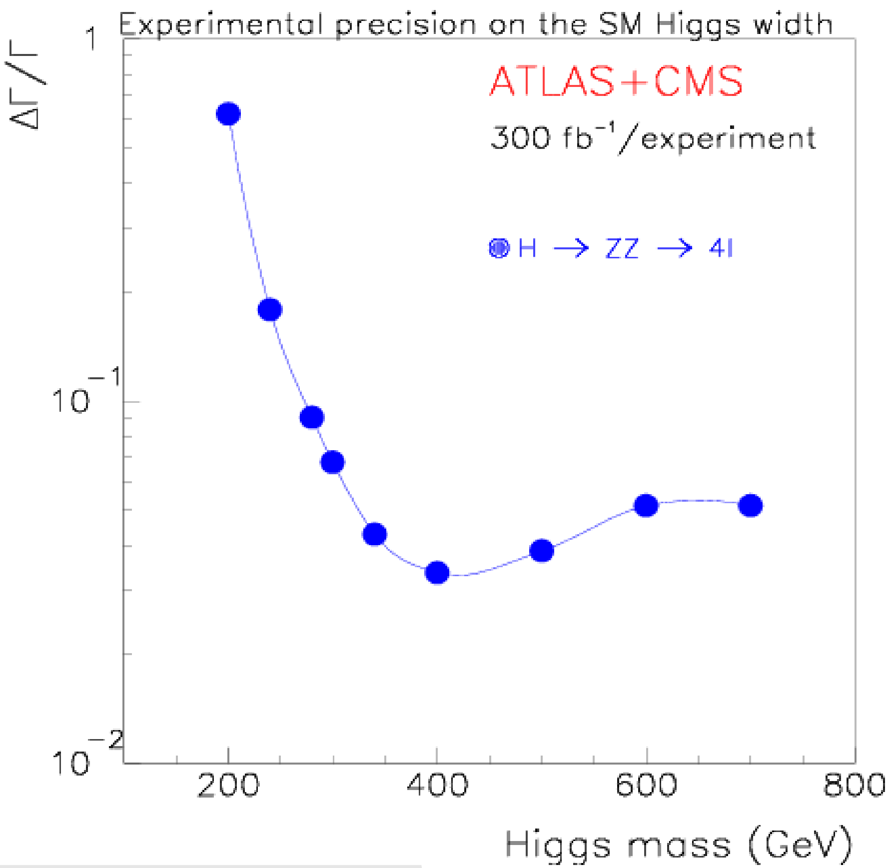
Precision Measurements of Higgs Mass

Standard Model Higgs



- No theoretical error included (e.g. mass shift for large Γ_H)
- Systematic uncertainties dominate
  → γ/lepton E scale (0.1% assumed, 0.02% goal)

Measurement of Higgs Width



Direct measurement: from width of reconstructed peak for

m_H > 200 GeV(Γ_H>$\Gamma_{detector}$ in SM)

- No theoretical error included

- Experimental systematics dominated by lepton energy resolution uncertainty ($\leq$ 1.5% from radiative $Z \rightarrow \ell\ell\gamma$ decays)

- Indirect measurement using cross section for $qq \rightarrow qq\ H \rightarrow qq\ \gamma\gamma, \tau\tau, WW$ (at lower m_H)
- MSSM higgs bosons: Γ too narrow for direct measurements

Higgs Couplings

Measurements of coupling ratios:

- Coupling to gauge bosons

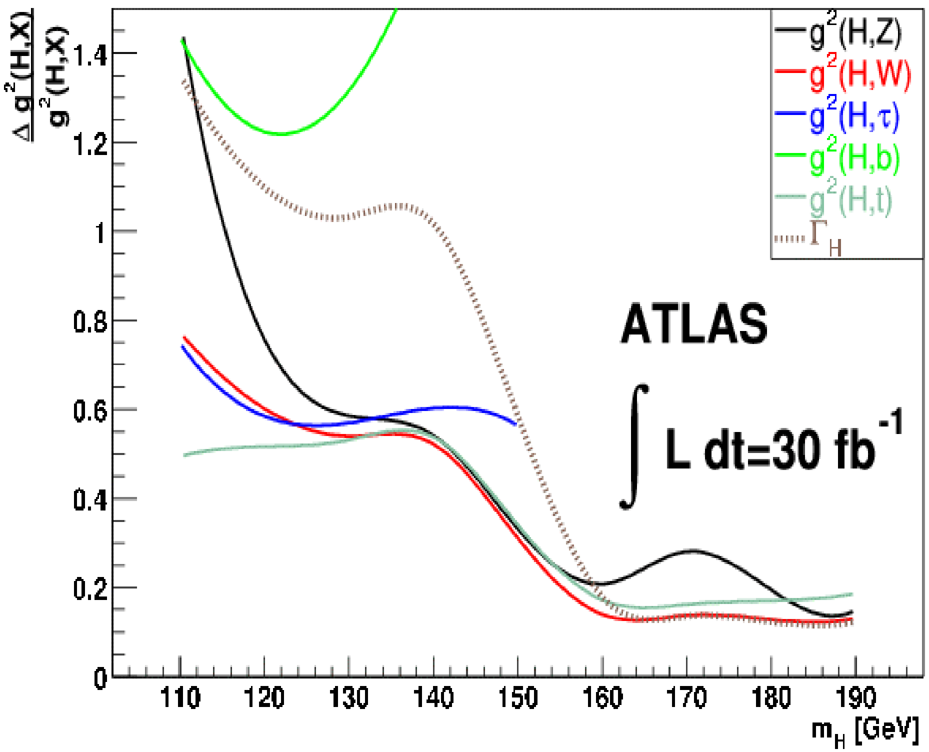
$$\frac{\sigma(ggH) \times BR(H\to WW^*)}{\sigma(ggH) \times BR(H\to ZZ^*)} = \frac{\Gamma_W}{\Gamma_Z}$$

$$\frac{\sigma(VBF) \times BR(H\to \gamma\gamma)}{\sigma(VBF) \times BR(H\to WW^*)} = \frac{\Gamma_\gamma}{\Gamma_W}$$

- Coupling to fermions

$$\frac{\sigma(ttH) \times BR(H\to \tau\tau)}{\sigma(ttH) \times BR(H\to WW^*)} = \frac{\Gamma_\tau}{\Gamma_W}$$

$$\frac{\sigma(WH) \times BR(H\to bb)}{\sigma(WH) \times BRH\to WW)} = \frac{\Gamma_b}{\Gamma_W}$$



New approach with information on all studies used simultaneously in a global fit; separate treatment of systematic uncertainties due to lepton and photon rec., b-jets and background renormalization.

Super Symmetry (SUSY)

The ability of ATLAS to study SUSY at the LHC has been investigated in the self-consistent Frameworks of:

- Super Gravity: SUGRA
  - SUSY is broken in a hidden sector: Gravity is the sole messenger
  - The Lightest Super Symmetric Particle (LSP) is $\tilde{\chi}^0_1$: stable, neutral, weakly interacting $\Rightarrow$ transverse missing energy
- Gauge Mediated Super Symmetry Breaking: GMSB
  - SUSY is broken in a hidden sector: particles get mass through SU(3)xSU(2)xU(1) gauge interactions
  - Grivitino is the LSP. NLSP = neutralino or stau, short or long-lived
- R-parity Violation
  - In SUSY possible to violate both L and B-number $\Rightarrow$ rapid proton decay : R-parity eliminates the "offending" terms. No reason why R should be a symmetry of the Langrangian
  - For the proton to remain stable, either L or B violating terms should be absent
  - The LSP no longer stable

SUSY Searches

In most models the dominant SUSY cross section is squark/ gluino pair production and decay chains ends with the *L*ightest *S*upersymmetric *P*article.

Typical decays:

$$\tilde{g} \rightarrow \tilde{q}_L q \qquad \tilde{q}_L \rightarrow q\tilde{\chi}_2^0 \rightarrow q\tilde{\chi}_1^0 X$$

Names	Spin	Mass Eigenstates	Gauge Eigenstates
Higgs bosons	0	$h^0\ H^0\ A^0\ H^\pm$	$H_u^0\ H_d^0\ H_u^+\ H_d^-$
squarks	0	$\tilde{u}_L\ \tilde{u}_R\ \tilde{d}_L\ \tilde{d}_R$	" "
		$\tilde{s}_L\ \tilde{s}_R\ \tilde{c}_L\ \tilde{c}_R$	" "
		$\tilde{t}_1\ \tilde{t}_2\ \tilde{b}_1\ \tilde{b}_2$	$\tilde{t}_L\ \tilde{t}_R\ \tilde{b}_L\ \tilde{b}_R$
sleptons	0	$\tilde{e}_L\ \tilde{e}_R\ \tilde{\nu}_e$	" "
		$\tilde{\mu}_L\ \tilde{\mu}_R\ \tilde{\nu}_\mu$	" "
		$\tilde{\tau}_1\ \tilde{\tau}_2\ \tilde{\nu}_\tau$	$\tilde{\tau}_L\ \tilde{\tau}_R\ \tilde{\nu}_\tau$
neutralinos	1/2	$\tilde{N}_1\ \tilde{N}_2\ \tilde{N}_3\ \tilde{N}_4$	$\tilde{B}^0\ \tilde{W}^0\ \tilde{H}_u^0\ \tilde{H}_d^0$
charginos	1/2	$\tilde{C}_1^\pm\ \tilde{C}_2^\pm$	$\tilde{W}^\pm\ \tilde{H}_u^+\ \tilde{H}_d^-$
gluino	1/2	$\tilde{g}$	" "
gravitino/ goldstino	3/2	$\tilde{G}$	" "

Typical signatures:

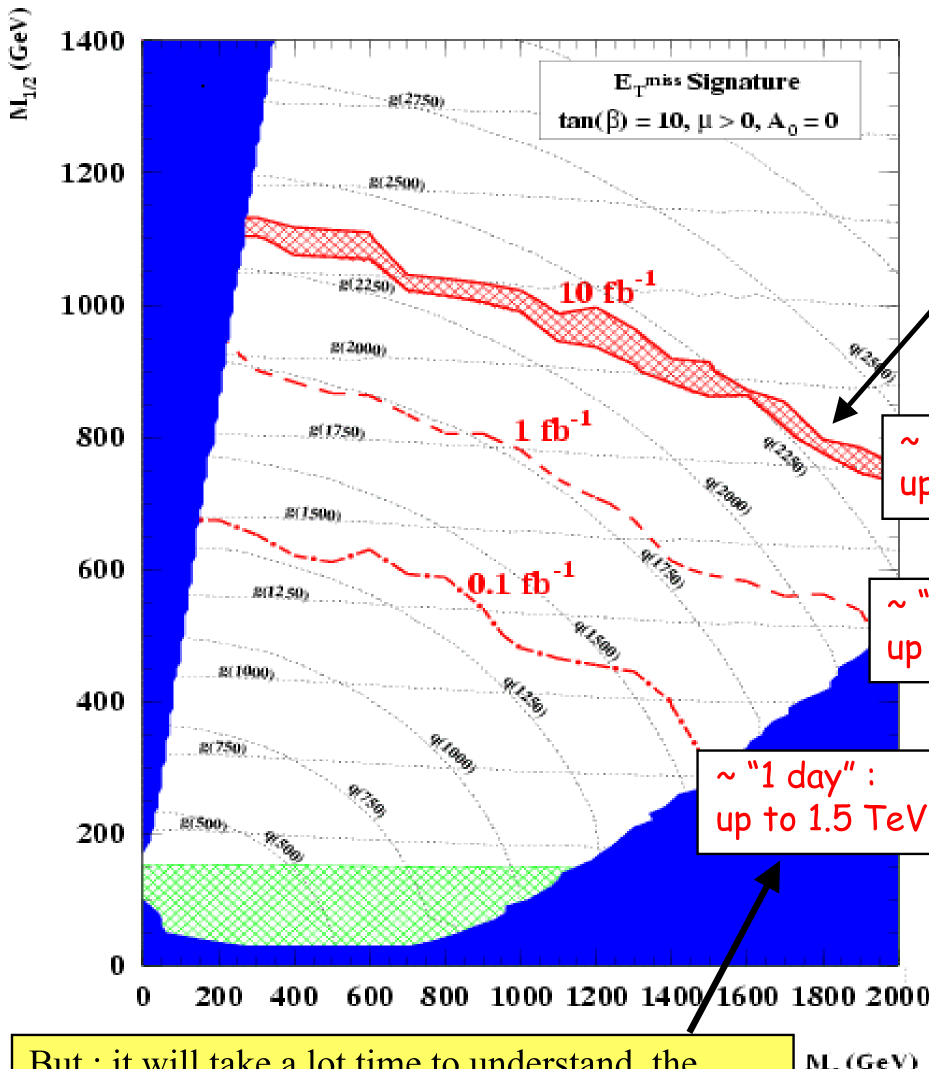
- **Large E_T^{miss}**
- **Lots of jets and leptons**

If R_P conserved no direct measurement of the mass of the LSP.

Assume R_P conserved and mSugra model then

Parameters: $(m_0, m_{1/2}, \tan\beta, A_0, \mu)$

mSUGRA Reach



5 σ contours

band indicates factor ± 2 variation in in background estimate

~ 100 days : up to 2.3 TeV

~ "10 days" : up to 2 TeV

~ "1 day" : up to 1.5 TeV

But : it will take a lot time to understand the detectors and the backgrounds …

Can be discovered up to $m_{\tilde{q}\tilde{g}} \sim$ 2.5-3.0 TeV

$\sigma(\tilde{q}\tilde{q}, \tilde{g}\tilde{g}, \tilde{q}\tilde{g}) \sim$ pb

($m_{\tilde{q}\tilde{g}} \sim$ 1 TeV)

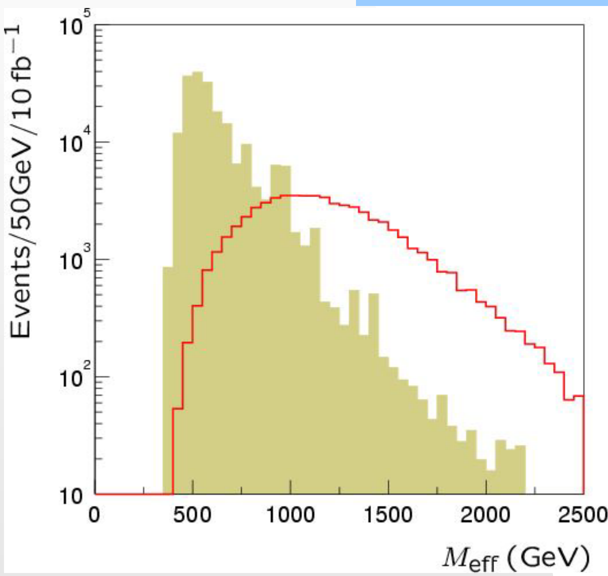
signature: cascade with many jets, leptons, W, Z, b, top in the final state

… can ATLAS perform precise measurements (masses, couplings etc.)?

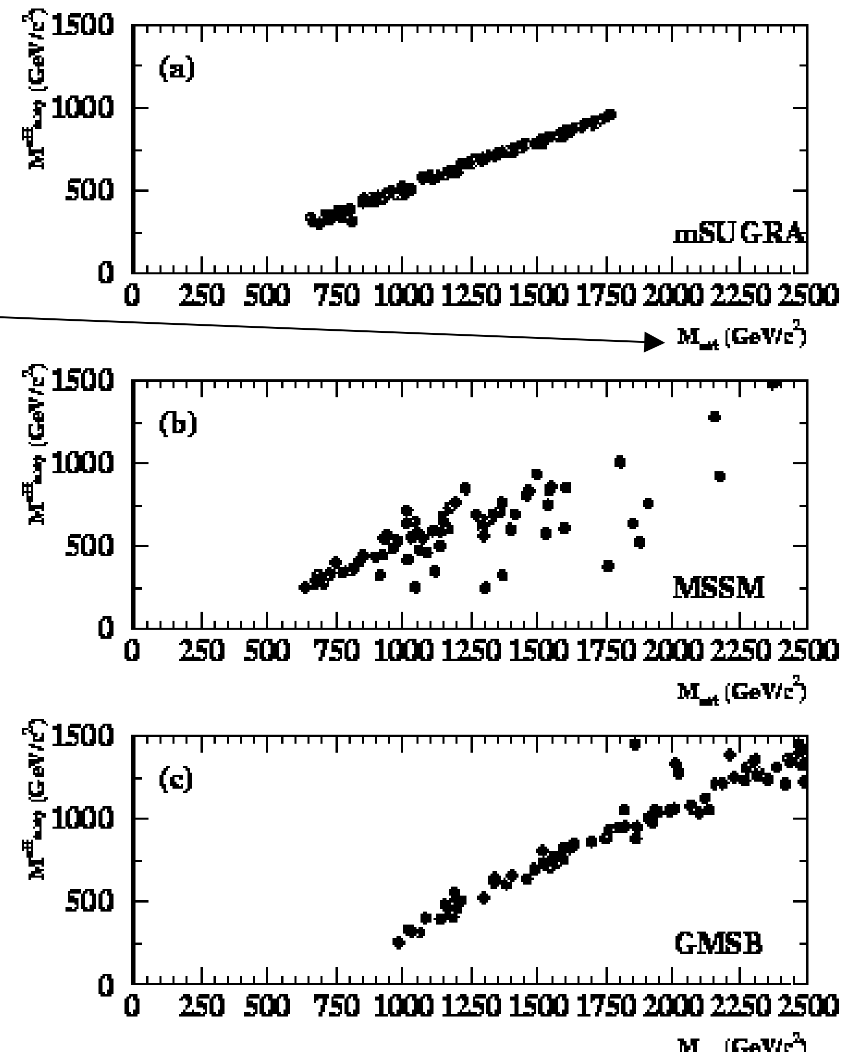
SUSY Mass Scale

For 'Jets + E_T^{miss} + 0 leptons' events, define:

$$M_{eff} = E_T^{miss} + \sum_{j=1}^{Njets} p_T^j$$



Peak position is related to the SUSY mass scale



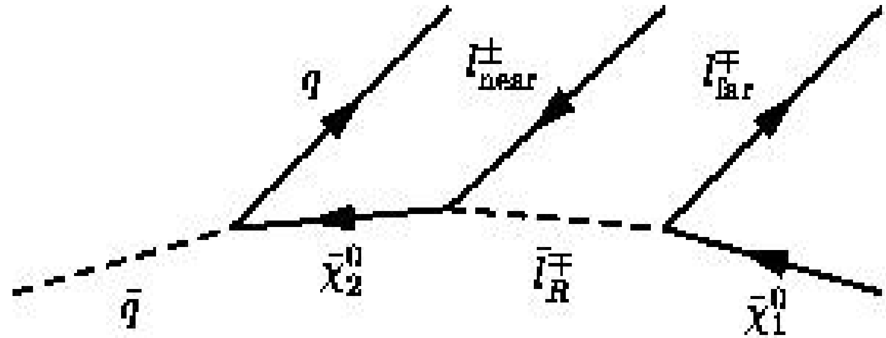
$$M_{eff}^{SUSY} = \left(M^{SUSY} - \frac{M_\chi^2}{M^{SUSY}} \right)$$

$$M^{SUSY} = \min\{mass(\tilde{u}), mass(\tilde{g})\}$$

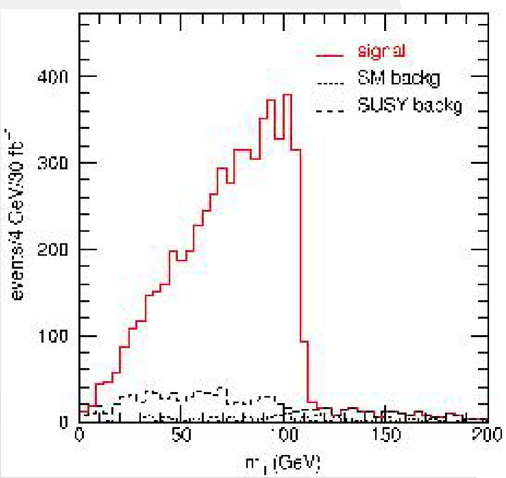
Dilepton Edge

Leptonic decays for χ^0_2 in large part of parameter space:

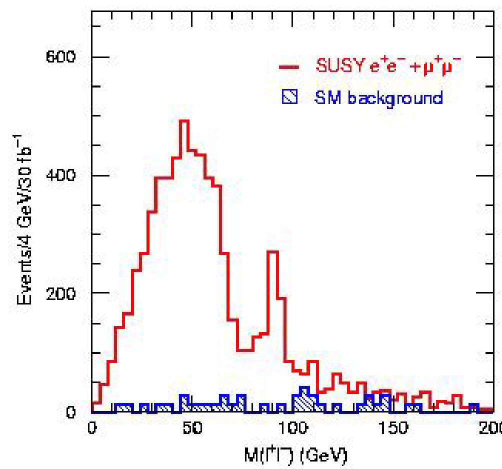
$$\tilde{\chi}_2^0 \rightarrow l^+ l^- \tilde{\chi}_1^0$$
$$\tilde{\chi}_2^0 \rightarrow \tilde{l}_R\, l \rightarrow l^+ l^- \tilde{\chi}_1^0$$
$$\tilde{\chi}_2^0 \rightarrow Z \tilde{\chi}_1^0$$



The shape of m_{ll} distribution shows whether 2 or 3 body decays



Decay to l and slepton



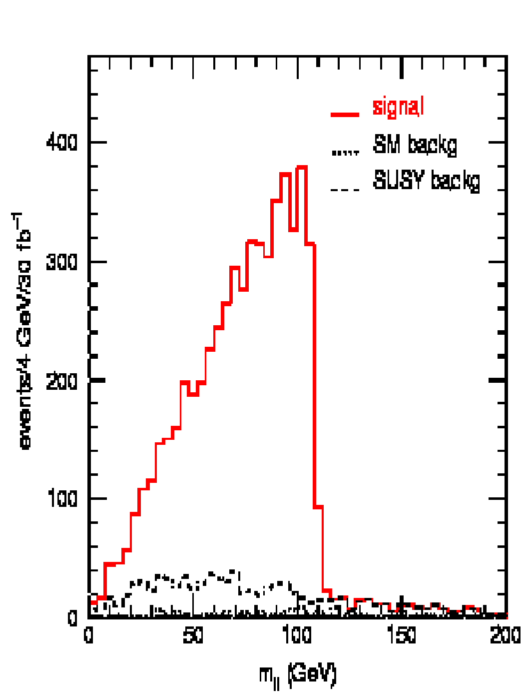
Decay to $l\, l\, \chi^0_1$ and $Z\, \chi^0_1$

Dilepton Edge Example

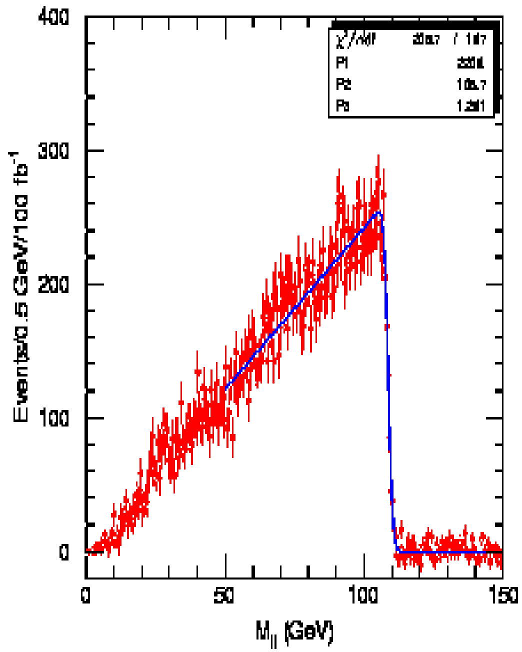
m_0 = 100 GeV, $m_{1/2}$ = 300 GeV

Expected edge position for signal:

$$M_{ll}^{\max} = M(\tilde{\chi}_2^0)\sqrt{1-\frac{M^2(\tilde{l}_R)}{M^2(\tilde{\chi}_2^0)}}\sqrt{1-\frac{M^2(\tilde{\chi}_1^0)}{M^2(\tilde{l}_R)}} = 108.93 \text{ GeV}$$



Signal after cuts



Flavour subtraction

SM background is primarily tt → jjllvv.
Signal is SF only,
OF subtraction removes SM background.

Edge position fitted to give mass relations at % level with 100 fb^{-1}

Mass Measurements

Edges give handle on sparticle masses:

$\ell^+\ell^-$

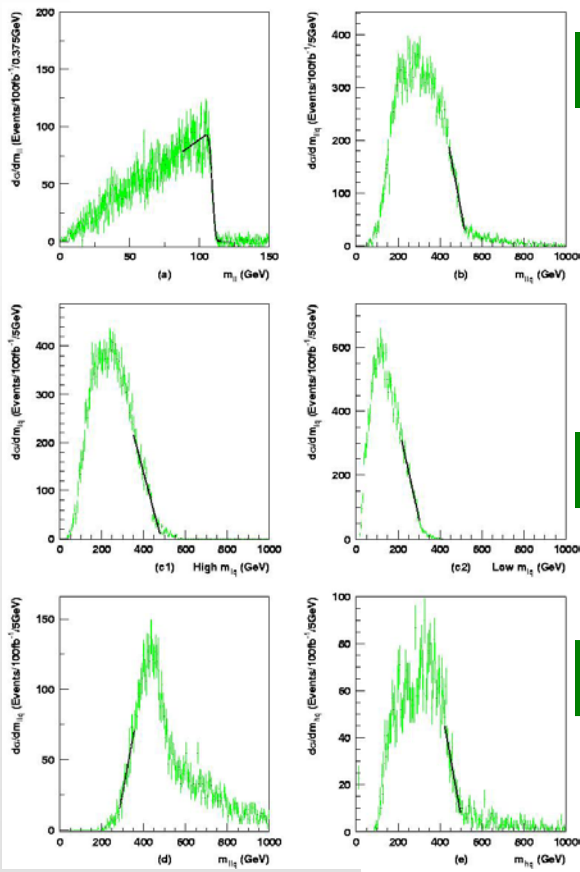
$\ell\ell q$ edge

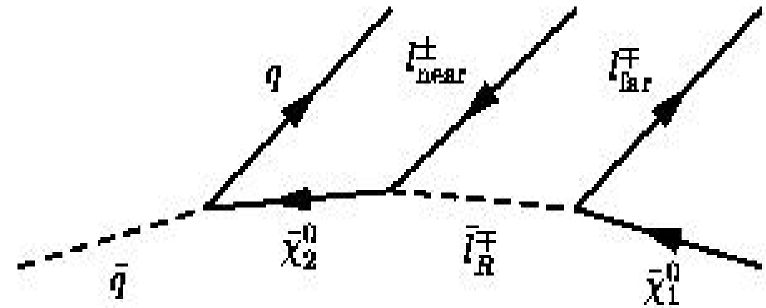
ℓq high

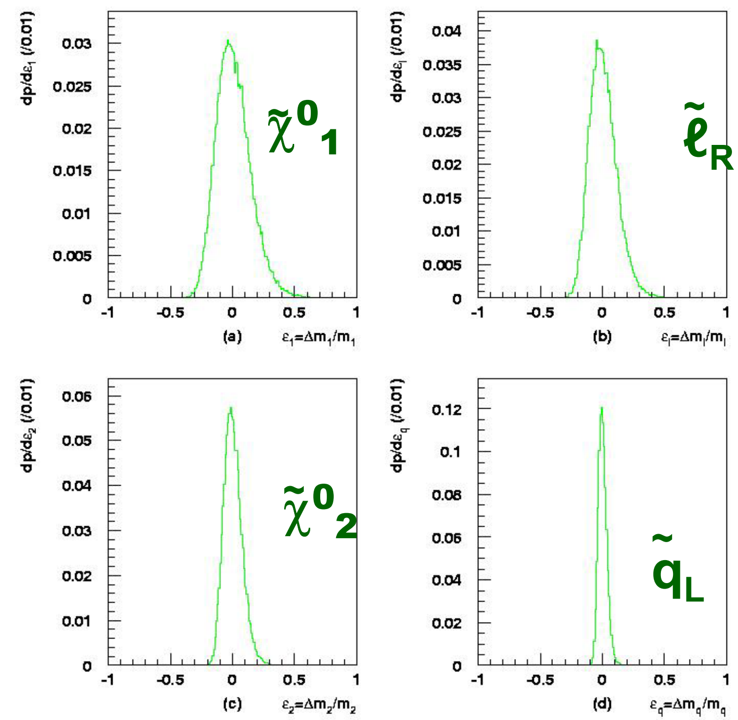
ℓq low

$\ell\ell q$ thr.

hq







Masses can be measured to ~ 3 - 12 %

Heavy Gauginos

Decays into heavy neutralinos and charginos rare but important to constrain model parameters:

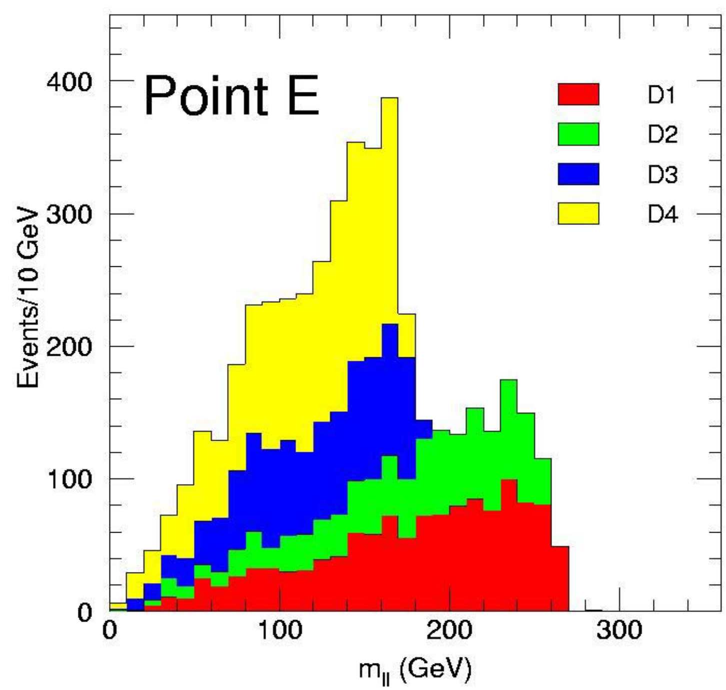
$\tilde{\chi}^0_3$, $\tilde{\chi}^0_4$, and $\tilde{\chi}^\pm_2$ are almost purely higgsinos
BR($\tilde{q}_L \to \tilde{\chi}^0_3$ X) ~ 0.1 % and decays to higgses favoured

$\tilde{\chi}^0_4$ and $\tilde{\chi}^\pm_2$ has dilepton edges:

$$\tilde{q}_L \to \tilde{\chi}^0_4\, q,\quad \tilde{\chi}^0_4 \to \tilde{\ell}^\pm_R\, \ell^\mp,\quad \tilde{\ell}^\pm_R \to \tilde{\chi}^0_1\, \ell^\pm \ [D1]$$

$$\tilde{q}_L \to \tilde{\chi}^0_4\, q,\quad \tilde{\chi}^0_4 \to \tilde{\ell}^\pm_L\, \ell^\mp,\quad \tilde{\ell}^\pm_L \to \tilde{\chi}^0_1\, \ell^\pm \ [D2],\quad \tilde{\ell}^\pm_L \to \tilde{\chi}^0_2\, \ell^\pm \ [D3]$$

$$\tilde{q}_L \to \tilde{\chi}^\pm_2\, q',\quad \tilde{\chi}^\pm_2 \to \tilde{\nu}_\ell\, \ell^\pm,\quad \tilde{\nu}_\ell \to \tilde{\chi}^\pm_1\, \ell^\mp \ [D4]$$



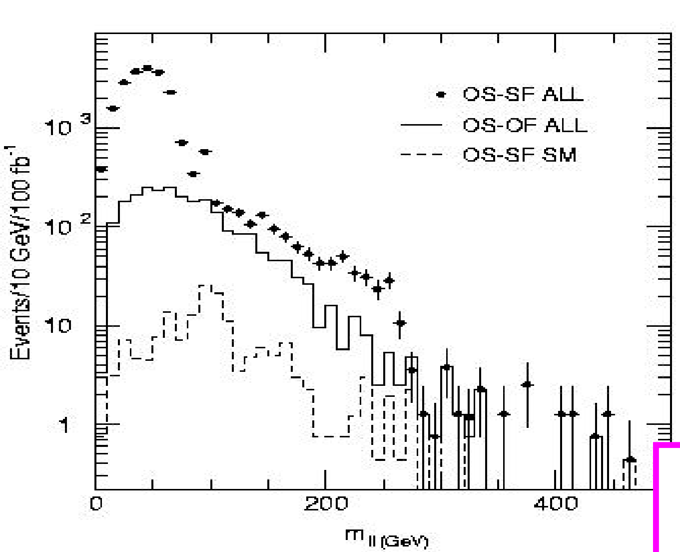
Heavy Gauginos

Analysis cuts:

- $\ell^+\ell^-$ with inv mass > 100 GeV
- E_T^{miss} > 100 GeV
- At least 4 jets
- M_{eff} > 600 GeV
- M_{T2} > 80 GeV

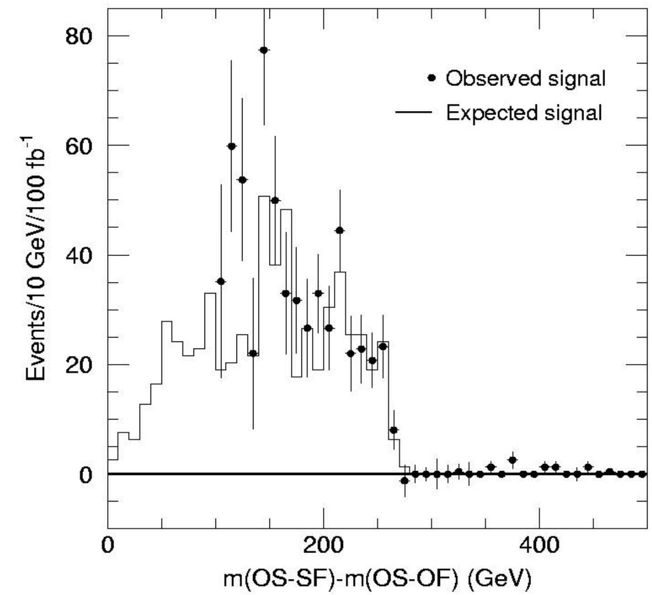
$$M_{T2}^2 \equiv \min_{\not p_1 + \not p_2 = \not p_T} \left[\max \{ m_T(p_{T\ell_1}, \not p_1), m_T(p_{T\ell_2}, \not p_2) \} \right]$$

Example: $(M_0, M_{1/2})$ = (150,250)



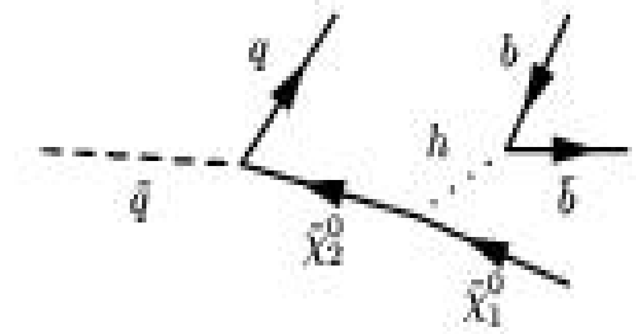
Before cuts

After OF subtraction - Clear edge in $m_{\ell\ell}$

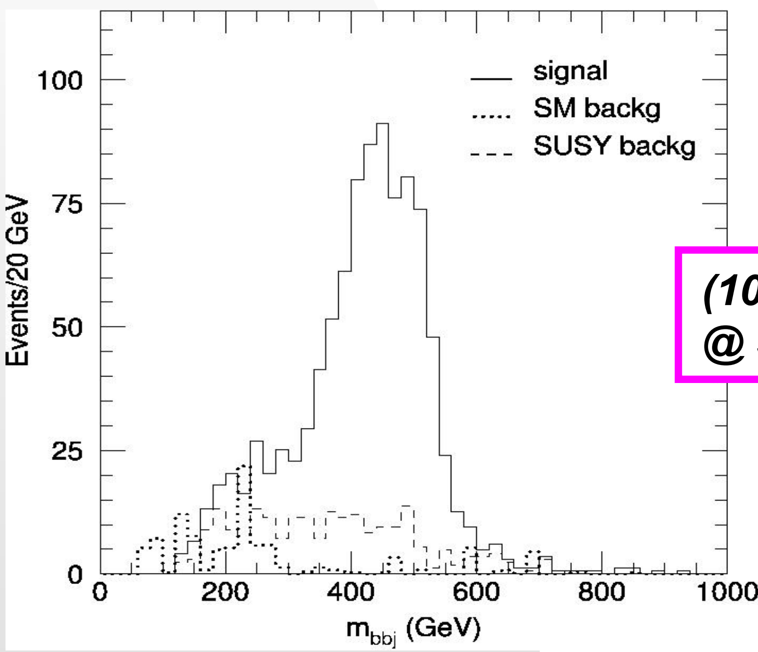


Decays to h

If $\tilde{\chi}^0_2$ heavy then decays to lightest higgs



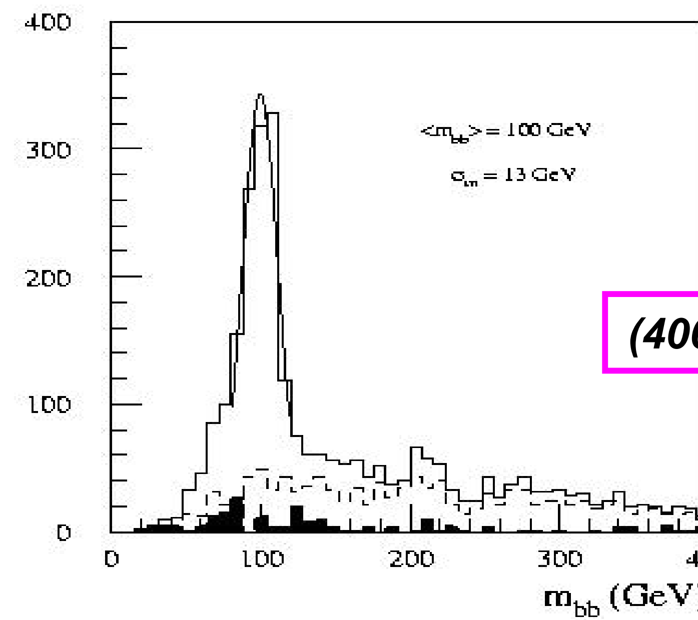
Still information on the other masses from edges but not as good as with leptons:



(100,300) @ 30 fb^{-1}

$\tilde{q}_L$ mass determined to ± 10 GeV

Maybe lightest higgs discovered in χ^0_2 decay?



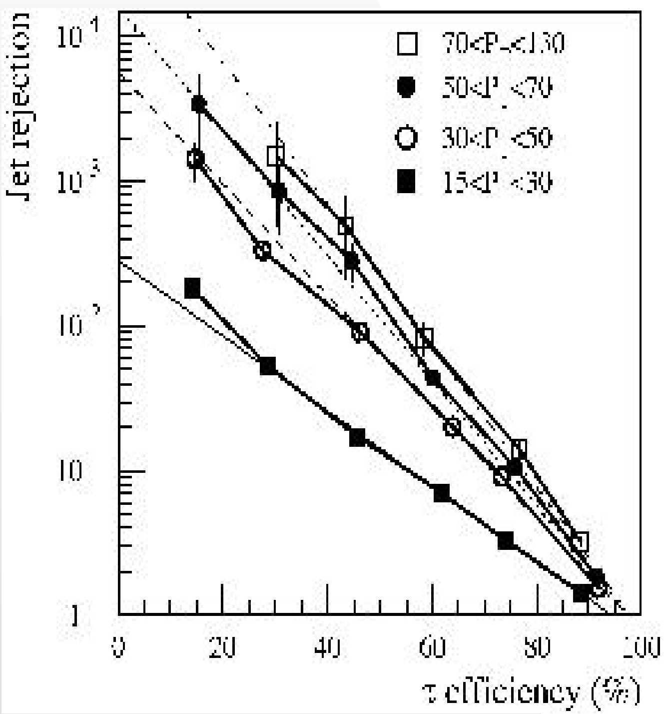
(400,400)

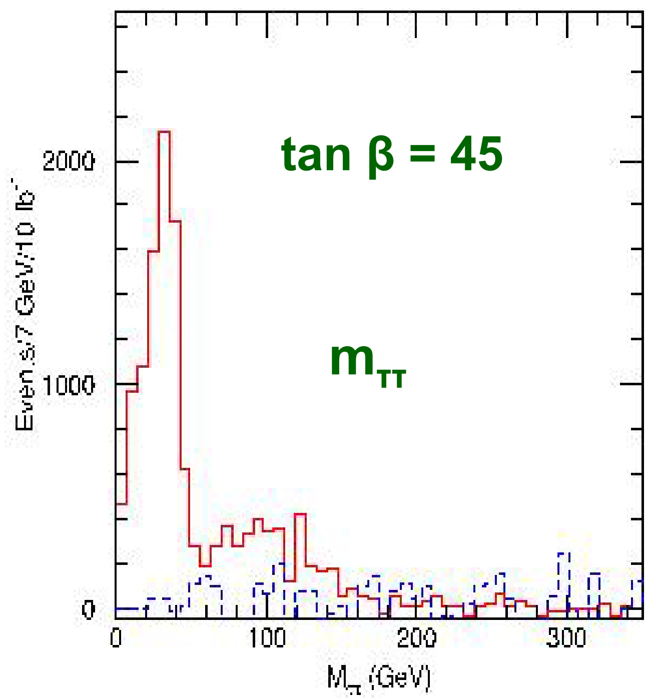
Decays to Staus

As tanβ increases so does the mass splitting between the lighter and heavier stau ►decays to $\tilde{\tau}_1$ favoured:

$$\tilde{\chi}_2^0 \rightarrow \tilde{\tau}_1 \tau \qquad \tilde{\tau}_1 \rightarrow \tau \tilde{\chi}_1^0$$

E_T^{miss} from LSP's means analyses relies on hadronic tau's.





SUSY background cancel in OS-SS

Endpoint measured to ~ 5 %

MSSM Higgs Searches

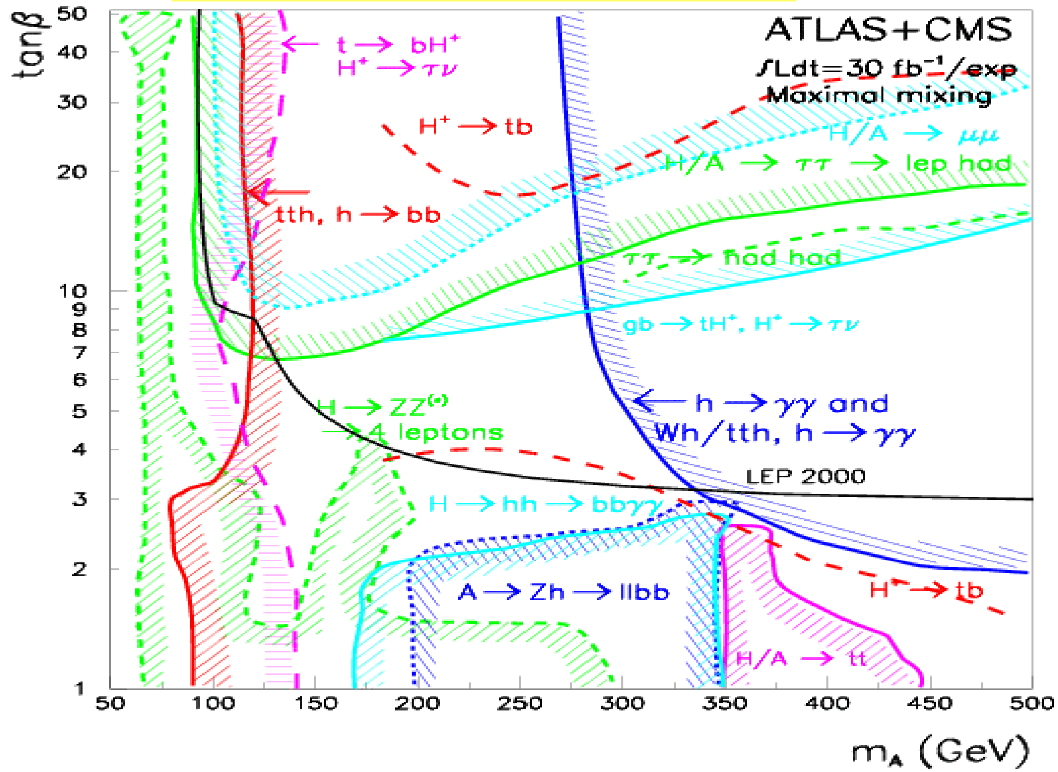
Large variety of observation modes

- SM like :
  - $h \to \gamma\gamma$, bb
  - $H \to 4\ell$
- MSSM specific :
  - $A/H \to \mu\mu$, $\tau\tau$, tt
  - $H \to hh$
  - $A \to Zh$
  - $H^{\pm} \to \tau\nu$
- If SUSY accessible:
  - $H/A \to \chi_2^0\, \chi_2^0$
  - $\chi_2^0 \to h\, \chi_1^0$

- VBF not yet assessed

Significance for $\int \mathcal{L}\, dt = 30\ \text{fb}^{-1}$, ATLAS+CMS combined

(SUSY particles heavy)



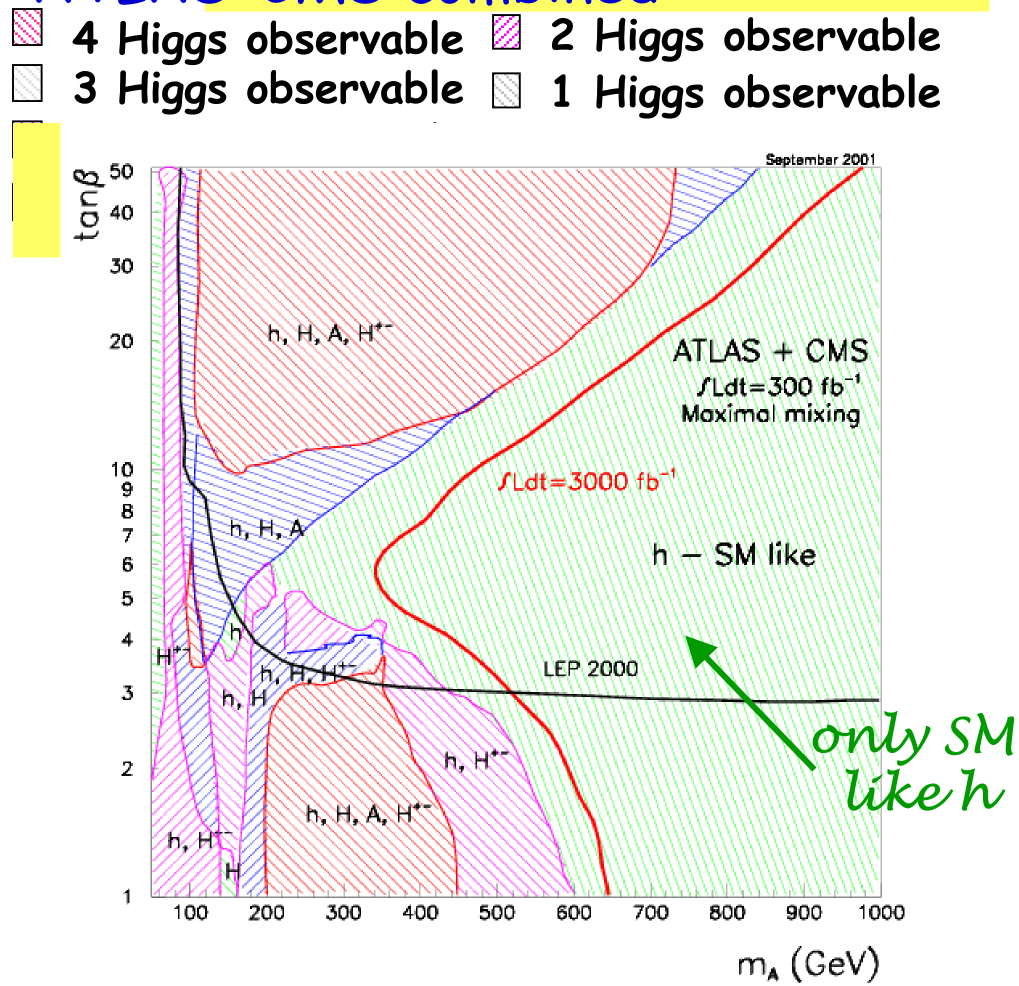
Plane fully covered

MSSM Higgs Searches

- ≥ 2 MSSM Higgs observable over most of parameter space:
  ➔ Disentangle SM and MSSM !

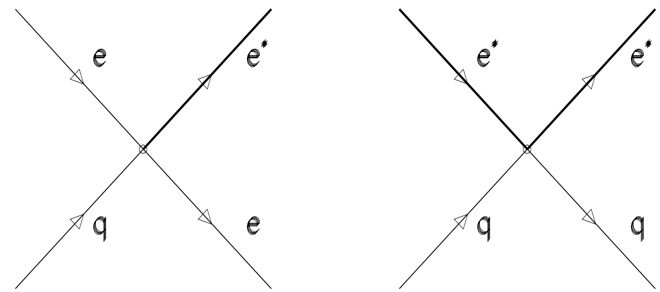
- But… We may be unlucky, that even if we do find a light Higgs, we will not be able to tell if it is SM or MSSM

Significance for $\int \mathcal{L}\, dt$ = 300 fb^{-1}, ATLAS+CMS combined

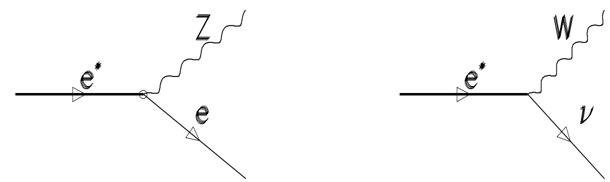


Exotic Physics
Search for Excited Leptons

- In composites models, quarks & leptons are bound states of constituents
- Quarks & leptons are ground states of a rich spectrum of fermions
- Observation of excited quarks & leptons would be an irrefutable evidence of composition
- Existence of 4-fermion contact interaction would result in an excess of leptons
- At the LHC, contact interactions play an important role in excited lepton production



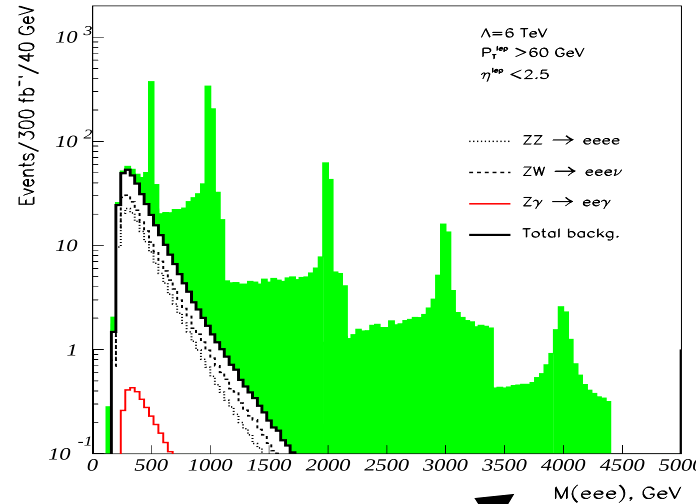
Productions by Contact Interactions

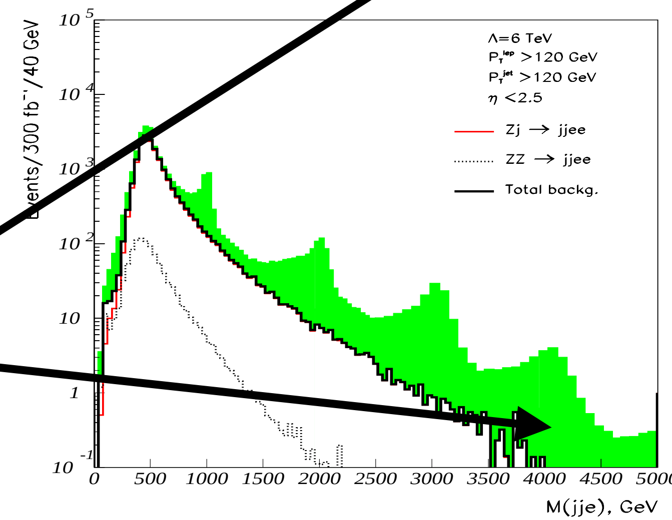


Decay via Gaugae Interactions

Search for Excited Electrons

- $e^*e \to Zee \to eeee$ final state
  - 4 isolated electrons
  - m_{ee} within 10 GeV of m_Z
  - Cut on E_T^{miss} to suppress WZ ($W \to l\nu$)
  - γ/e rejection > 500 suppress Z γ
- $e^*e \to Zee \to jjee$ final state
  - Search for 2 leptons + 2 jets (similar cuts as above)
  - m_{jj} within 10 GeV of m_Z





The reach ~ 4 TeV depending on the compositeness scale Λ

Lepton Flavor Violation (LFV)

- In the SM, lepton flavor is conserved separately for each generation

	K^0-$\bar{K}^0$ (λ_{ds})	B_d^0-$\bar{B}_d^0$ (λ_{db})	D^0-$\bar{D}^0$ (λ_{uc})
Data	$3.5\ 10^{-6}$	$3.26\ 10^{-4}$	$< 1.32\ 10^{-4}$
1Loop SM	1.4-$1.6\ 10^{-6}$	10^{-4}-10^{-3}	10^{-8}-10^{-7}

$\Rightarrow$ Good agreement between SM and data. But the data only constrains LFV couplings involving the first generation. Extended models must find a way to suppress first generation LFV couplings

- SuperKamiokande Results consistent with $\nu_\mu \rightarrow \nu_\tau$ provided $\sin^2\theta_{\mu\tau} \approx 1$ and $\Delta m^2 \sim 10^{-3}$ eV^2 . Models that can naturally accommodate this mixing have LFV

Lepton Flavor Violation

- Examples:
  - In SUSY, the slepton mass matrix is not flavor diagonal $\Rightarrow$ LFV: $\chi_2^0 \rightarrow \chi_1^0 \mu\tau \Rightarrow$ BR $(\tau \rightarrow \mu\gamma) \leq 10^{-9}$ compare to that expected from the rare decay $\tau \rightarrow \mu\gamma$ ($\sim 10^{-6}$)
  - In the 2HDM-III, no discrete symmetry to suppress LFV couplings

$$\eta_{ij} = \lambda_{ij} \frac{\sqrt{m_i m_j}}{v}$$

$$\lambda_{ij} (i,j = 2,3; i \neq j)$$

Not constrained by this data

$$K^0 - \bar{K}^0 : \lambda_{ds} < 0.2$$

$$B^0 - \bar{B}^0 : \lambda_{db} < 0.25$$

$$D^0 - \bar{D}^0 : \lambda_{uc} < 0.6$$

LFV and muon g-2

- Constrain on LFV coupling $\lambda_{\tau\mu}$ from the μ anomalous magnetic moment

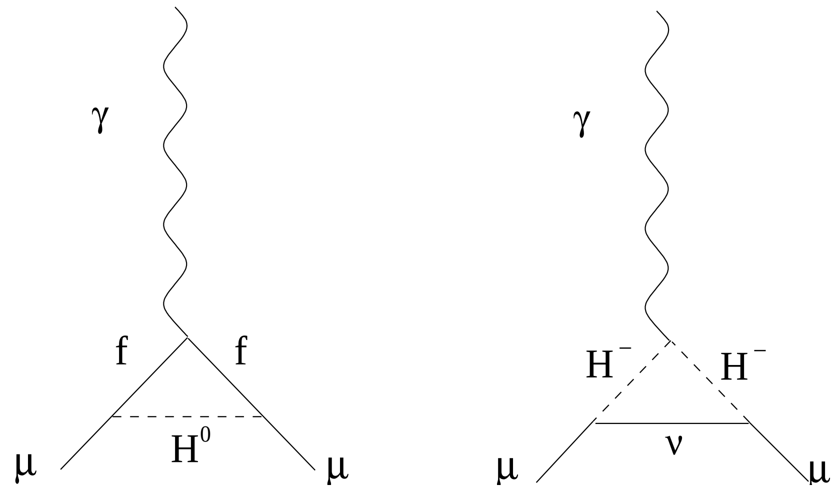
$$a_\mu^{exp} = 11659203\,(8)\text{x}10^{-10}$$

$$a_\mu^{SM} = 11659177\,(7)\text{x}10^{-10}$$

$$\Delta a_\mu = a_\mu^{exp} - a_\mu^{SM} = 26(11)\text{x}10^{-10}$$

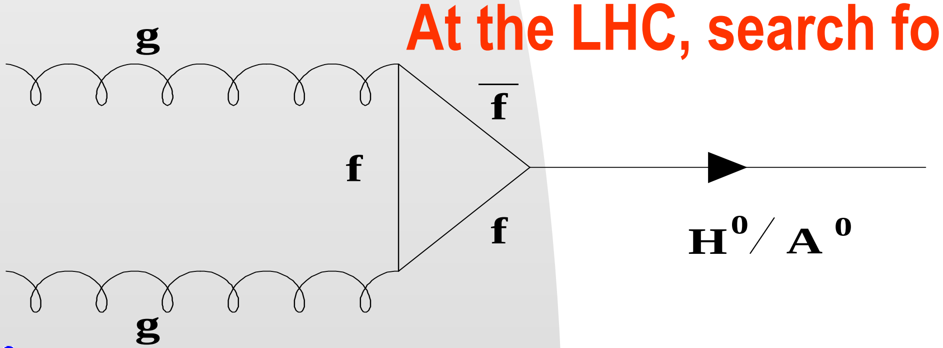
$$90\%CL:$$

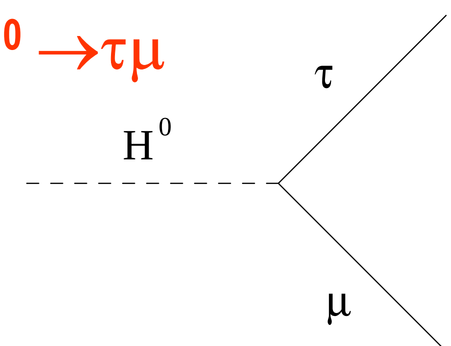
$$8\text{x}10^{-10} \leq \Delta a_\mu \leq 44\text{x}10^{-10}$$



This contribution depends on on $\lambda_{\tau\mu}$

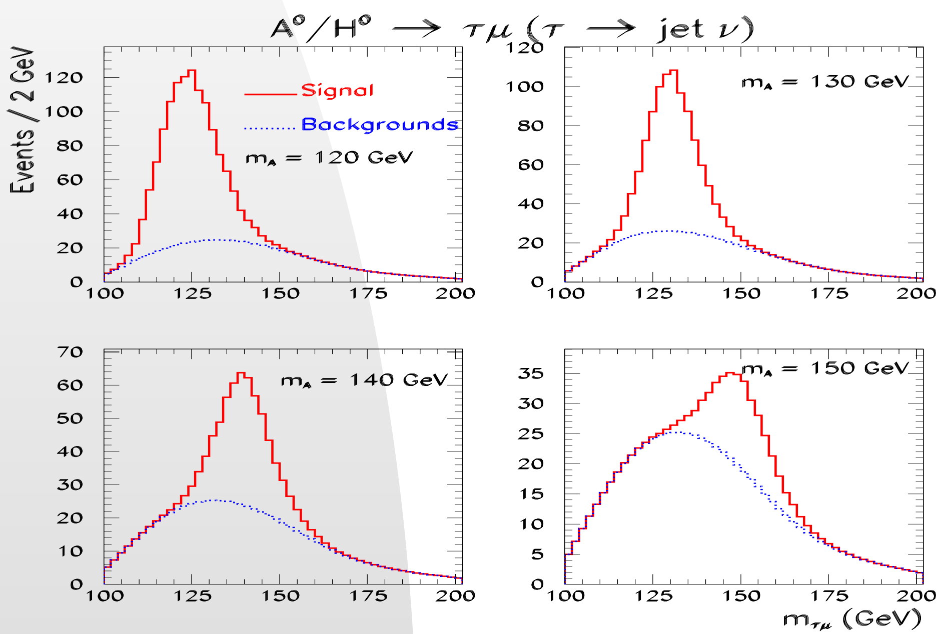
At the LHC, search for $A^0/H^0 \rightarrow \tau\mu$





Search for $A^0/H^0 \rightarrow \tau\mu$ at the LHC

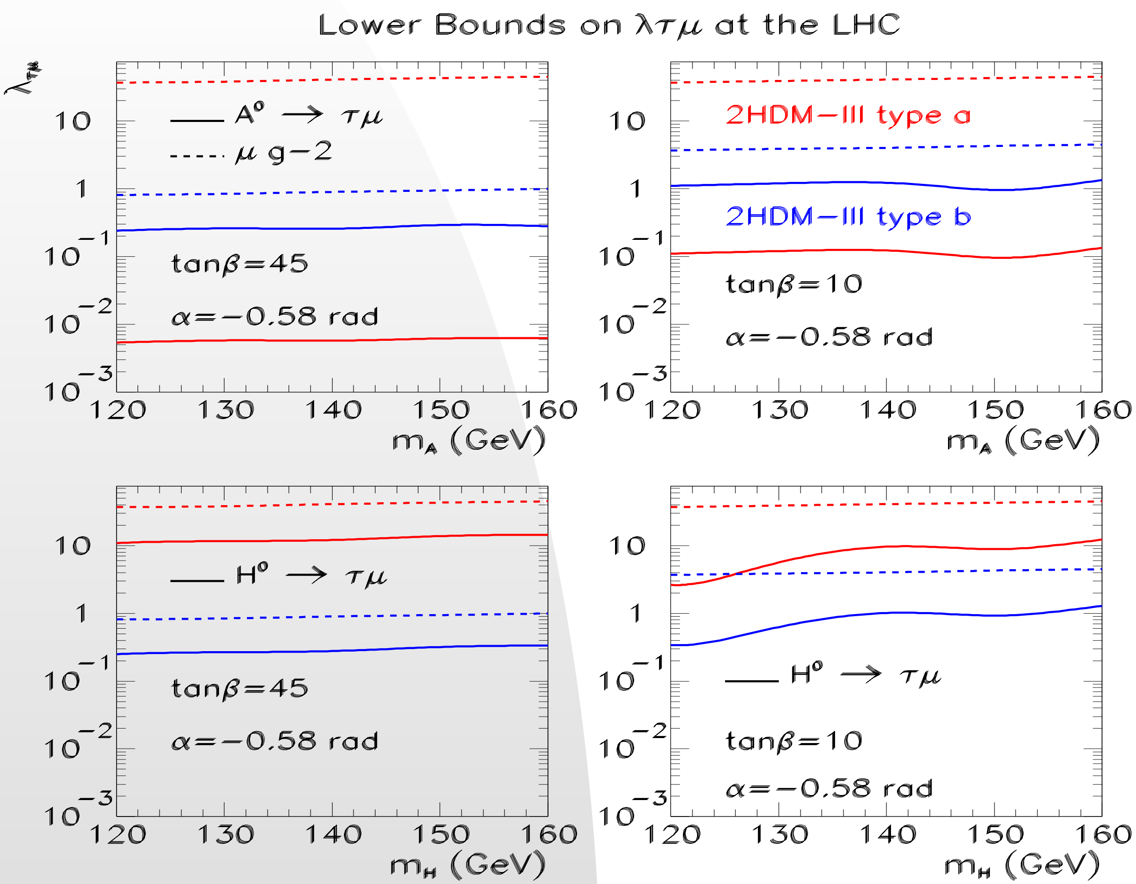
- 1 isolated μ 1 hadronic τ jet (or 1 isolated e from $\tau \rightarrow e\nu\nu$)
- jet veto and b-jet veto, τ ID efficiency of 30%
- Single charged track within $\Delta R < 0.3$ (1-prong hadronic τ decays)
- Kinematic cuts: $$\Delta p_T = p_T^{\mu} - p_T^{\tau-jet} > 0$$



Reconstructed $m_{\tau\mu}$ in the hadronic channel: signal observable up to 150 GeV

Search for $A^0/H^0 \to \tau\mu$ at the LHC

- Expected bounds of LFV coupling $\lambda_{\tau\mu}$ at the LHC compared to the Tevatron and the μ g-2



$\lambda_{\tau\mu}$~0.01/0.1 can be reached at the LHC for 100 fb^{-1}: A factor 10-100 better than at the Tevatron or from muon g-2

Large Extra Dimensions

- In the 2HDM-II

$$H^- \to \tau_R^- \bar{\nu} \quad \text{or} \quad H^+ \to \tau_L^+ \nu$$

H^- to τ^-_L (or H^+ to τ^+_R) suppressed

- In Large Extra Dimensions
  - The RH SM neutrino is a singlet, it can propagate in bulk just like gravity
  - It is possible to generate small neutrino masses without the seesaw mechanics

$$H^- \to \tau_L^- \psi$$

Can be enhanced by the large number of KK states

Thus

$$H^- \to \tau_R^- \bar{\nu} + \tau_L^- \psi$$

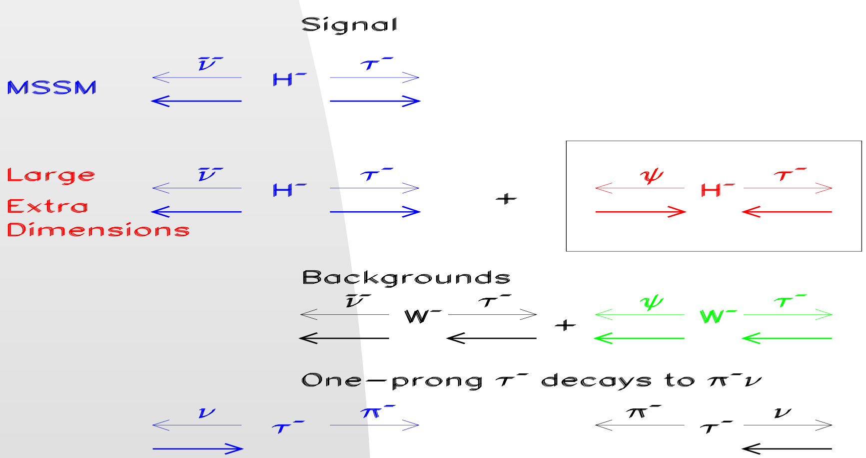
Can $H^- \to \tau_L^- \psi$ be observed at the LHC?

If yes, can it be used to distinguish between the 2HDM and large Extra Dim.?

Large Extra Dimensions

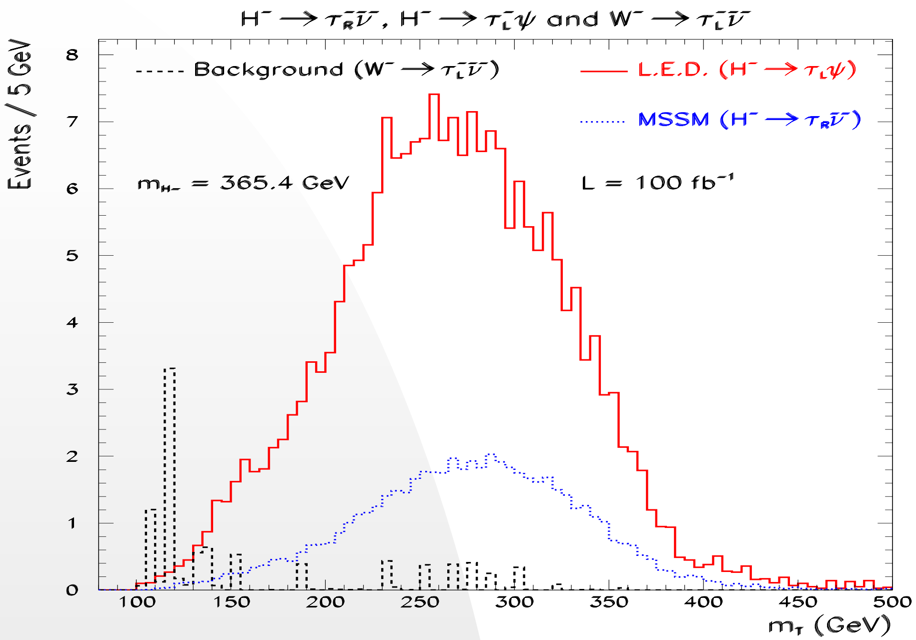
- No additional Higgs boson in this model: $gb \rightarrow tH^{\pm}$
- Consider 1-prong Hadronic τ decays:

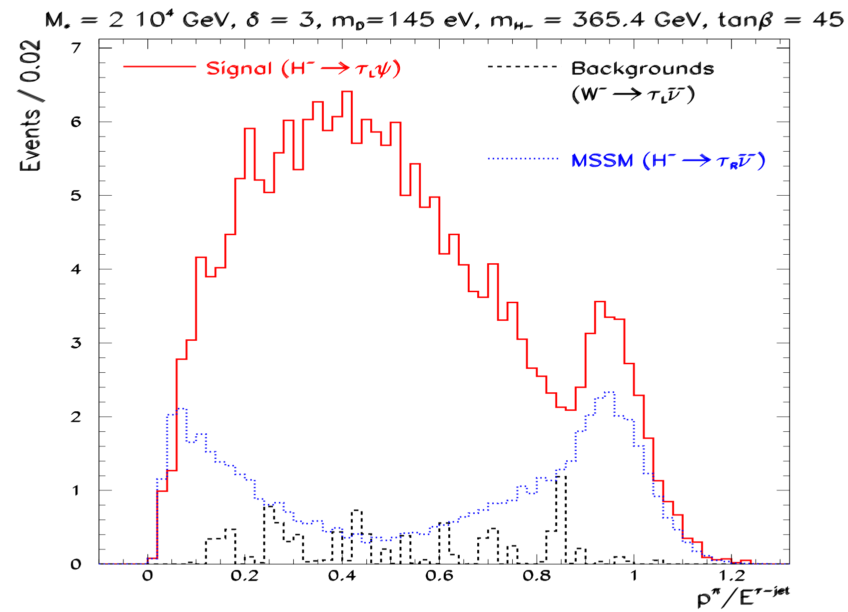
$\tau^{\pm} \rightarrow \pi^{\pm} \nu_{\tau}$	11.1%
$\tau^{\pm} \rightarrow \rho^{\pm} (\rightarrow \pi^{\pm} \pi^{0}) \nu_{\tau}$	25.2%
$\tau^{\pm} \rightarrow a_1^{\pm} (\rightarrow \pi^{\pm} \pi^{0} \pi^{0}) \nu_{\tau}$	9.0%



π Polarization can help distinguish between 2HDM and Large Extra Dimensions

Large Extra Dimensions





- Observation of signal in m_T distribution not enough to distinguish between 2HDM and Large extra Dimension
- In addition, the reconstruction of the fraction of the energy carried by the charged track in 1-prong hadronic τ decays may provide a signature for Large Extra Dimensions

Conclusions:

- LHC will probe QCD to unexplored kinematic limits;
- Jet studies (test of pQCD, constrain p.d.f.'s, physics studies);
- Luminosity uncertainties can be reduced by measurements of relative luminosities: high-Q^2 and wide x-range;
- Prompt-photon production will lead to improved knowledge of background levels ($H \rightarrow \gamma\gamma$), $f_g(x)$ and parton dynamics;
- α_s at high-energy scales (test of the running of α_s);
- Multiple parton scattering: source of background and/or new physics channels;
- Minimum-bias and the underlying event: improved understanding of events dominated by soft processes.

Conclusions:

- LHC will allow precision measurements: unexplored kinematic regions, high-statistics (W, Z, b, t factory);
- ATLAS: valuable precision measurements of SM parameters;
- W mass can be measured with a precision of 15 MeV (combinig e/μ and ATLAS + CMS);
- Top mass: ~ 2 GeV (combined with Δm_W~15 MeV, constrains M_H to ~ 25%);
- Sensitivity FCNC top decays at level of ~10^{-4} : new Physics!
- $\sin^2\theta_{eff}^{lept}(M_Z^2)$ can be determined with statistical precision of 1.4×10^{-4} (competitive to lepton collider measurements!)
- EW single top production: direct measurement of V_{tb}; measurement of top polarization (Wg with statistical precision of ~ 1.6%);
- Sensitivity to anomalous TGC's: indicative of new physics!
- Useful measurements on B-physics sector: sensitivity to sin2β comparable to that of LHCb. Significant contribution the measurement of B^0_s mixing, and sensitivity to rare B-decays to search for new physics.

Summary and Outlook

- ATLAS will find TeV scale SUSY if it is there. The first 10 fb^{-1} will reach up to ~ 2 TeV.
- Many measurements of sparticle masses possible even in R_P conserving SUSY
- Lepton signatures important.

  - Low luminosity runs gives lots of useful info on SUSY models but high luminosity needed to fully constrain models

Conclusions

- ATLAS can discover the Higgs in range from LEP2 limit 114 GeV to 1 TeV
- SM Higgs observed with 10 fb^{-1}:
  - Vector Boson Fusion significantly enhances sensitivity for low and medium m_H:
  - Known channels ($H \rightarrow bb$, $\gamma\gamma$, 4ℓ…) well assessed
    - Forward jet tagging efficiency crucial
- Most of MSSM plane explored with 10 fb^{-1}:
- Ongoing effort in establishing prospects for the measurement of Higgs parameters
- Let's see what "reality" has in store for us….

Conclusions

- The observation of an excess of electrons over SM expectation could be an indication of excited electrons. Singly produced excited electrons can be detected up to 4 TeV at the LHC, thus providing an irrefutable signature for compositeness
- Evidence of atmospheric neutrino oscillation may lead to $A^0/H^0 \rightarrow \tau\mu$. Sensitivity to this process at the LHC will allow a reach in the LFV coupling $\lambda_{\tau\mu}$ ~ 0.01/0.1: a factor of 10-100 better than at the Tevatron or from the muon g-2
- Evidence of Large Extra Dimensions can be inferred from $H^{\pm} \rightarrow \tau^{\pm}\nu$ by reconstructing:
  - The transverse mass
  - the energy carried by the charged track in 1-prong hadronic τ decays