LHC physics : the first year ….

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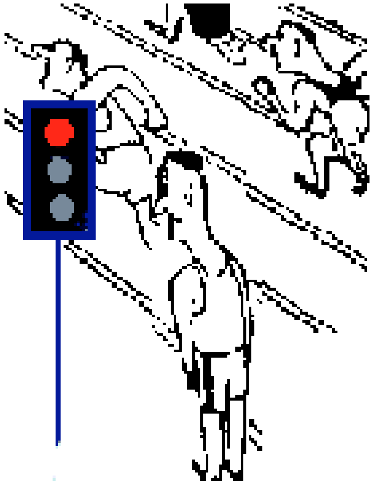
❶ Machine start-up scenario

❷ Which detectors, triggers and performance at the beginning ?
Construction → test beam → cosmics → first collisions

❸ Physics goals and potential with the first fb^{-1} (a few examples …)



Here : ATLAS and CMS

❶ Machine start-up scenario

(from Chamonix XII Workshop, January 2003)


~ 300 dipoles delivered
~ 200 cold-tested


TI8

- ~ **January 2007 - March 2007: machine cool-down**
- ~ **April 2007 : start machine commissioning (mainly single beam)**
- ~ **Summer 2007 : two beams in the machine → first collisions**
  - -- 43 + 43 bunches, L=6 x 10^{31} cm^{-2} s^{-1} (possible scenario; tuning of machine parameters)
  - -- 936+936 bunches (bunch spacing 75 ns, no electron cloud), L > 5x 10^{32}

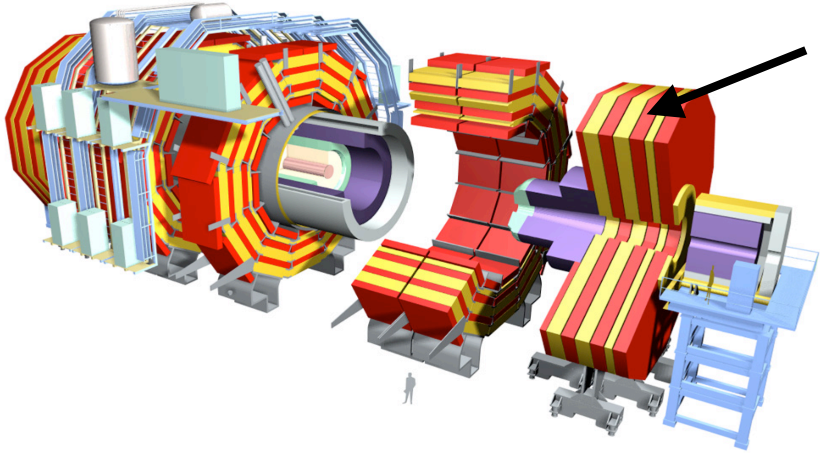
  } ~ 4 months
  - -- 2-3 month shut-down ?
  - -- **2808 + 2808 bunches (bunch spacing 25 ns), L up to ~2x10^{33} (first year goal)**

    → ~ 7 months of physics run

A lot of uncertainties in this plan → here assume 1 - 10 fb^{-1} /expt on tape after the first year of operation

❷

Which detectors the first year ?

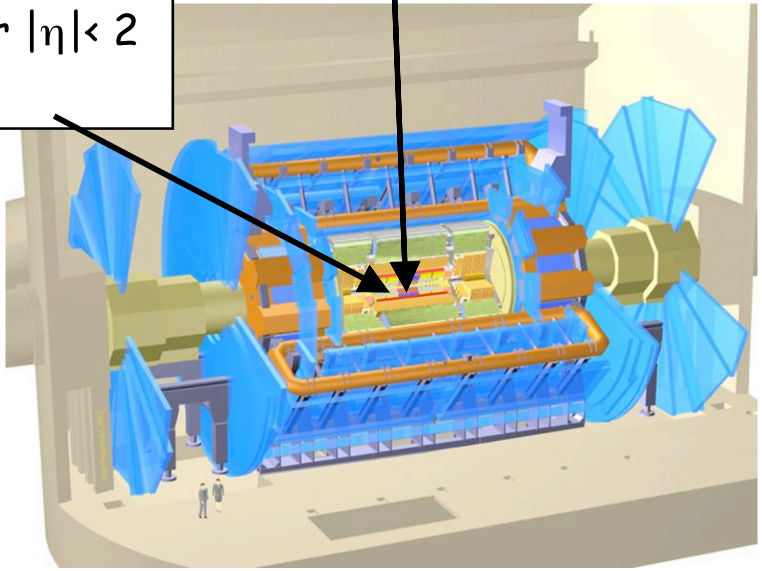


RPC over $|\eta|<1.6$ (instead of $|\eta|< 2.1$)
4th layer of end-cap chambers missing

Pixels and end-cap ECAL
installed during first shut-down

2 pixel layers/disks instead of 3

TRT acceptance over $|\eta|< 2$
(instead of $|\eta|< 2.4$)



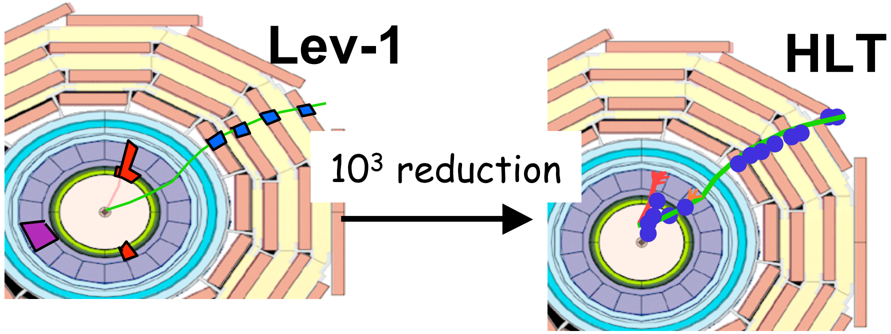
Both experiments:
deferrals of high-level Trigger/DAQ processors
→ LVL1 output rate limited to
~ 50 kHz CMS (instead of 100 kHz)
~ 25 kHz ATLAS (instead of 75 kHz)

Impact on physics visible but acceptable

Main loss : B-physics programme strongly reduced (single μ threshold p_T> 14-20 GeV)

Which trigger ?

CMS, L = 2x 10^{33}



LVL1

Channel	Threshold [GeV] ε = 95%	Rate [kHz]
Inclusive isolated e/γ	29	3.3
Di-electrons/di-photons	17	1.3
Inclusive isolated muon	14	2.7
Di-muons	3	0.9
Single-tau / two-taus	86/59	2.2/1.0
1-jet, 3-jets, 4-jets	177 , 86 , 70	3.0
Jet * E_T^{miss}	88 * 46	2.3
Min-bias (Calibration)		0.9
Total		**16 kHz**

~ 50 kHz with x3 safety

HLT (to tape)

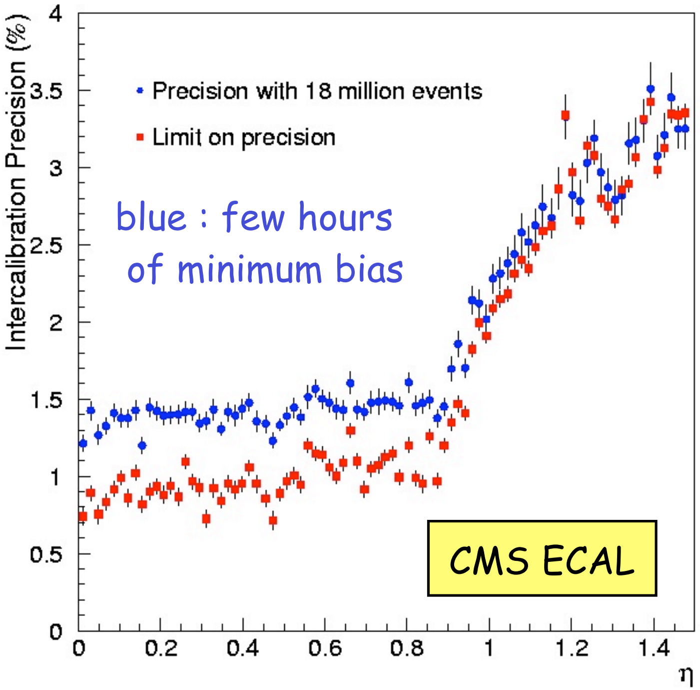
Channel	Threshold [GeV] ε = 90…95%	Rate [Hz]
1 e, 2 e	29 , 17 + 17	34
1 γ, 2 γ	80 , 40 + 25	9
1 μ, 2 μ	19 , 7 + 7	29
1 τ, 2 τ	86, 59 + 59	4
1jet OR 3jet OR 4	657 , 247, 113	9
Jet * E_T^{miss}	180 + 123	5
Calibration,Other		~17
Total (purity ~50%)		**~105 Hz**

- LVL1 rate limited by staging of HLT processors
- HLT rate by cost of offline computing (1 PB/year)
- Should preserve guiding principles of LHC trigger !

Inclusive approach to the "unknown", safe overlap with Tevatron reach, avoid biases from exclusive selections, margin for offline optimization and QCD uncertainties, enough bandwidth for calibration/control triggers (esp. at beginning !)

Which detector performance on day one ?

A few examples and educated guesses
based on test-beam results and simulation studies



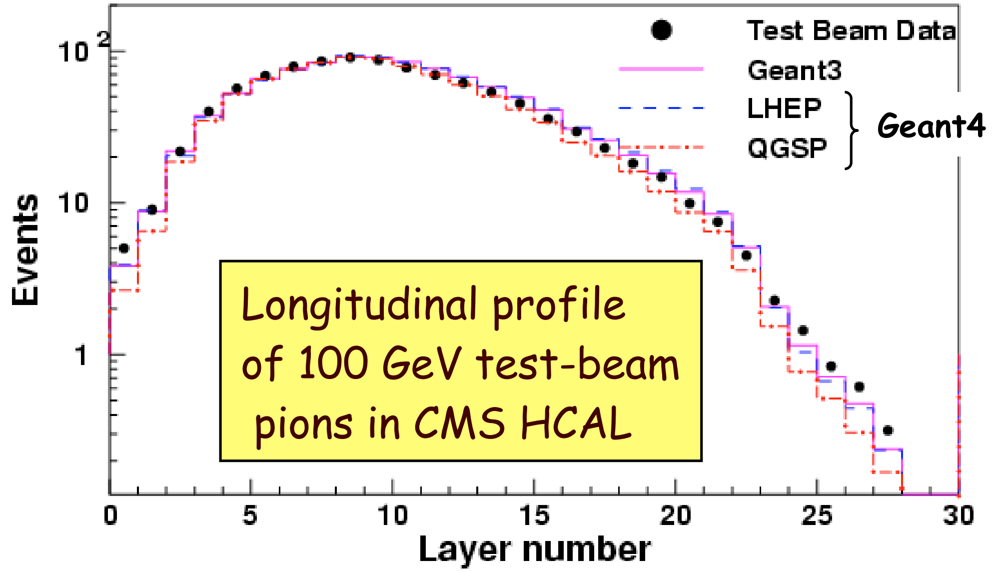
	Expected performance day 1	Physics samples to improve (examples)
ECAL uniformity	~ 1% (ATLAS), 4% (CMS)	Minimum-bias, Z→ ee
e/γ scale	1-2 % ?	Z → ee
HCAL uniformity	2-3 %	Single pions, QCD jets
Jet scale	< 10%	Z (→ ll) +1j, W → jj in tt events
Tracking alignment	20-500 μm in Rϕ ?	Generic tracks, isolated μ , Z → $\mu\mu$

Ultimate statistical precision achievable after few days of operation. Then face systematics ....

E.g. : tracker alignment : 100 μm (1 month) → 20μm (4 months) → 5 μm (1 year) ?

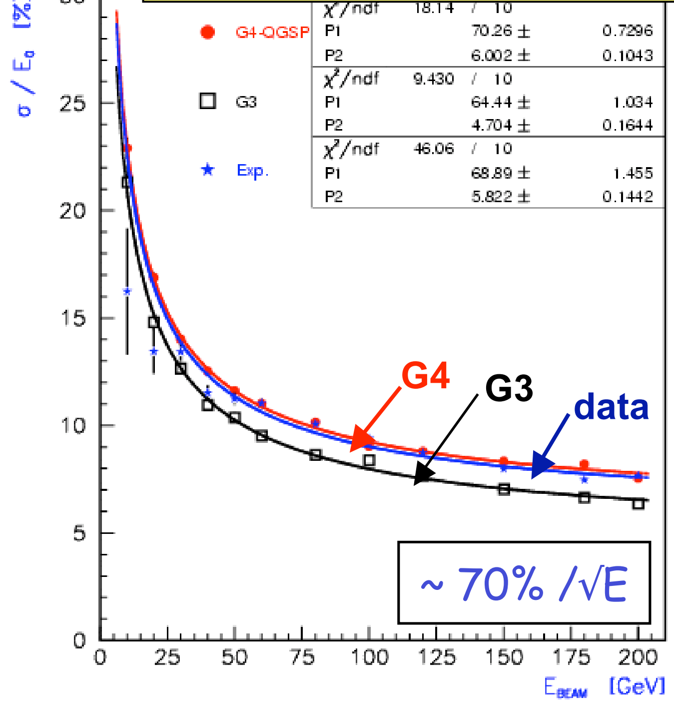
Steps to achieve the detector goal performance

- Stringent construction requirements and quality controls (piece by piece …)
- Equipped with redundant calibration/alignment hardware systems
- Prototypes and part of final modules extensively tested with test beams (allows also validation of Geant4 simulation)
- In situ calibration at the collider (accounts for material, global detector, B-field, long-range mis-calibrations and mis-alignments) includes :
  - -- cosmic runs : end 2006-beg 2007 during machine cool-down
  - -- beam-gas events, beam-halo muons during single-beam period
  - -- calibration with physics samples (e.g. Z→ ll, tt, etc.)



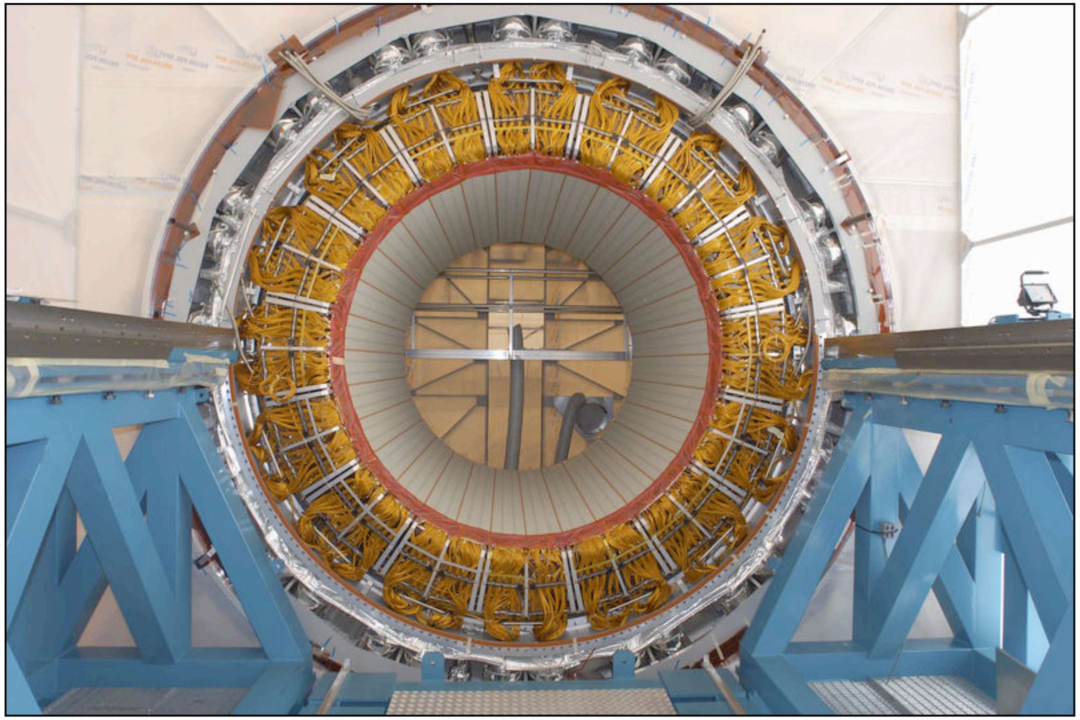
Longitudinal profile of 100 GeV test-beam pions in CMS HCAL

Test-beam π E- resolution ATLAS HAD end-cap calo



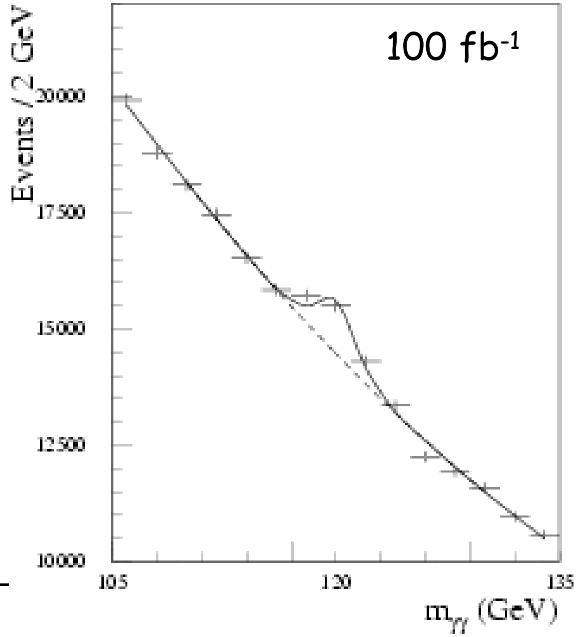
~ 70% /√E

Example of this procedure : ATLAS electromagnetic calorimeter



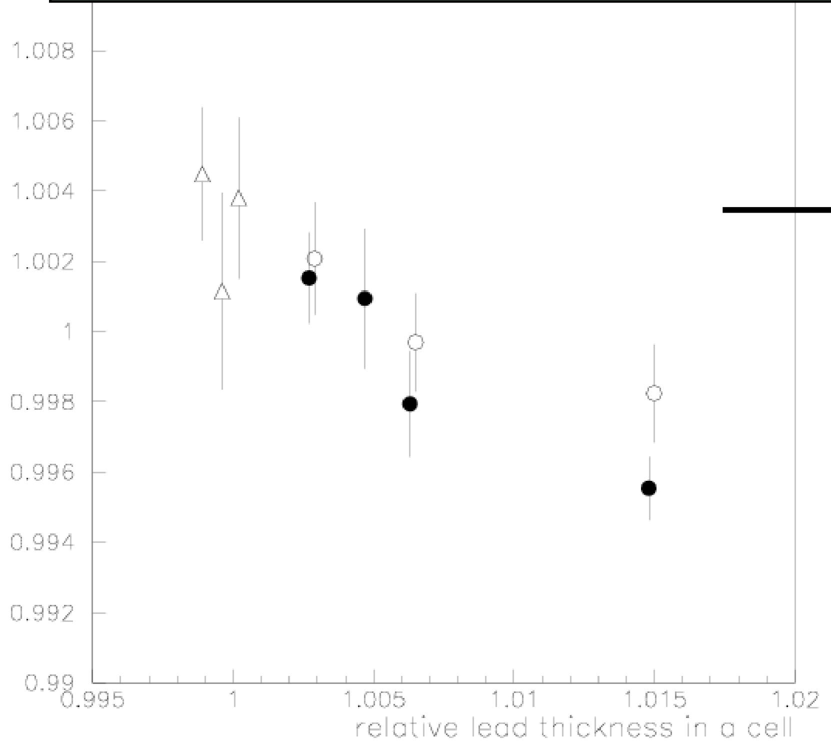
Pb-liquid argon sampling calorimeter with Accordion shape, covering $|\eta| < 2.5$

$H \rightarrow \gamma\gamma$: to observe signal peak on top of huge $\gamma\gamma$ background need mass resolution of ~ 1% → response uniformity (i.e. total constant term of energy resolution) $\leq 0.7\%$ over $|\eta| < 2.5$

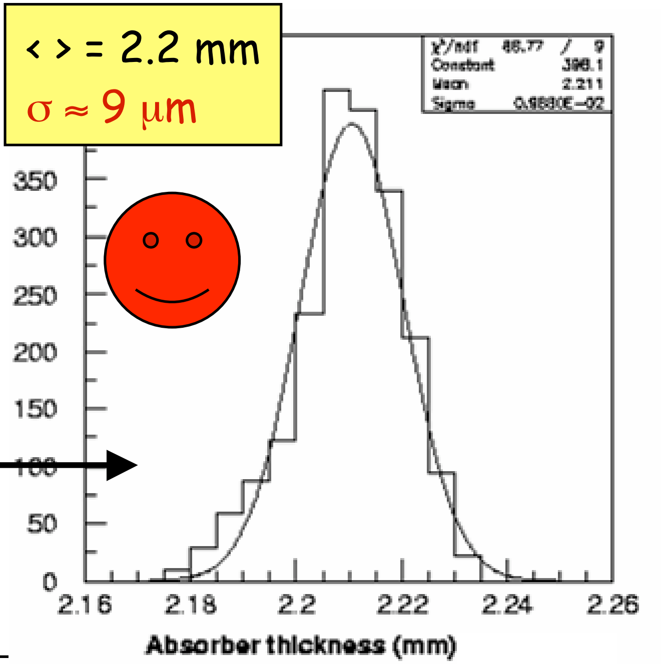


① Construction phase (e.g. mechanical tolerances):

287 GeV electron response variation with Pb thickness from '93 test-beam data



1% more lead in a cell → 0.7% response drop
→ to keep response uniform to 0.2-0.3%, thickness of Pb plates must be uniform to 0.5% (~ 10 μm)

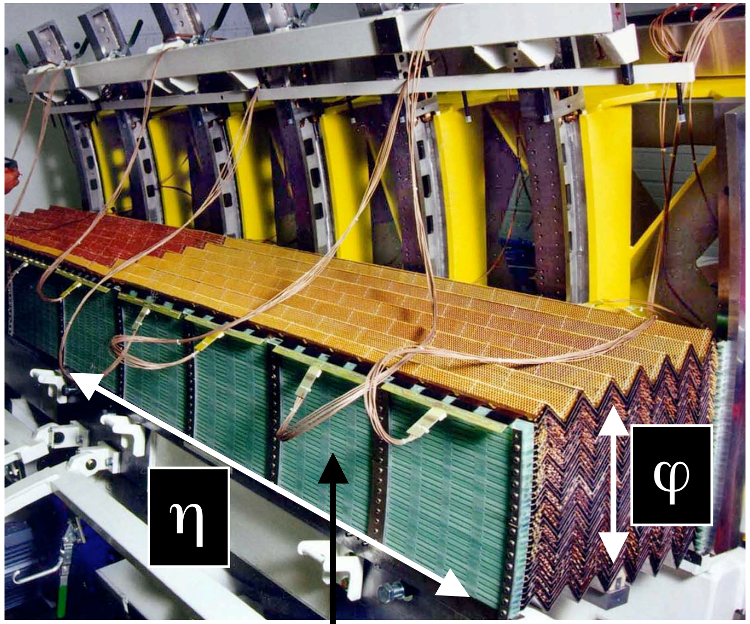


< > = 2.2 mm
$\sigma \approx 9\ \mu m$

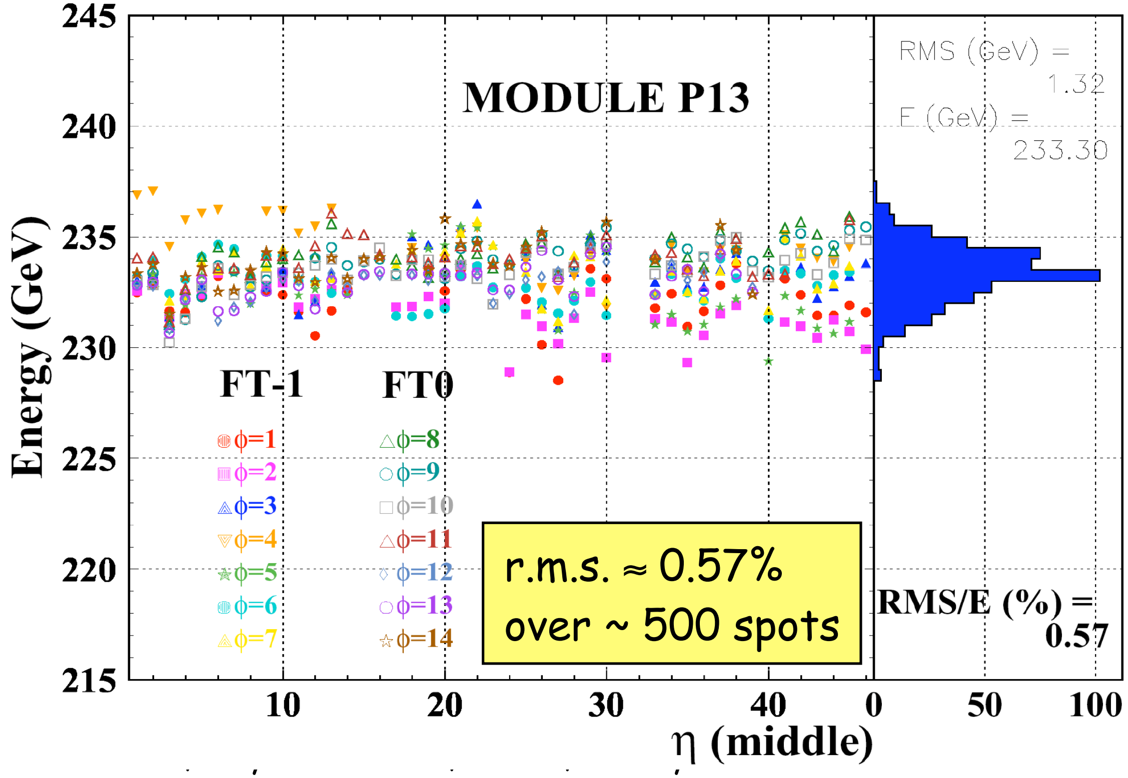
Thickness of all 1536 absorber plates (1.5m long, 0.5m wide) for end-cap calorimeter measured with ultrasounds during construction

② Beam tests of 4 (out of 32) barrel modules and 3 (out of 16) end-cap modules:

1 barrel module:
$\Delta\eta \times \Delta\varphi = 1.4 \times 0.4$
≡~ 3000 channels



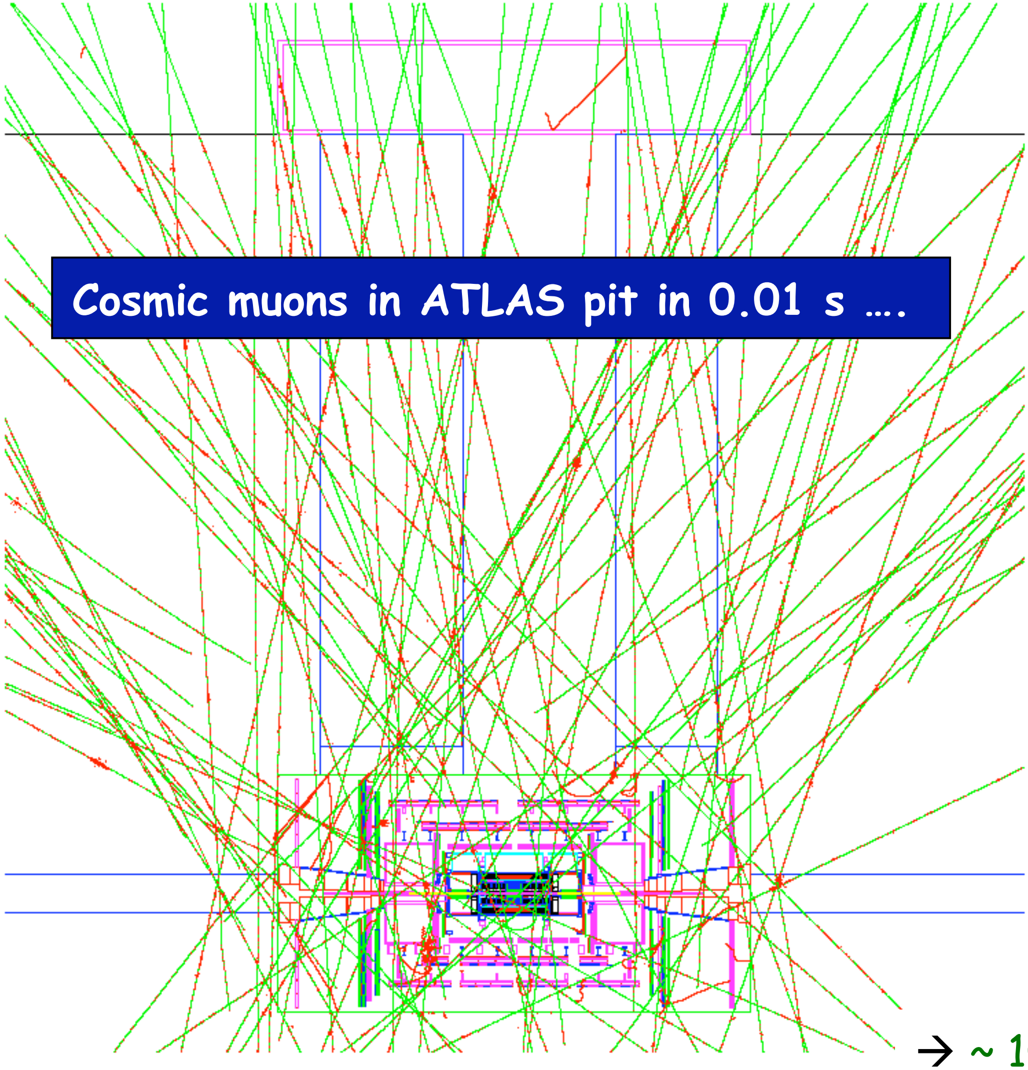
Scan of a barrel module with 245 GeV e^-



r.m.s. ≈ 0.57%
over ~ 500 spots

Uniformity over "units" of size
$\Delta\eta \times \Delta\varphi = 0.2 \times 0.4$: ~ 0.5%
400 such units over the full ECAL

③ Check calibration with cosmic muons:



Cosmic muons in ATLAS pit in 0.01 s ….

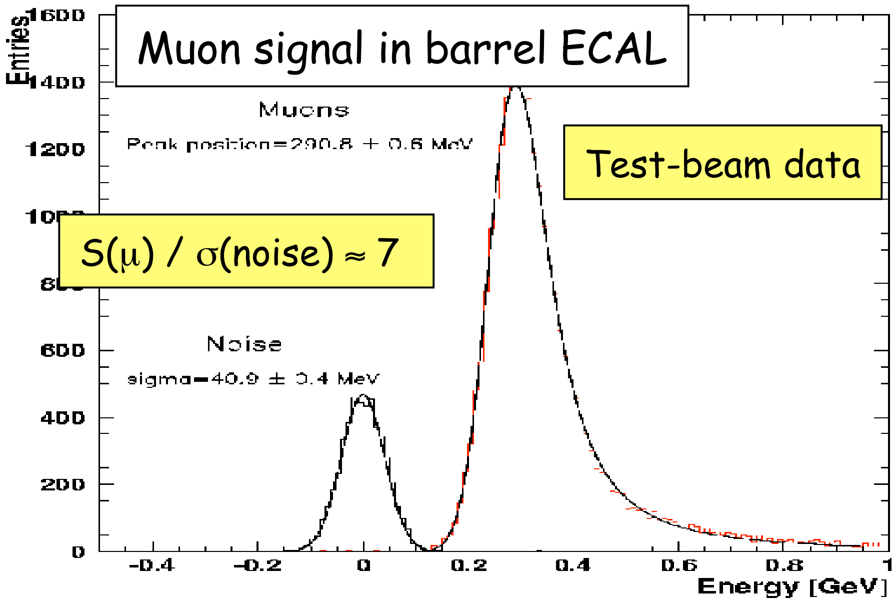
From full simulation of ATLAS (including cavern, overburden, surface buildings) + measurements with scintillators in the cavern:

Through-going muons (hits in ID + top and bottom muon chambers)	~ 25 Hz
Pass by origin (|z| < 60 cm, R < 20 cm, hits in ID)	~ 0.5 Hz
Useful for ECAL calibration (|z| < 30 cm, E_{cell} > 100 MeV, ~ 90^0)	~ 0.5 Hz

→ ~ 10^6 events in ~ 3 months of data taking

→ enough for initial detector shake-down

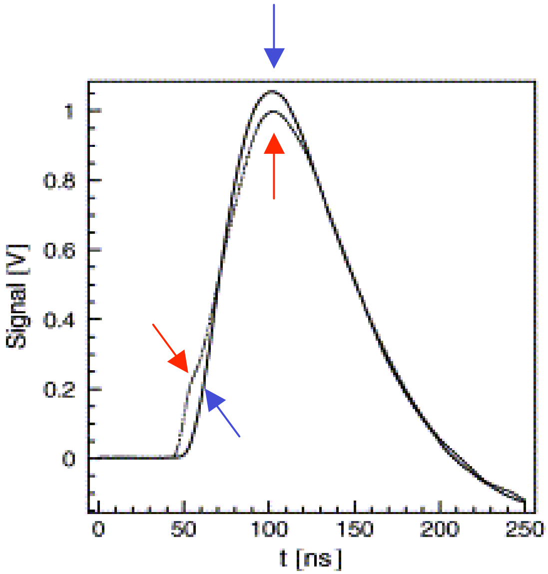
(catalog problems, gain operation experience, some alignment/calibration, detector synchronization, …)


Muon signal in barrel ECAL

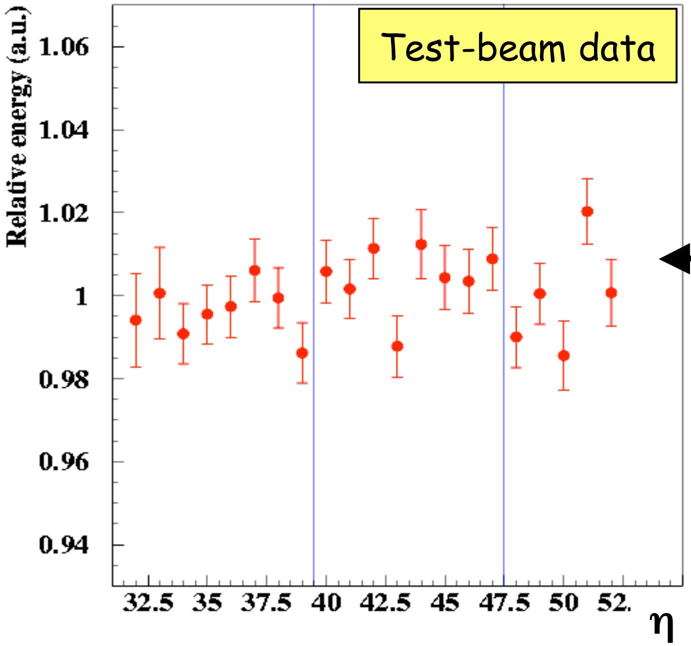
Test-beam data

$S(\mu) / \sigma(\text{noise}) \approx 7$

Precision of ECAL readout calibration system : 0.25%.
But : η-dependent differences between calibration and physics signals



→ can be checked with cosmic muons


Test-beam data

From studies with test-beam muons:
can check (and correct) calorimeter response variation vs η to 0.5% in < 3 months of cosmics runs

Note : not at level of ultimate calibration uniformity (~ 0.25%) but already a good starting point

④ First collisions : calibration with $Z \rightarrow ee$ events

rate ~ 1 Hz at 10^{33}, ~ no background, allows ECAL standalone calibration

$c_{tot} = c_L \oplus c_{LR}$

$c_L \approx 0.5\%$ demonstrated at the test-beam over units $\Delta\eta \times \Delta\varphi = 0.2 \times 0.4$

$c_{LR} \equiv$ long-range response non-uniformities from unit to unit (400 total)

(module-to-module variations, different upstream material, etc.)

Use $Z \rightarrow ee$ events and Z-mass constraint to correct long-range non-uniformities.

From full simulation : ~ 250 $e^{\pm}$ / unit needed to achieve $c_{LR} \leq 0.4\%$ → $c_{tot} = 0.5\% \oplus 0.4\% \leq 0.7\%$

~ 10^5 $Z \rightarrow ee$ events (few days of data taking at 10^{33})

Nevertheless, let's consider the worst (unrealistic ?) scenario : no corrections applied

- $c_L = 1.3\ \%$ measured "on-line" non-uniformity of individual modules
- $c_{LR} = 1.5\ \%$ no calibration with $Z \rightarrow ee$

$c_{tot} \approx 2\%$

conservative : implies very poor knowledge of upstream material (to factor ~2)

$H \rightarrow \gamma\gamma$ significance m_H~ 115 GeV degraded by ~ 25%

→ need 50% more L for discovery

❸ Physics goals and potential in the first year (a few examples ….)

Channels (examples …)	Events to tape for 10 fb^{-1} (per experiment)
$W \rightarrow \mu\,\nu$	7×10^7
$Z \rightarrow \mu\,\mu$	1.1×10^7
$tt \rightarrow W\,b\,W\,b \rightarrow \mu\,\nu + X$	0.08×10^7
QCD jets p_T>150	$\sim 10^7$
Minimum bias	$\sim 10^7$
$\tilde{g}\tilde{g}$ m = 1 TeV	$10^3 - 10^4$

assuming 1% of trigger bandwidth

~ 1 PB of data per year per experiment → challenging for software and computing (esp. at the beginning …)

➡ Already in first year, large statistics expected from:
-- known SM processes → understand detector and physics at $\sqrt{s}$ = 14 TeV
-- several New Physics scenarios

Note: overall event statistics limited by ~ 100 Hz rate-to-storage
~ 10^7 events to tape every 3 days assuming 30% data taking efficiency

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Goal # 1

Understand and calibrate detector and trigger in situ using well-known physics samples

e.g. - Z → ee, μμ tracker, ECAL, Muon chambers calibration and alignment, etc.
- tt → blν bjj 10^3 evts/day after cuts → jet scale from W→jj, b-tag perf., etc.

Understand basic SM physics at $\sqrt{s}$ = 14 TeV → first checks of Monte Carlos
(hopefully well understood at Tevatron and HERA)

†

e.g. - measure cross-sections for e.g. minimum bias, W, Z, tt, QCD jets (to ~ 10-20 %),
look at basic event features, first constraints of PDFs, etc.
- measure top mass (to 5-7 GeV) → give feedback on detector performance

Note : statistical error negligible after few weeks run

Goal # 2

Prepare the road to discovery:
-- measure backgrounds to New Physics : e.g. tt and W/Z+ jets (omnipresent …)
-- look at specific "control samples" for the individual channels:
e.g. ttjj with j ≠ b "calibrates" ttbb irreducible background to ttH → ttbb

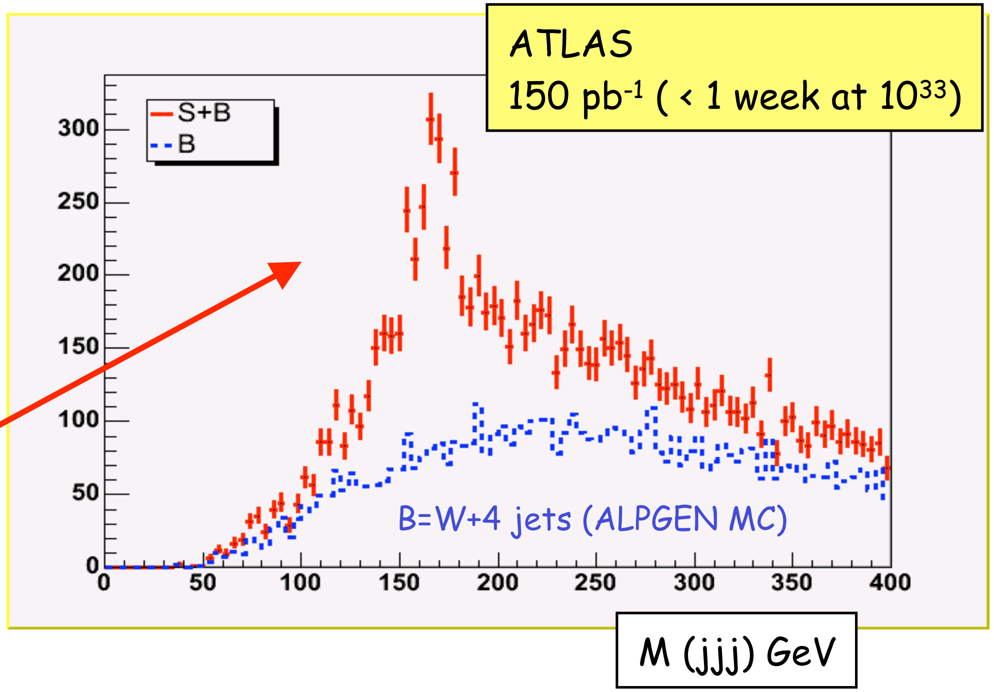
†

Goal # 3

Look for New Physics potentially accessible in first year (e.g. SUSY, some Higgs ? …)

Example of initial measurement : top signal and top mass

- Use gold-plated tt → bW bW → blν bjj channel
- Very simple selection:
  - -- isolated lepton (e, μ) $p_T > 20$ GeV
  - -- exactly 4 jets $p_T > 40$ GeV
  - -- no kinematic fit
  - -- no b-tagging required (pessimistic, assumes trackers not yet understood)
- Plot invariant mass of 3 jets with highest p_T



ATLAS
150 pb^{-1} (< 1 week at 10^{33})

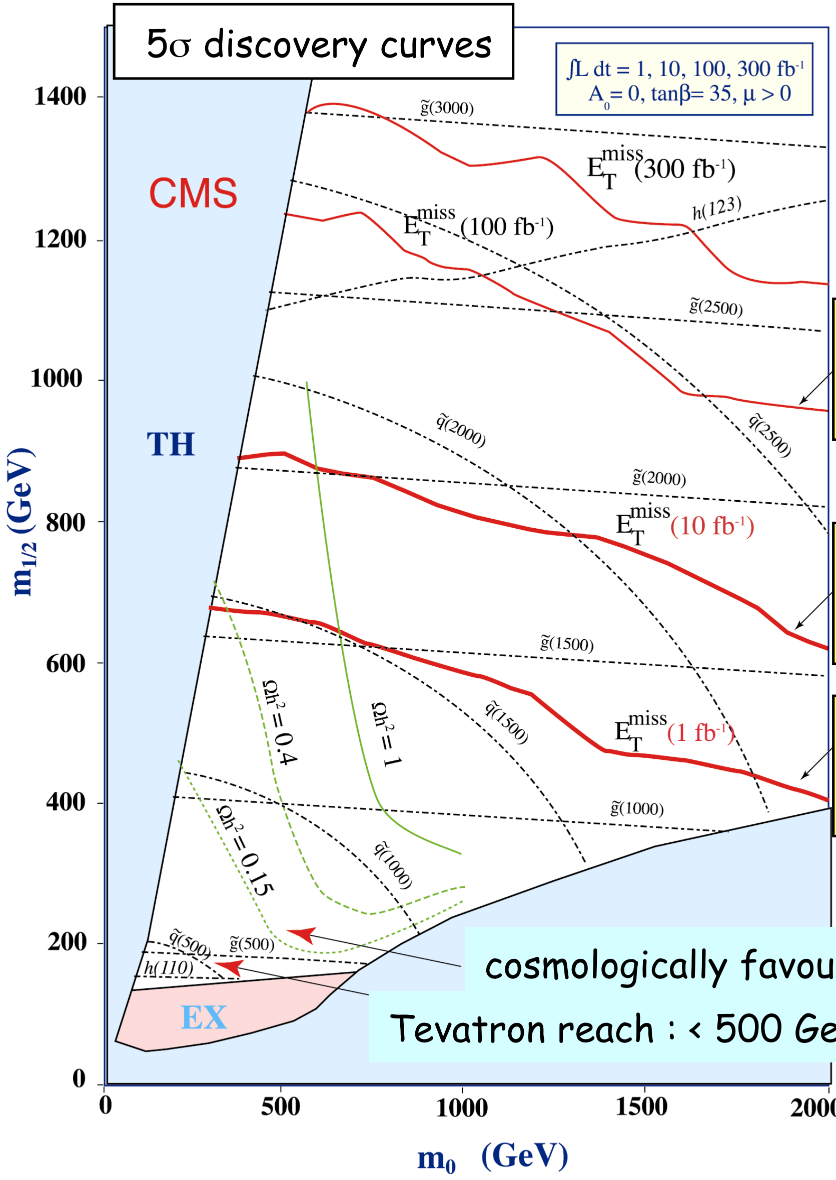
Time	Events at 10^{33}	Stat. error δM_{top} (GeV)	Stat. error $\delta\sigma/\sigma$
1 year	3×10^{5}	0.1	0.2%
1 month	7×10^{4}	0.2	0.4%
1 week	2×10^{3}	0.4	2.5%

- top signal visible in few days also with simple selection and no b-tagging
- cross-section to ~ 20% (10% from luminosity)
- top mass to ~7 GeV (assuming b-jet scale to 10%)
- get feedback on detector performance :
  m_{top} wrong → jet scale ?
  gold-plated sample to commission b-tagging

Example of possible early discovery : SUPERSYMMETRY

Large $\tilde{q}\tilde{q}, \tilde{q}\tilde{g}, \tilde{g}\tilde{g}$ cross-section → ≈ 100 events/day at 10^{33} for $m(\tilde{q}, \tilde{g}) \sim 1$ TeV

Spectacular signatures → SUSY could be found quickly



~ one year at 10^{34}:
up to ~2.5 TeV

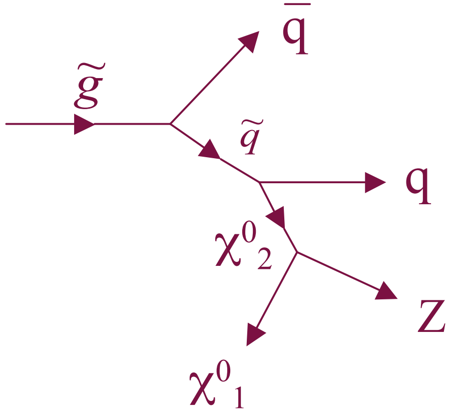
~ one year at 10^{33} :
up to ~2 TeV

~ one month at 10^{33} :
up to ~1.5 TeV

cosmologically favoured region

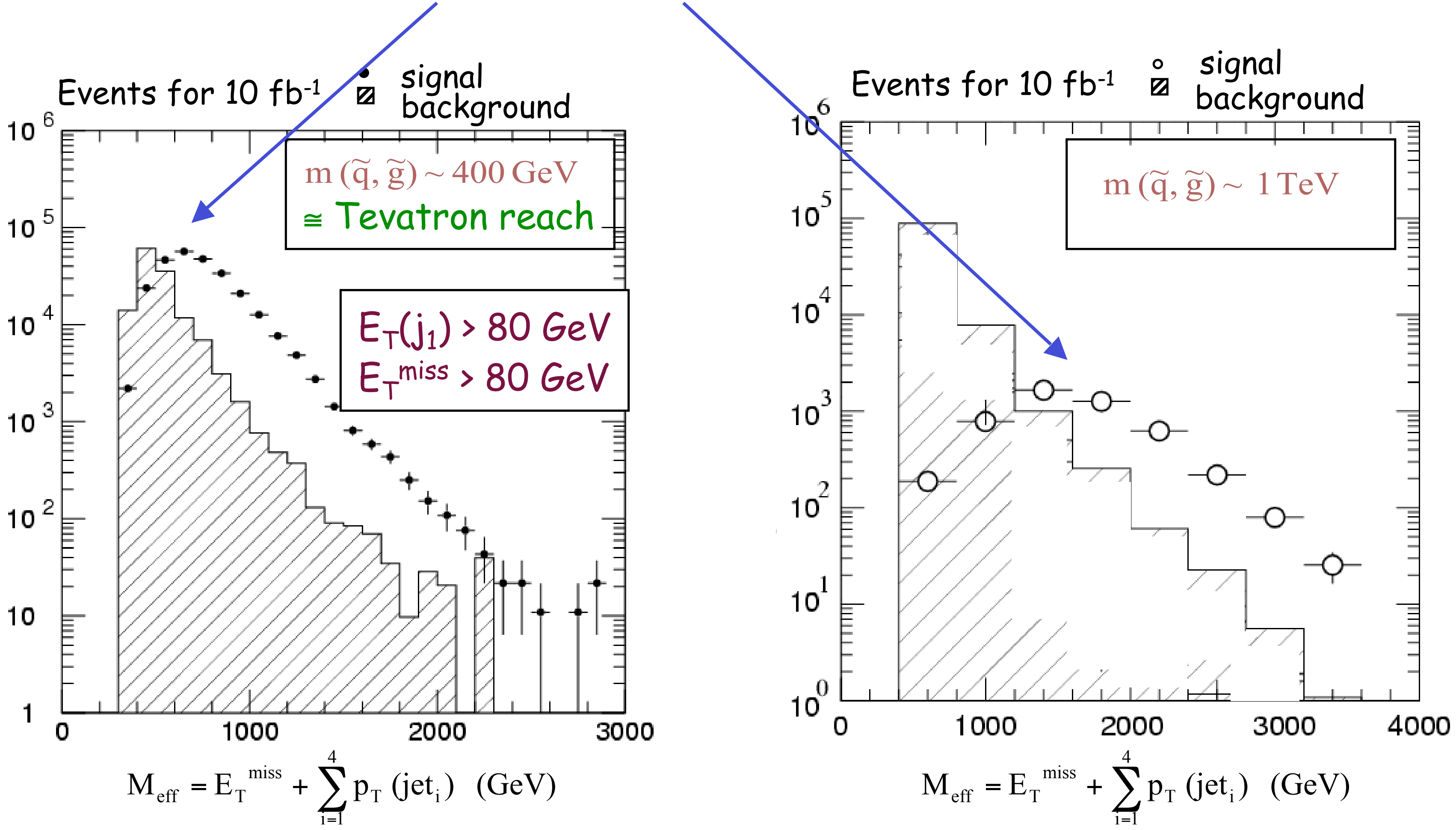
Tevatron reach : < 500 GeV

Using multijet + E_T^{miss} (most powerful and model-independent signature if R-parity conserved)



Measurement of sparticle masses likely requires > 1 year. However ...

Peak position correlated to $M_{SUSY} \equiv \min(m(\tilde{q}), m(\tilde{g}))$



ATLAS

From M_{eff} peak → first/fast measurement of SUSY mass scale to ≈ 20% (10 fb^{-1}, mSUGRA)

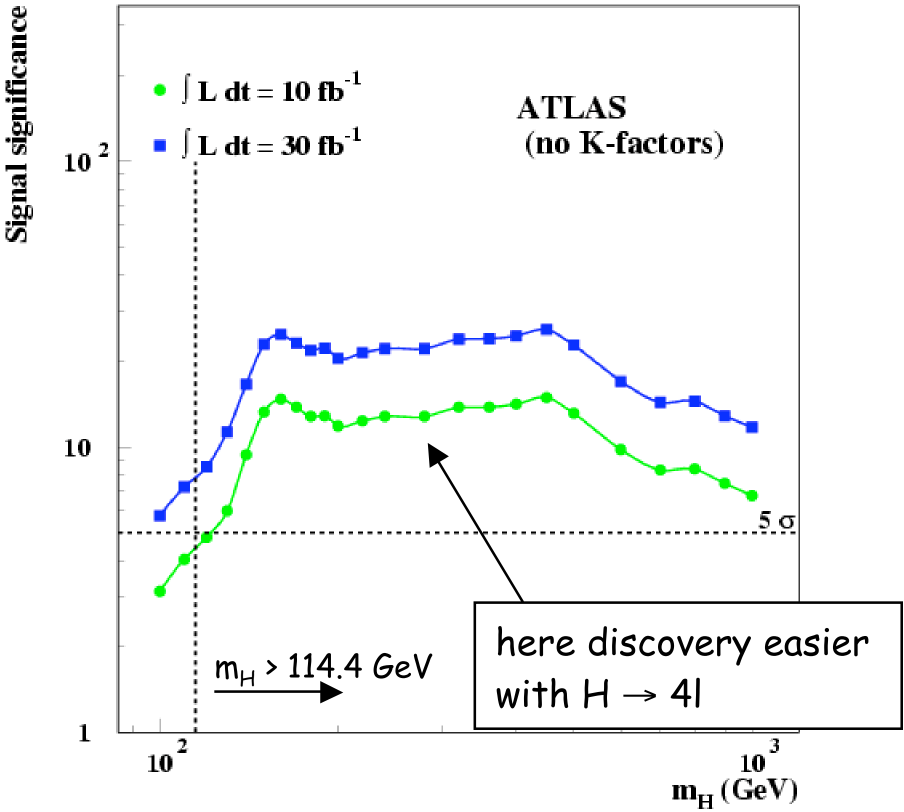
Detector/performance requirements:

-- quality of E_T^{miss} measurement (calorimeter inter-calibration, cracks)

→ use control samples (e.g. $Z \to ll$ +jets)

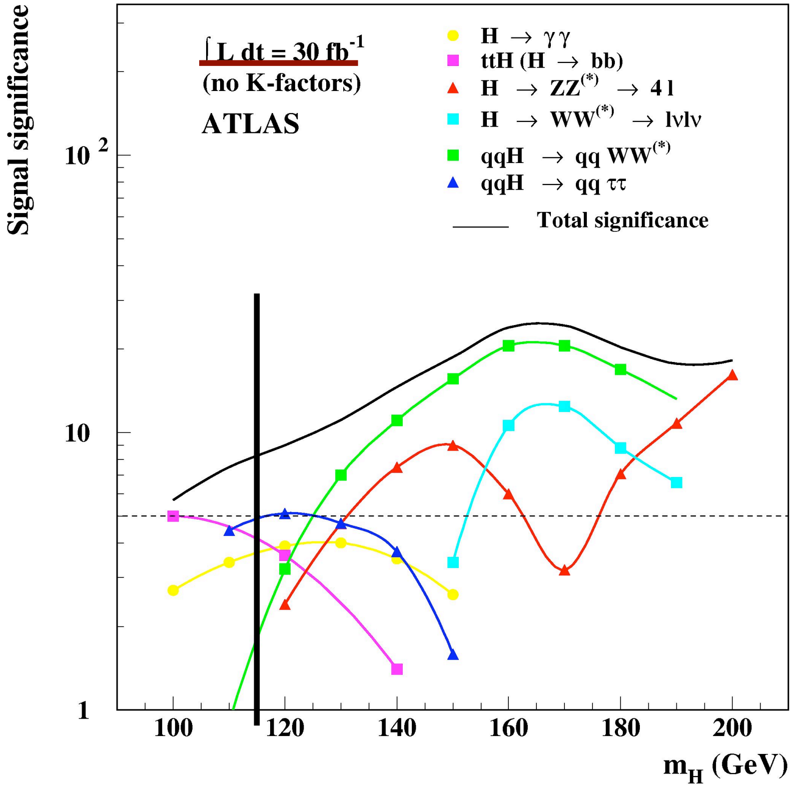
-- "low" Jet / E_T^{miss} trigger thresholds for low masses at overlap with Tevatron region (~400 GeV)

What about light Higgs (m_H ~ 115 GeV) ? Difficult in the first year ….



m_H > 114.4 GeV

here discovery easier with H → 4l



m_H ~ 115 GeV 10 fb^{-1}

ATLAS	$H \to \gamma\gamma$	$ttH \to ttbb$	$qqH \to qq\tau\tau$ (ll + l-had)
S	130	15	~ 10
B	4300	45	~ 10
S/ √B	2.0	2.2	~ 2.7

K-factors ≡ σ(NLO)/σ(LO) ≈ 2 not included

total $S/\sqrt{B} \approx 4^{+2.2}_{-1.3}$

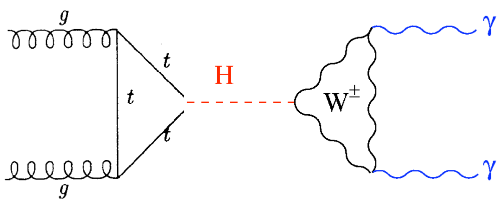
Full GEANT simulation, simple cut-based analyses

Remarks:

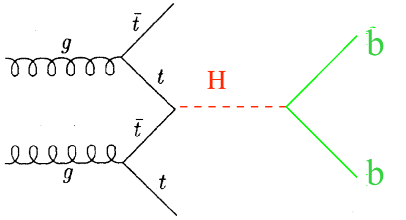
Each channel contributes $\sim 2\sigma$ to total significance → observation of all channels important to extract convincing signal in first year(s)

The 3 channels are complementary → robustness:

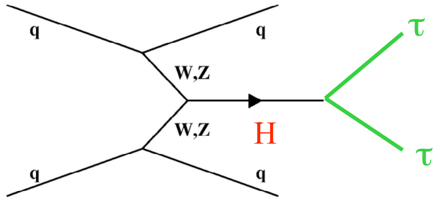
$H \to \gamma\gamma$



$t\bar{t}H \to t\bar{t}\, b\bar{b} \to bl\nu\, bjj\, b\bar{b}$



$qqH \to qq\tau\tau$



- different production and decay modes
- different backgrounds
- different detector/performance requirements:
  - -- ECAL crucial for $H \to \gamma\gamma$ (in particular response uniformity) : $\sigma/m \sim 1\%$ needed
  - -- b-tagging crucial for $t\bar{t}H$: 4 b-tagged jets needed to reduce combinatorics
  - -- efficient jet reconstruction over $|\eta| < 5$ crucial for $qqH \to qq\tau\tau$: forward jet tag and central jet veto needed against background

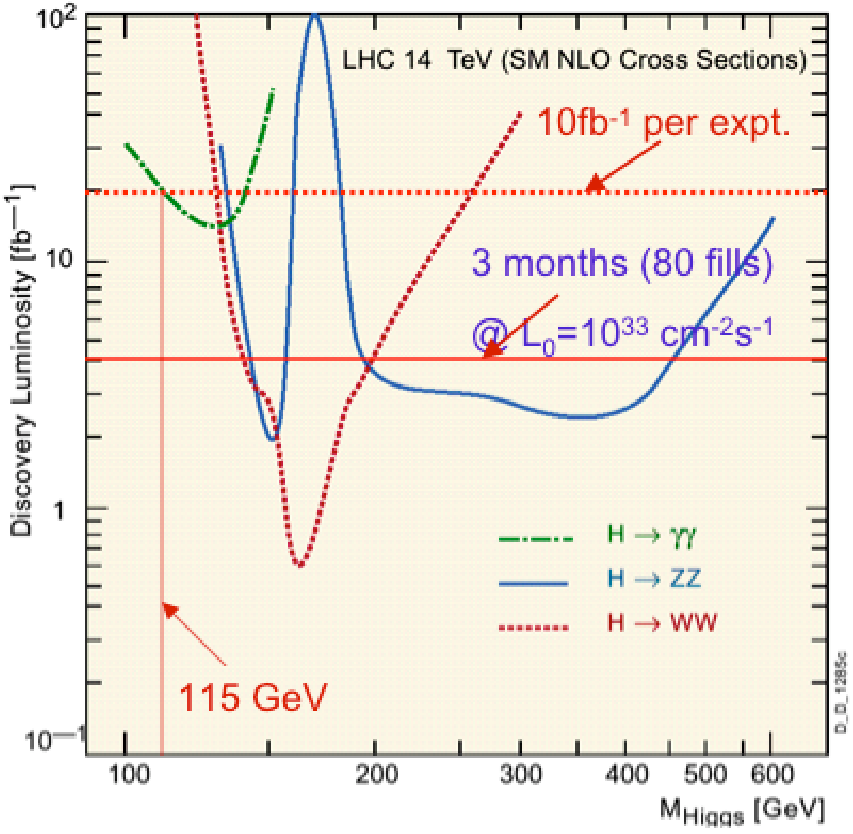
Note : -- all require "low" trigger thresholds

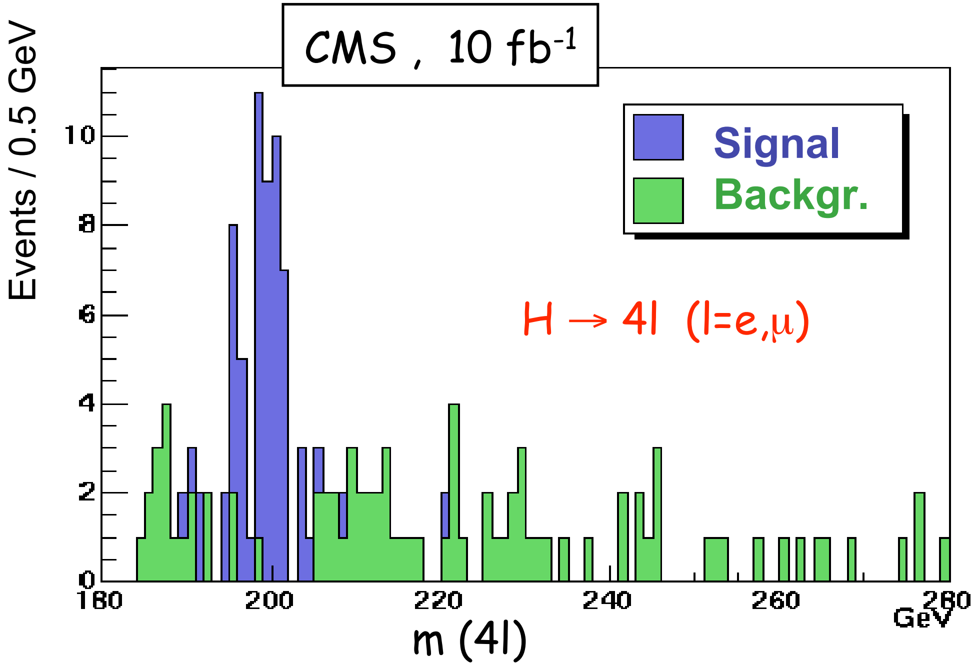
E.g. ttH analysis cuts : p_T (l) > 20 GeV, p_T (jets) > 15-30 GeV

-- all require very good understanding (1-10%) of backgrounds

If $m_H > 180$ GeV : early discovery may be easier with $H \to 4l$ channel

Luminosity needed for 5σ discovery (ATLAS+CMS)





- $H \to WW \to l\nu\, l\nu$: high rate (~ 100 evts/expt) but no mass peak → not ideal for early discovery …
- $H \to 4l$: low-rate but very clean : narrow mass peak, small background

Requires: -- ~ 90% e, μ efficiency at low p_T (analysis cuts : $p_T^{1,2,3,4} > 20, 20, 7, 7$, GeV)

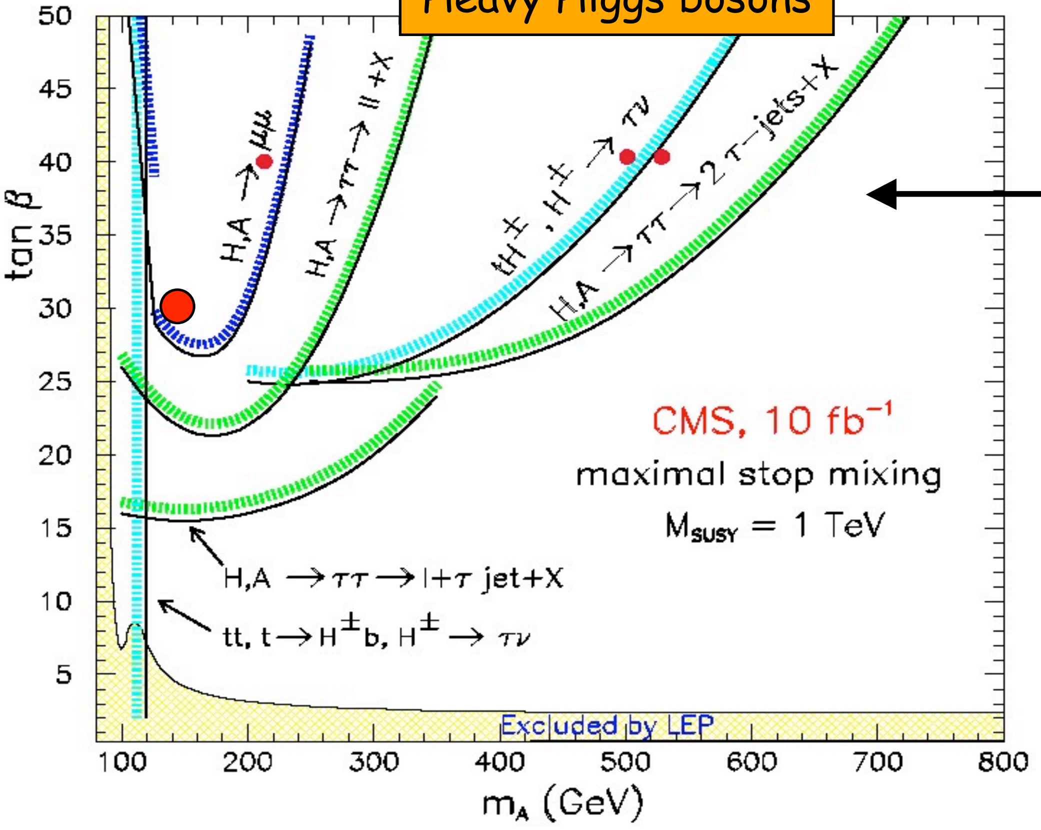
-- $\sigma/m \sim 1\%$, tails < 10% → good quality of E, p measurements in ECAL and tracker

MSSM Higgs bosons : h, H, A, $H^{\pm}$

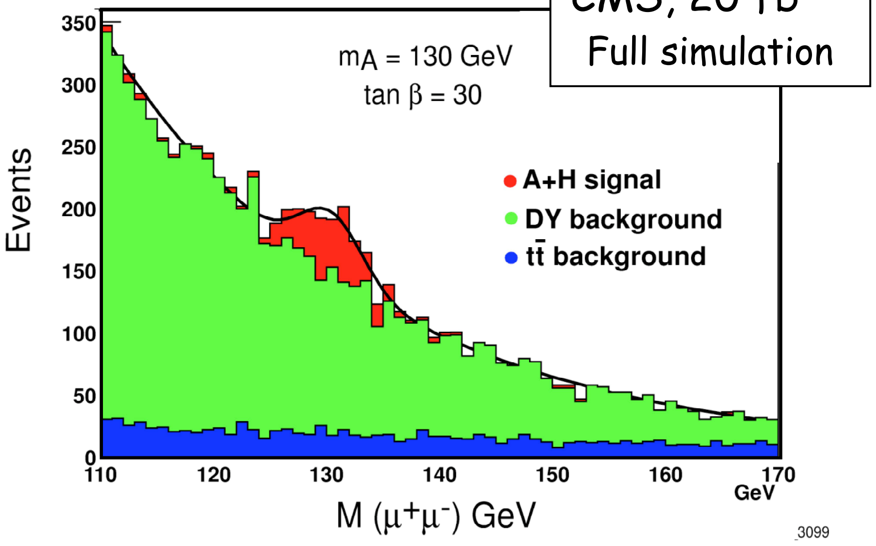
$m_h < 135$ GeV
$m_A \approx m_H \approx m_{H\pm}$ at large m_A

h : similar to SM Higgs over most of the allowed region

Heavy Higgs bosons



-- bbA, bbH, $H^{\pm}$ cross-section ~ $tg^2\beta$
-- best sensitivity from A/H → ττ, $H^{\pm}$ → τν
(not easy the first year ...)
-- A/H → μμ experimentally easier
(esp. at the beginning)



CMS, 20 fb^{-1}
Full simulation

Requires non-ultimate b-tagging (one jet), and non-ultimate tracking resolution (A/H intrinsic width non negligible)

Conclusions

- LHC has potential for major discoveries already in the first year (months ?) of operation
  Event statistics : 1 day at LHC at 10^{33} $\equiv$ 10 years at previous machines for SM processes
  SUSY may be discovered "quickly", light Higgs more difficult … and what about surprises ?

- Machine luminosity performance will be the crucial issue in first year(s)

- Experiments: lot of emphasis on test beams and on construction quality checks
  → results indicate that detectors "as built" should give good starting-point performance.

- However: lot of data (and time …) will be needed at the beginning to:
  -- commission the detector and trigger in situ (and the software …)
  -- reach the performance needed to optimize the physics potential
  -- understand standard physics at $\sqrt{s}$ = 14 TeV and compare to MC predictions
  [Tevatron (and HERA) data crucial to speed up this phase …]
  -- measure backgrounds to possible New Physics (with redundancy from several samples …)

- Efficient/robust commissioning with physics data in the various phases
  (cosmics, one-beam period, first collisions, …) is our next challenge
  Crucial to reach quickly the "discovery-mode" and extract a convincing "early" signal

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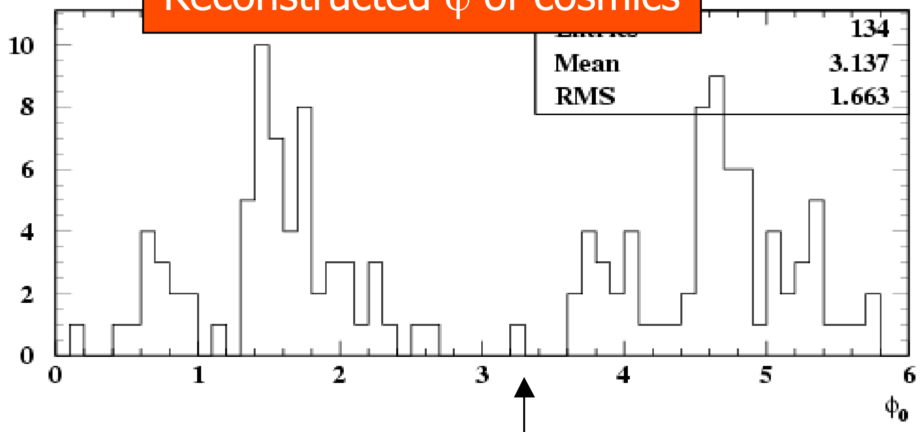
Back-up slides

Commissioning ID with cosmics and beam gas (preliminary ideas …)

Cosmics : O (1Hz) tracks in Pixels+SCT+TRT

- useful statistics for debugging readout, maps of dead modules, etc.
- check relative position Pixels/SCT/TRT and of ID wrt ECAL and Muon Spectrometer
- first alignment studies: may achieve statistical precision of ~ 10 μm in parts of Pixels/SCT
- first calibration of R-t relation in straws

Reconstructed φ of cosmics



standard ATLAS patt. rec.
(no optimisation for cosmics …)

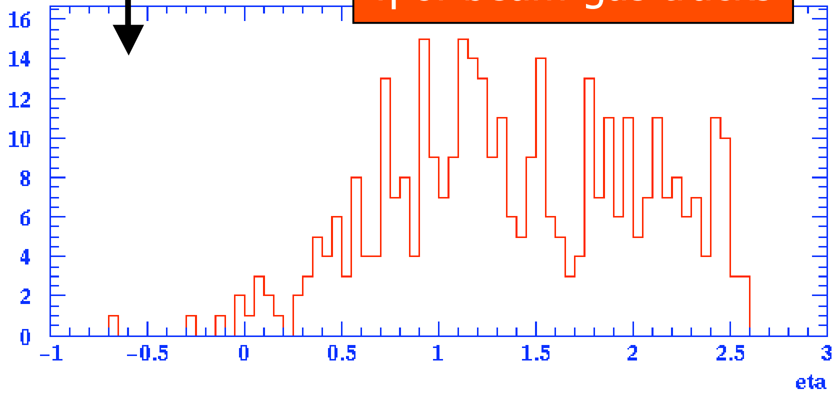
Beam-gas :

- ~ 25 Hz of reconstructed tracks with $p_T > 1$ GeV and |z|<20 cm

→ $>10^7$ tracks (similar to LHC events) in 2 months

- enough statistics for alignment in "relaxed" environment → exceed initial survey precision of 10-100 μm

η of beam-gas tracks



LVL1 menus and rates (indicative only …)

	ATLAS		CMS	
L = $2*10^{33}$ cm^{-2} s^{-1}	**Threshold** (GeV)	**Rate** (kHz)	**Threshold** (GeV)	**Rate** (kHz)
Inclusive muon	20	0.8	14	2.7
Two muons	6	0.2	3	0.9
Inclusive electron	25	12.0	29	3.3
Two electrons	15	4.0	17	1.3
1 Jet, 3 Jet, 4 Jet	200, 90, 65	0.6	177, 86,70	3.0
Jet + E_T^{miss}	60-60	0.4	88-46	2.3
tau + E_T^{miss}	25-30	2.0		
Inclusive tau			86	2.2
Two taus			59-59	1.0
Elecron + Jet			21-45	0.8
Others (pre-scaled, calibration, …)		5.0		0.9
Total		**~ 25** **(no safety margin)**		**~16** **(factor ~3 safety margin)**

→ B-physics programme strongly reduced (e.g. B → J/ψ (→ ee) K^0_S , hadronic channels)

-- HLT/DAQ deferrals limit available networking and computing for HLT → limit LVL1 output rate
-- Large uncertainties on LVL1 affordable rate vs money (component cost, software performance, etc.)

Selections (examples ...) Real thresholds set for 95% efficiency at these E_T	LVL1 rate (kHz) $L= 1 \times 10^{33}$ no deferrals	LVL1 rate (kHz) $L= 2 \times 10^{33}$ no deferrals	LVL1 rate (kHz) $L= 2 \times 10^{33}$ with deferrals An example for illustration...
MU6,8,20	23	→ 19	→ 0.8
2MU6	---	0.2	0.2
EM20i,25,25	11	→ 12	→ 12
2EM15i,15,15	2	4	4
J180,200,200	0.2	0.2	0.2
3J75,90,90	0.2	0.2	0.2
4J55,65,65	0.2	0.2	0.2
J50+xE50,60,60	0.4	0.4	0.4
TAU20,25,25 +xE30	2	2	2
MU10+EM15i	---	0.1	0.1
Others (pre-scaled, etc.)	5	5	5
Total	~ 44	~ 43	~ 25

LVL1 designed for 75 kHz
→ room for factor ~ 2 safety

Likely max affordable rate,
no room for safety factor

❸ Which data samples ?

Total trigger rate to storage at 2×10^{33} reduced from ~ 540 Hz (HLT/DAQ TP, 2000) to ~ 200 Hz (now)

High-Level-Trigger output

⬇

Selection (examples …)	Rate to storage at 2×10^{33} (Hz)	Physics motivations (examples …)
e25i, 2e15i	~ 40 (55% W/b/c → eX)	Low-mass Higgs (ttH, H→ 4λ, qqττ)
μ20i, 2μ10	~ 40 (85% W/b/c → μX)	W, Z, top, New Physics ?
γ60i, 2γ20i	~ 40 (57% prompt γ)	H → γγ, New Physics (e.g. X → γ yy m_X~ 500 GeV) ?
j400, 3j165, 4j110	~ 25	Overlap with Tevatron for new X → jj in danger …
j70 + xE70	~ 20	SUSY : ~ 400 GeV squarks/gluinos
τ35 + xE45	~ 5	MSSM Higgs, New Physics (3rd family !) ? More difficult high L
2μ6 (+ m_B)	~ 10	Rare decays B → μμX
Others	~ 20	Only 10% of total !
(pre-scaled, exclusive, …)		
Total	~ 200	No safety factor included.

"Signal" (W, γ, etc.) : ~ 100 Hz

Best use of spare capacity when L < 2×10^{33} being investigated

Impact also on high-p_T physics : ~ no safety margin left

Main impact expected on light Higgs

To include factor ~ 2 safety (e.g. QCD cross-sections likely higher than expected) should limit rate to ~ 10 kHz (!) :

- must raise EM trigger thresholds, e.g. :
  - from 2EM15i (4 kHz) to 2EM20i (1 kHz) → what about light H → 4e (p_T>20,20,7,7 GeV) ?
  - from EM25i (12 kHz) to EM30i (4.5 kHz)
- and/or must use less inclusive selections
  - → what about total rate when summing all possible channels ? E.g.
  - → what about biases (e.g. final states with low-p_T jets, small E_T^{miss}) ?
  - → what about unknown discovery physics ?
- must decrease pre-scaled/control triggers (note : should rather be increased if higher thresholds and more exclusive menus)

EM25i + 2J30	4 kHz
EM25i + xE15	7 kHz
EM25i + tau35	?
EM25i + ?	?
Total	> 9 kHz

OR= 9 kHZ

qqH →ττ

not much smaller than EM25i (12 kHz) !

ttH → lν bb + X m_H= 120 GeV

Thresholds (GeV)	Normalised S/√B
p_T (e) > 20, p_T (μ) > 20	1
p_T (e) > 25, p_T (μ) > 20	0.98
p_T (e) > 30, p_T (μ) > 20	0.96
p_T (e) > 30, p_T (μ) > 30	0.92
p_T (e) > 35, p_T (μ) > 25	0.92

Physics TDR (reference)

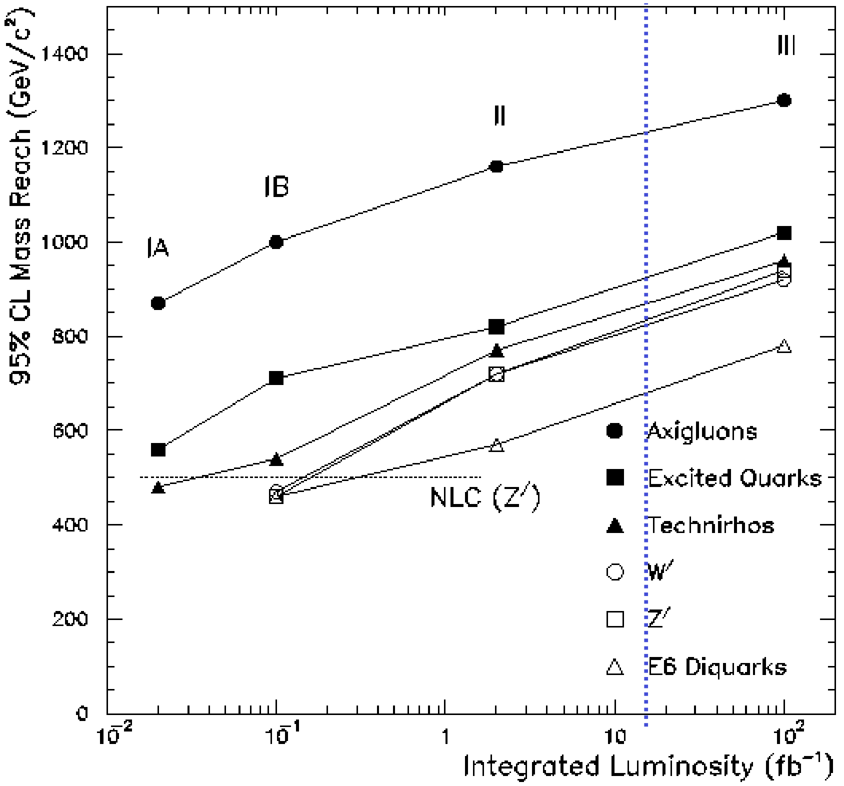
with deferrals depending on e.g. QCD cross-sections

Note : ~ 8% loss from pixel staging not included

Jet triggers already at the limit for overlap with Tevatron

E.g. : New particles decaying into two jets

CDF : 95% C.L. mass reach



CDF/D0 reach for 15 fb^{-1}:

m ~ 700-1200 GeV (95% C.L.)

→ Jacobian peak at p_T (jet) ~ 350-600 GeV

ATLAS :

single-jet trigger threshold : p_T = 400 GeV

di-jet trigger threshold : p_T = 350 GeV ?

Relevant issues for early discovery:

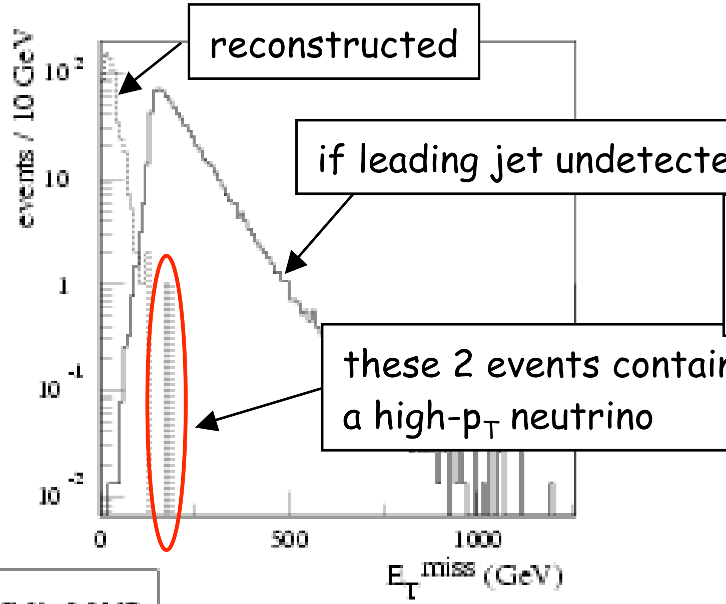
-- J70+xE70 thresholds for unprescaled triggers

-- enough pre-scaled lower-threshold triggers to normalize B

-- quality of E_T^{miss} measurement (calorimeter inter-calibration, cracks)

Cracks can be monitored with Z (→ ll) + jets

B rejection tools:
E_T^{miss} isolation, removal of jets in cracks

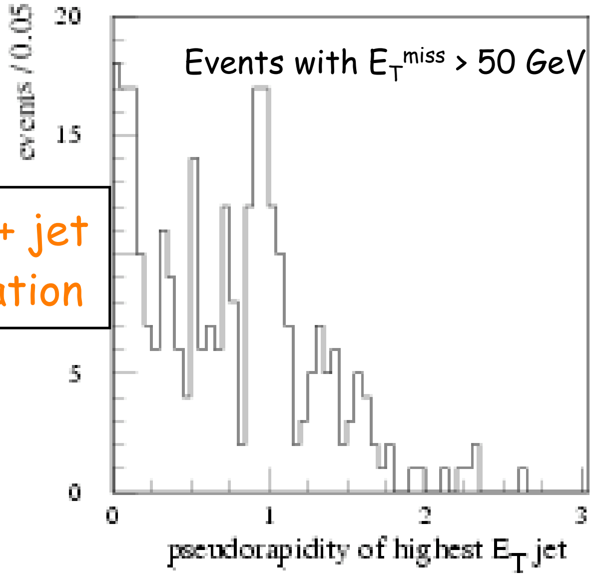


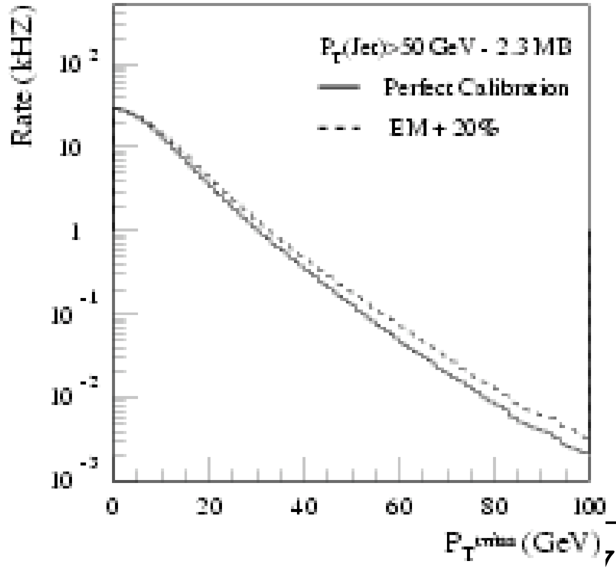
reconstructed

if leading jet undetected

these 2 events contain a high-p_T neutrino

Z (→ μμ) + jet full simulation

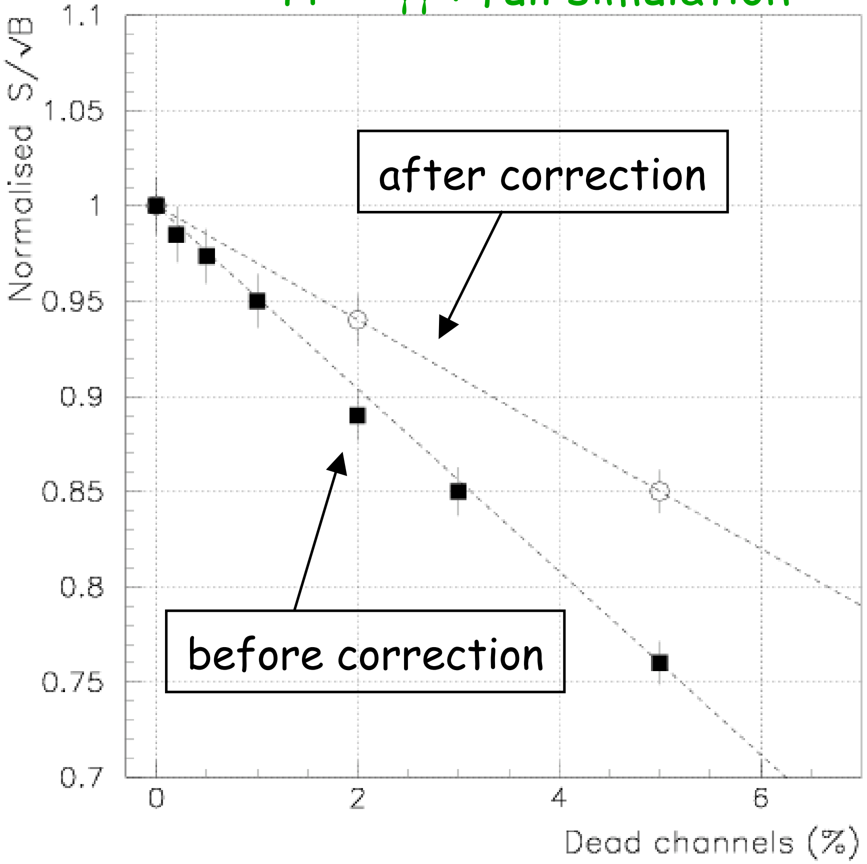




"Poor" initial calorimeter calibration may increase trigger rates → impact on low-mass SUSY

Uncorrected non-compensation simulated by + 20% enhancement of EM scale → + 50% rate for E_T^{miss} > 80 GeV

What about dead channels ?



H → γγ : full simulation

after correction

before correction

Requirement : fraction of dead channels < 0.3%
Measurements of the final assembled ECAL
(at warm and cold) gave : ~ 0.1% of dead channels

Summary of physics impact of staging initial detector

Staged items	Main impact during first run on	Effect
1 pixel layer	ttH → ttbb	~8% loss in significance
Gap scintillator	H → 4e	~8% loss in significance
MDT	A/H → 2μ	~5% loss in significance for m~ 300 GeV
Trigger processors	B-physics → High-p_T physics →	program jeopardised no safety margin (e.g. for EM triggers)

Requires 10-15% more integrated luminosity to compensate.

Complete detector needed at high luminosity:

-- robust pattern recognition (efficiency, fakes rate) in the presence of pile-up and radiation background
-- muon measurement } at (very) high p_T
-- powerful b-tag
-- robustness against detector aging and $L > 10^{34}$
-- precise measurements (e.g. light Higgs) may require low trigger thresholds

Data samples for calibration and control

❶ Well-known, clean processes from standard trigger menu: e.g. tt, $Z \rightarrow ll$

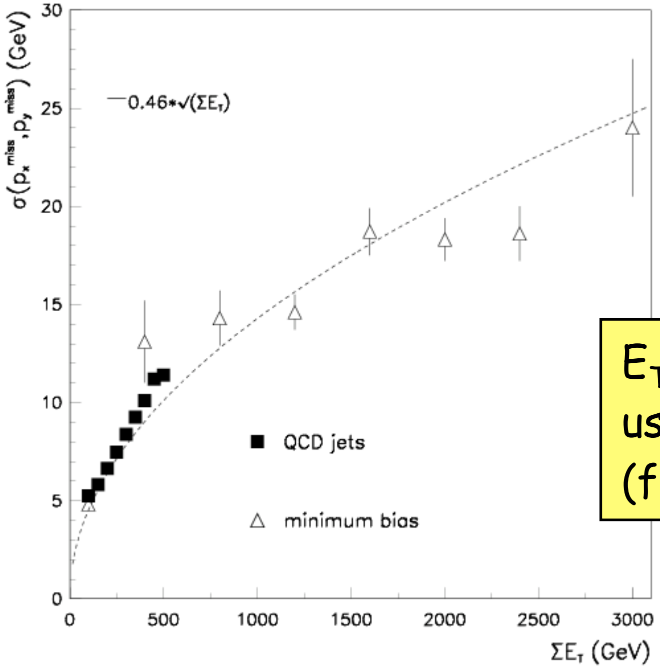
❷ Additional lower-thresholds samples needed (esp. at the beginning) → pre-scaled triggers

- Minimum-bias events: pp interaction properties, MC tuning, LVL1 efficiency, radiation background in Muon chambers, etc.
- QCD jets ($20 \leq E_T \leq 400$ GeV) : QCD cross-sections and MC tuning, trigger efficiency, calorimeter inter-calibration, jet algorithms, background to Higgs, SUSY, etc.
- Inclusive $e^{\pm}$ $p_T > 10$ GeV : trigger efficiency, ECAL calibration, ID alignment, E/p, $e^{\pm}$ reconstruction at low-p_T, etc.

efficiency, $\mu^{\pm}$ reconstruction at low-p_T,
n calorimeters, ID alignment, etc.

These are only few examples …

~ 10^7 events per sample



E_T^{miss} resolution vs ΣE_T using minimum-bias and QCD jets (full GEANT3 simulation)

Rate :
~ 10 Hz/sample first weeks
~ few Hz/sample under normal operation

≥ 10% of total rate

Which physics the first year(s) ?

Expected event rates at production in ATLAS or CMS at L = 10^{33} cm^{-2} s^{-1}

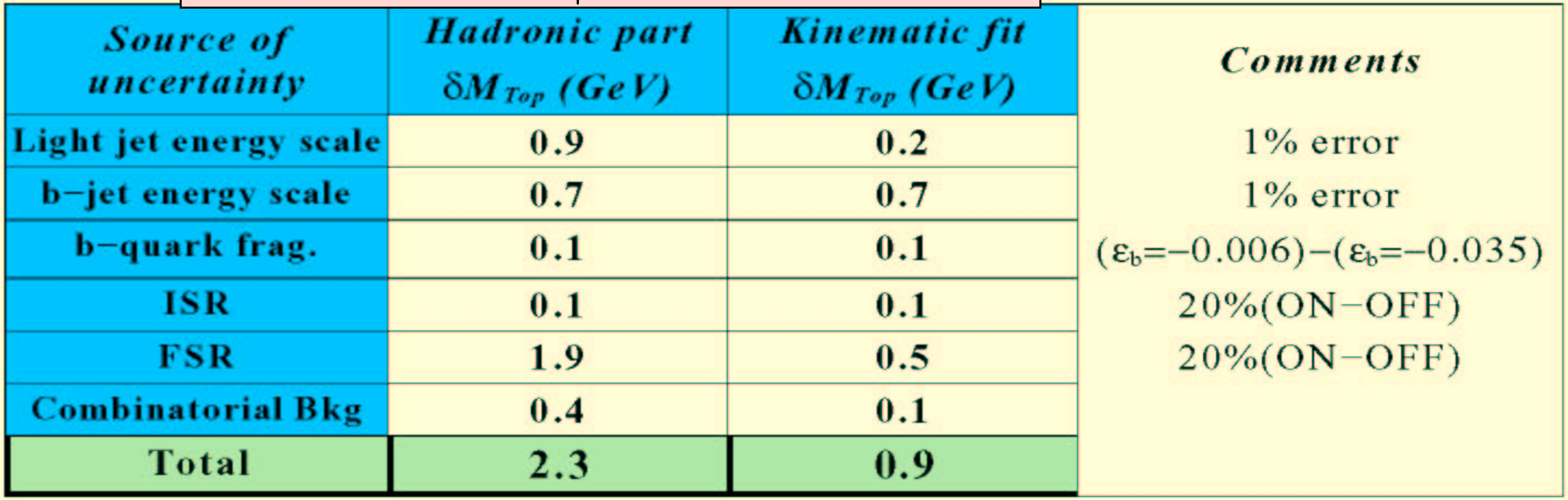
Process	Events/s	Events for 10 fb^{-1}	Total statistics collected at previous machines by 2007
$W \to e\nu$	15	10^8	10^4 LEP / 10^7 Tevatron
$Z \to ee$	1.5	10^7	10^6 LEP
$t\bar{t}$	1	10^7	10^4 Tevatron
$b\bar{b}$	10^6	10^{12} – 10^{13}	10^9 Belle/BaBar ?
H m=130 GeV	0.02	10^5	?
$\tilde{g}\tilde{g}$ m= 1 TeV	0.001	10^4	---
Black holes m > 3 TeV (M_D=3 TeV, n=4)	0.0001	10^3	---

➡ Already in first year, large statistics expected from:

-- known SM processes → understand detector and physics at √s = 14 TeV

-- several New Physics scenarios

Systematic error on m_{top} (TDR performance, 10 fb^{-1})



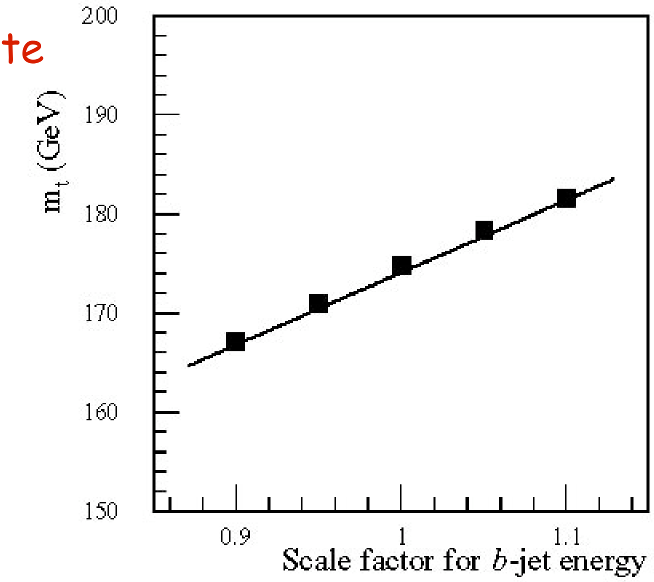
Source of uncertainty	*Hadronic part* δM_{Top} *(GeV)*	*Kinematic fit* δM_{Top} *(GeV)*	*Comments*
Light jet energy scale	0.9	0.2	1% error
b−jet energy scale	0.7	0.7	1% error
b−quark frag.	0.1	0.1	$(\varepsilon_b=-0.006)-(\varepsilon_b=-0.035)$
ISR	0.1	0.1	20%(ON−OFF)
FSR	1.9	0.5	20%(ON−OFF)
Combinatorial Bkg	0.4	0.1	
Total	**2.3**	**0.9**	

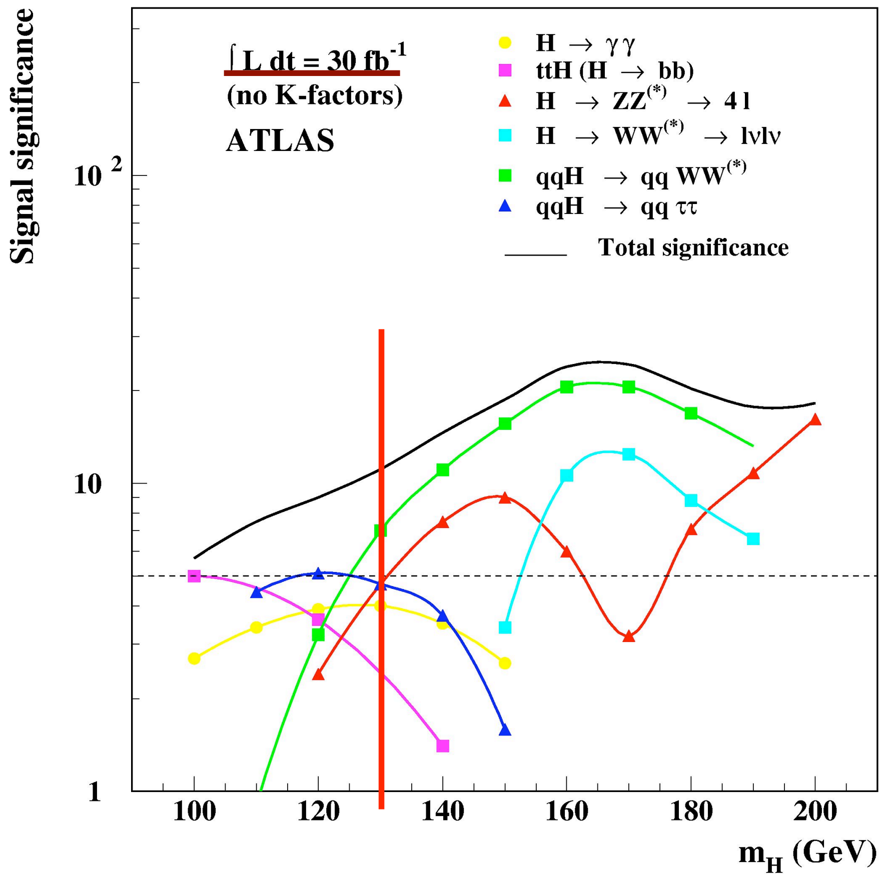
Initial performance : uncertainty on b-jet scale expected to dominate

b-jet scale uncertainty	δ m (top)
1%	0.7 GeV
5%	3.5 GeV
10%	7 GeV

Cfr: 10% on q-jet scale + m_W (PDG) → 3 GeV on m(top)

Initial δ m (top) ~ 5-7 GeV ?





m_H ~ 130 GeV 10 fb^{-1}

λ= e,μ

	$H \to \gamma\gamma$	$qqH \to qq\tau\tau$ (ll + l-had)	$H \to 4l$	$qqH \to qqWW$
S	120	~ 8	~ 5	18
B	3400	~ 6	< 1	15
S/ √B	2.0	~ 2.7	2.8	3.9

↑ K – factor ≈ 2 not included ↑

total S/√B ≈ 6

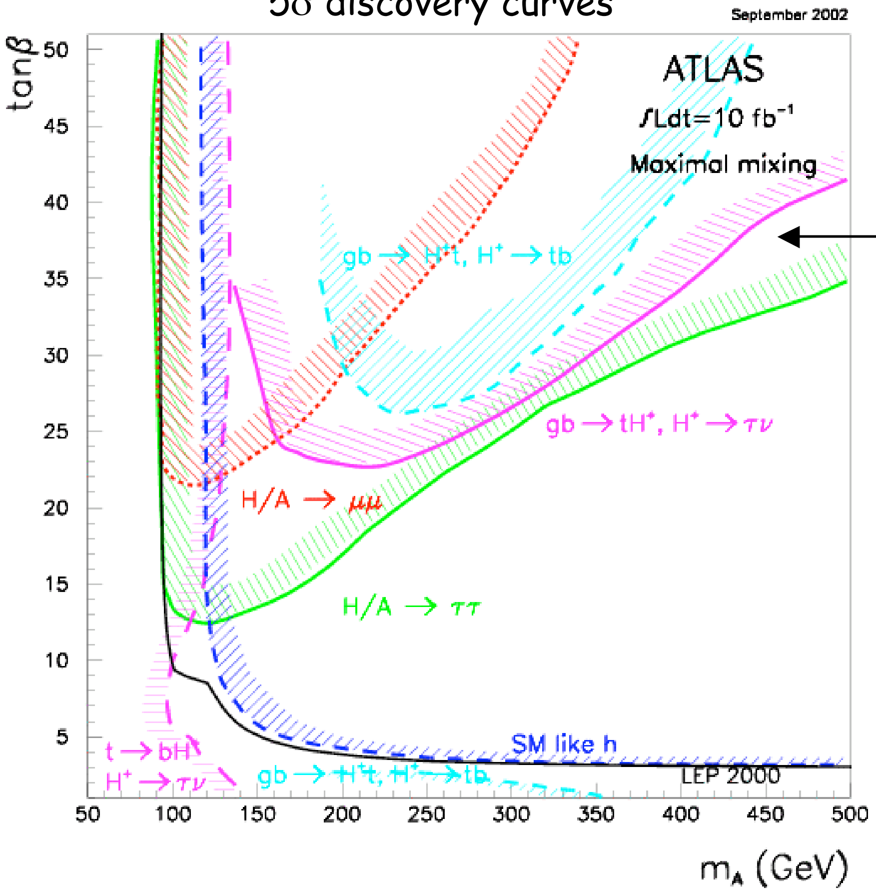
- 4 complementary channels for physics and for detector requirements
- S/√B < 3 per channel (except qqWW counting channel) → observation of all channels important in first year
- H → 4l low rate but very clean: small background, narrow mass peak
  Detector requirements:
  -- ≥ 90% e, μ efficiency at low p_T (analysis cuts : $p_T^{1,2,3,4}$ > 20, 20, 7, 7, GeV)
  → in particular low di-lepton LVL1 thresholds
  -- σ/m ~ 1%, tails < 10% → E, p measurement and resolution in ECAL and tracker at low p_T

Channel	**Main background**	**S/B**	**background systematics for 5σ**	**Proposed technique/comments**
H->γγ	Irreduc. γγ Reducible γj	2-3%	0.4%	Side-bands stat Err ~0.5% for 30-100 fb^{-1}
ttH H->bb	ttjj	30%	6%	Mass side-bands Anti b-tagged ttjj ev. Under study J.Cammin
H->ZZ*-> 4 lep	ZZ->4l and ττll	3-6	60%	Mass side-bands Stat Err <30% 30fb^{-1}
H->WW*->llνν	WW*, tW	30-50%	6%	No mass peak Bkg enriched region ? Study to be performed
VBF channels In general	Rejection QCD/EW	Study forward jet tag and central jet veto		Use EW ZZ and WW leptonic Study to be performed
VFB H->WW	tt, WW, Wt	50-200%	10%	Bkg. enriched samples with discr. Variables Study to be performed
VBF H->ττ	Zjj, tt	50-400%	10%	Missing Et calibration Z-> ττ (mass tails ?) Study to be performed
MSSM (bb)H/A->ττ	Z->ττ, Wj	25% tgβ=15 MA=300	5%	Mass side-bands Stat Err ~5% 30fb^{-1}
MSSM (bb)H/A -> μμ	Z/γ*->μμ	12% tgβ=15 MA=150	~2%	Mass side-bands Stat Err ~2% 30fb^{-1}

MSSM Higgs bosons h, H, A, $H^{\pm}$

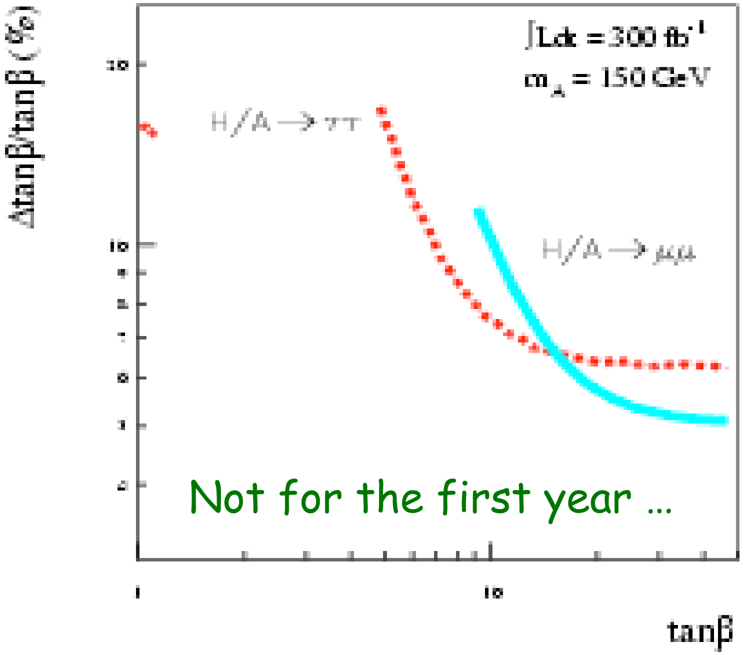
m_h < 135 GeV
$m_A \approx m_H \approx m_{H\pm}$ at large m_A

5σ discovery curves



-- A, H, $H^{\pm}$ cross-section ~ $tg^2\beta$
-- best sensitivity from A/H → ττ, $H^{\pm}$ → τν
(not easy the first year ...)
-- A/H → μμ experimentally easier
(esp. at the beginning)

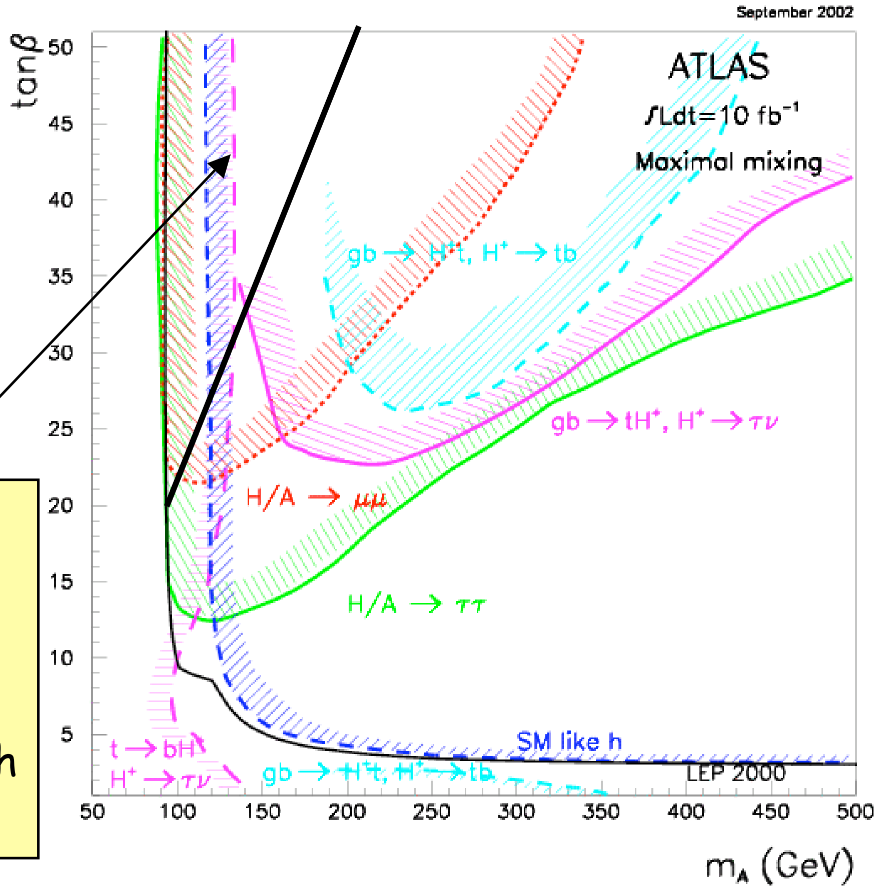
Measurement of tg β



Not for the first year ...

- Large variety of channels and signatures accessible
- bbA/H → 4b is more difficult than at the Tevatron (because of huge QCD background)

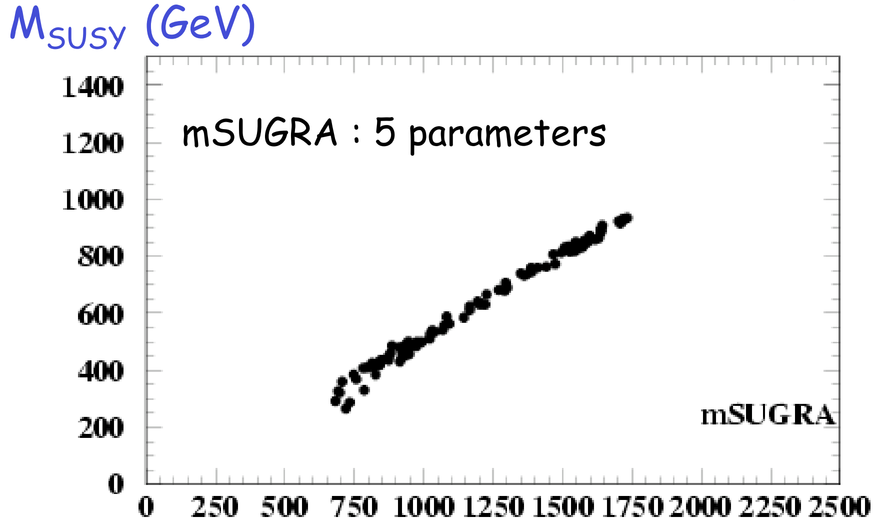
F. Gianotti, "Physics at LHC", Vienna, 17 July 2004



Here ≥5σ discovery of bbA/H → 4b possible at Tevatron with 15 fb^{-1}

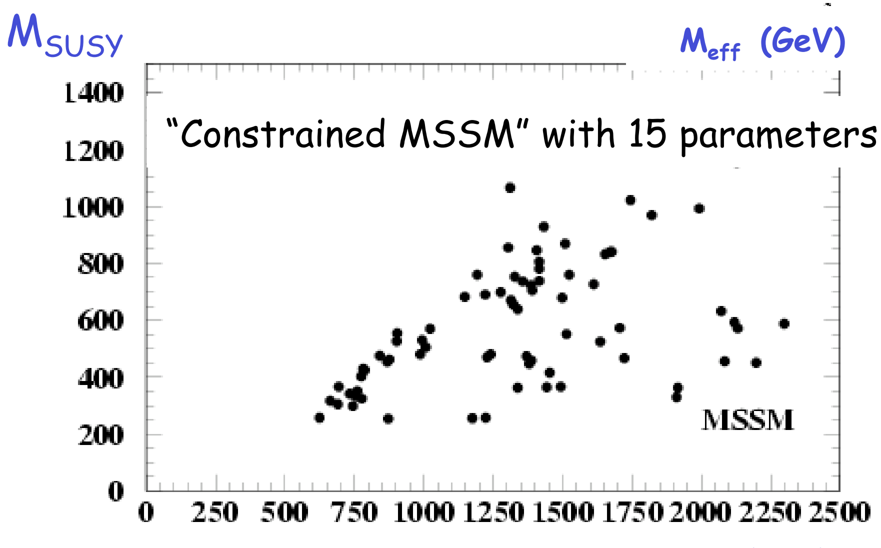
SUSY mass scale (~ model-independent)

D.Tovey



mSUGRA : 5 parameters

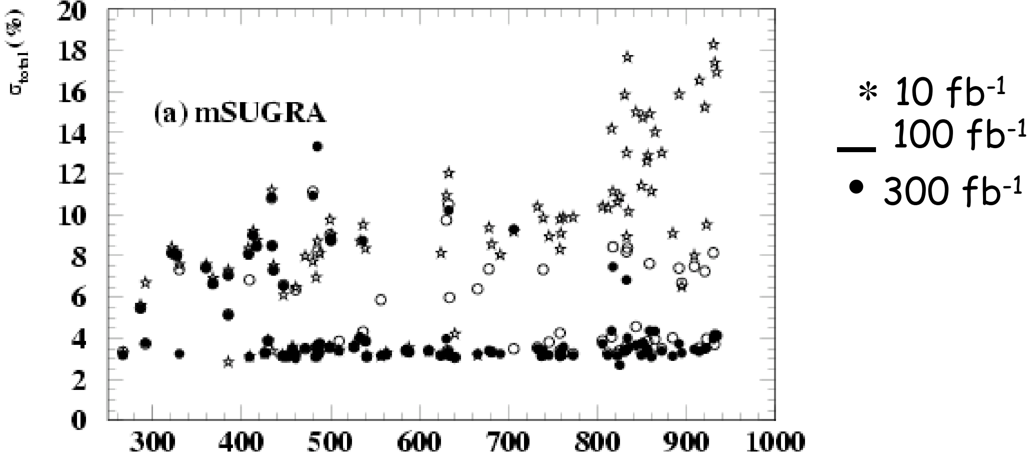
M_{eff} (GeV)



"Constrained MSSM" with 15 parameters

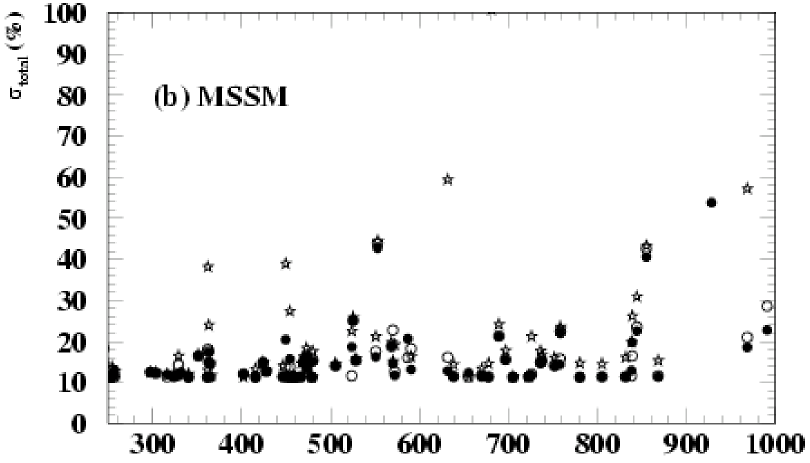
M_{eff} (GeV)

% precision on M_{SUSY} vs M_{SUSY}



- ∗ 10 fb^{-1}
- — 100 fb^{-1}
- ● 300 fb^{-1}

M_{SUSY} (GeV)



conservative !

Intrinsic spread from model parameters (infinite statistics, no experimental error):

~ 2 % mSUGRA

~10 % constrained MSSM

Including experimental uncertainties (~50% from background subtraction, ~1.5% from E-scale):

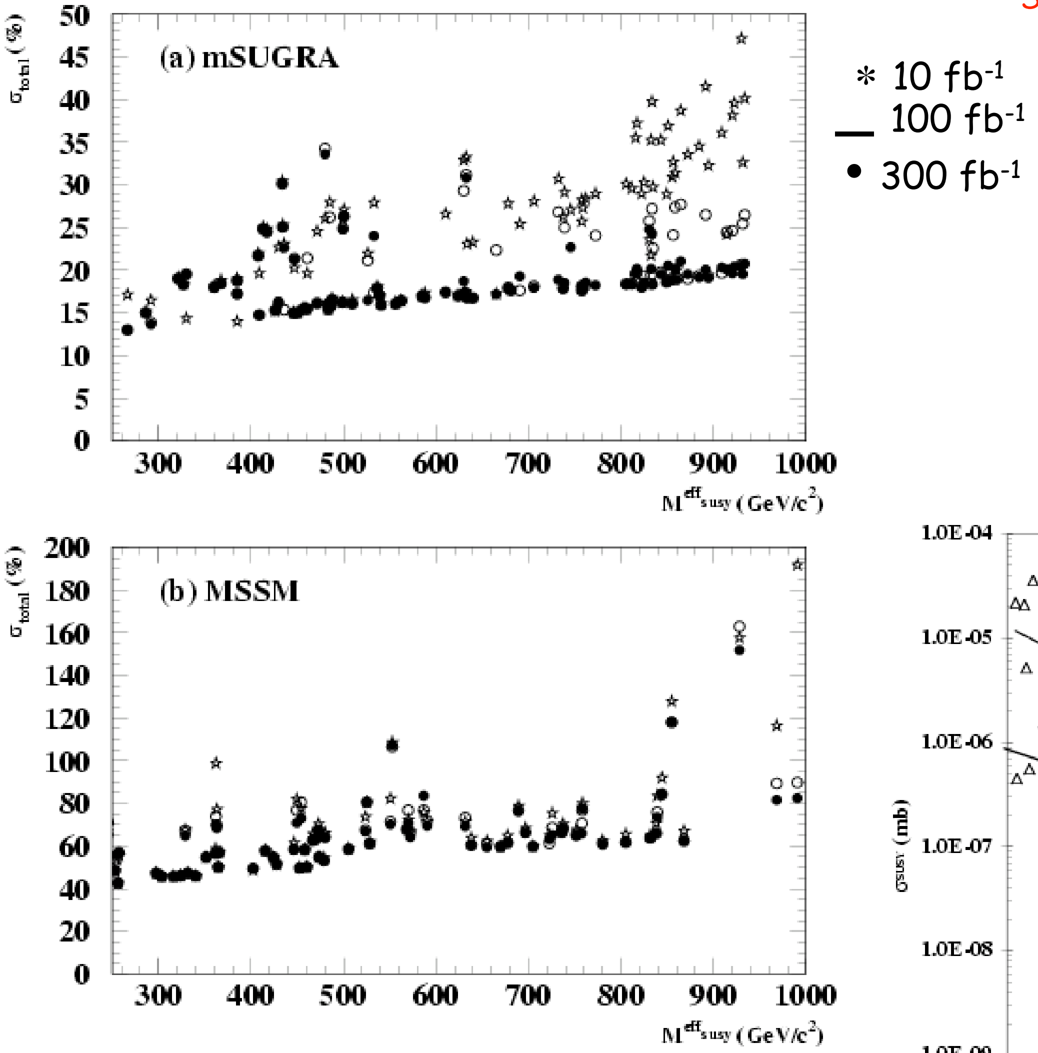
≤ 20% (10%) mSUGRA for 10 (100) fb^{-1}

≤ 60% (30%) constrained MSSM for 10 (100) fb^{-1}

SUSY cross-section (more model-dependent)

D.Tovey

Precision on measured SUSY cross-section vs M^{eff}_{SUSY}

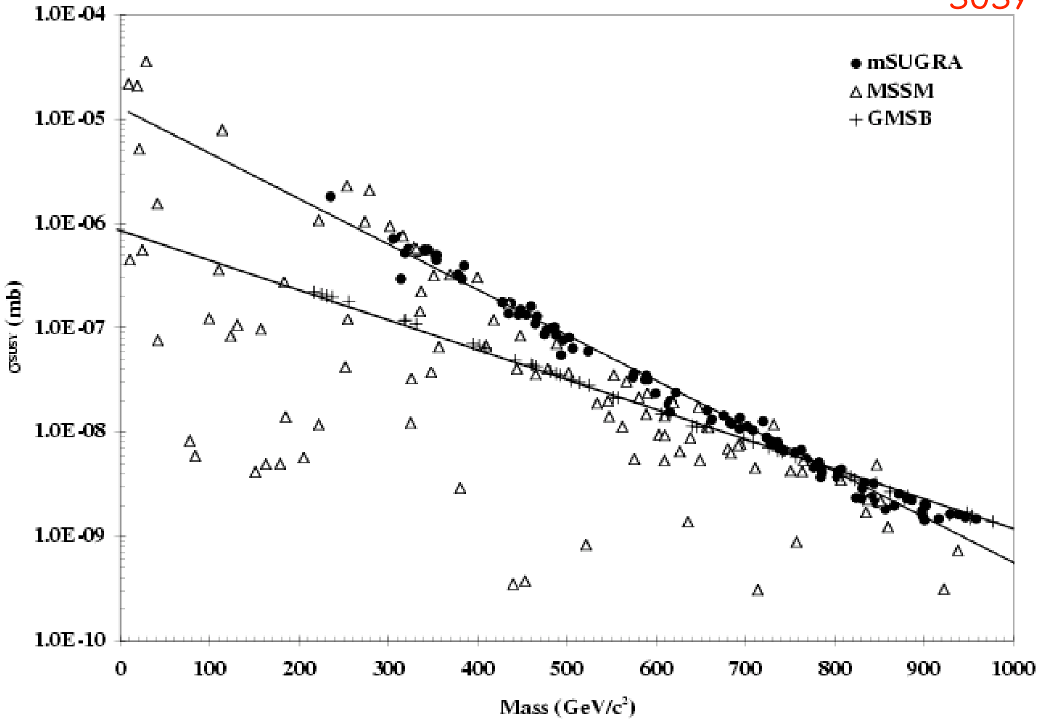


Including experimental uncertainties :

≤ 30% mSUGRA for 300 fb^{-1}

≤ 80% constrained MSSM for 300 fb^{-1}

Theoretical SUSY cross-section vs M^{eff}_{SUSY}



Z'

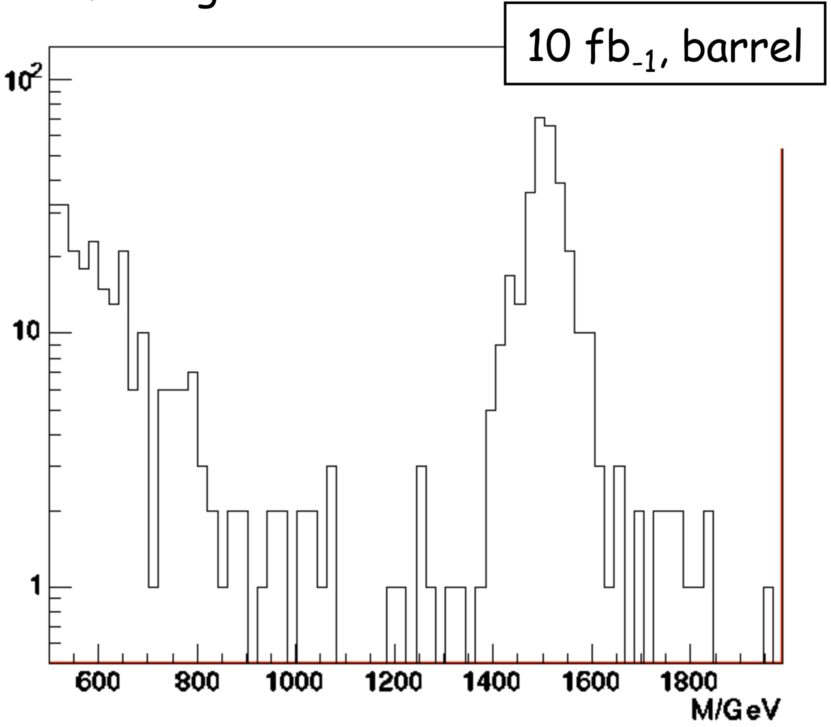
Quick discovery, assuming SM couplings (SSM)

mass	σ x BR(Z --> e e) in peak	events, 10 fb^{-1}
1 TeV	360 fb	3600
1.5 TeV	64 fb	640
2.0 TeV	15.7 fb	157

present limits:
690 GeV (direct),
1500 GeV(EW fit)

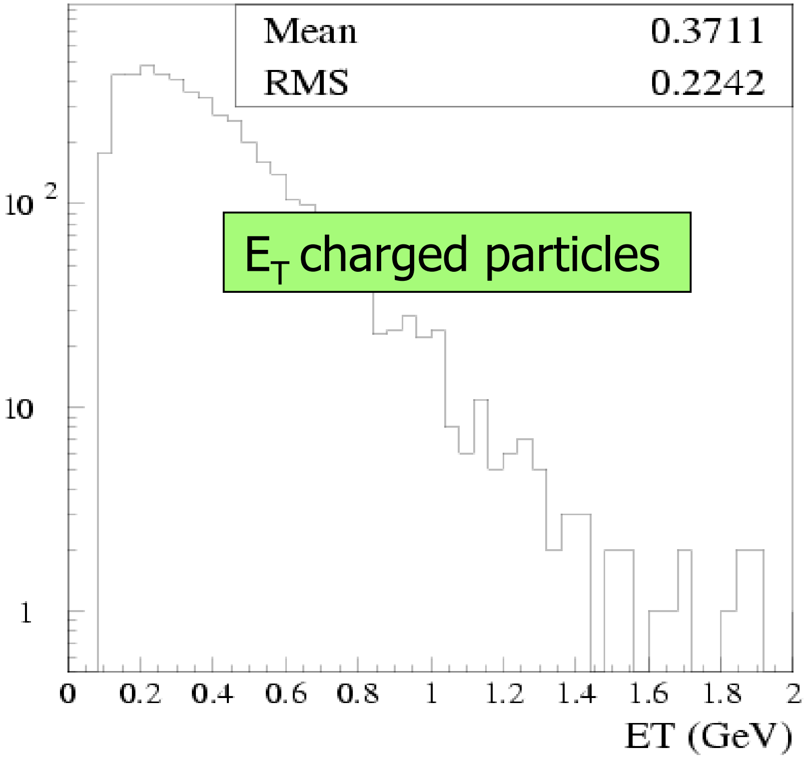
Allows to compare and test different detector components for high energy particles: ee, μμ ,ττ, **bb,jj**

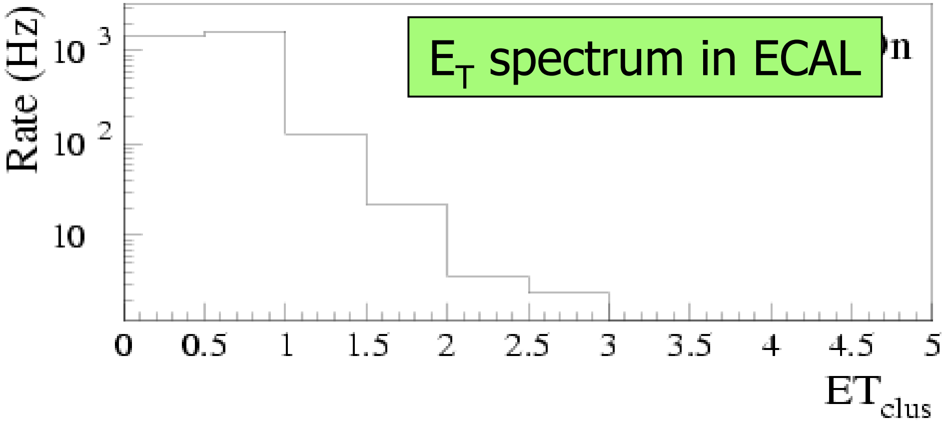
Z--> ll + jets samples needed for E calibration

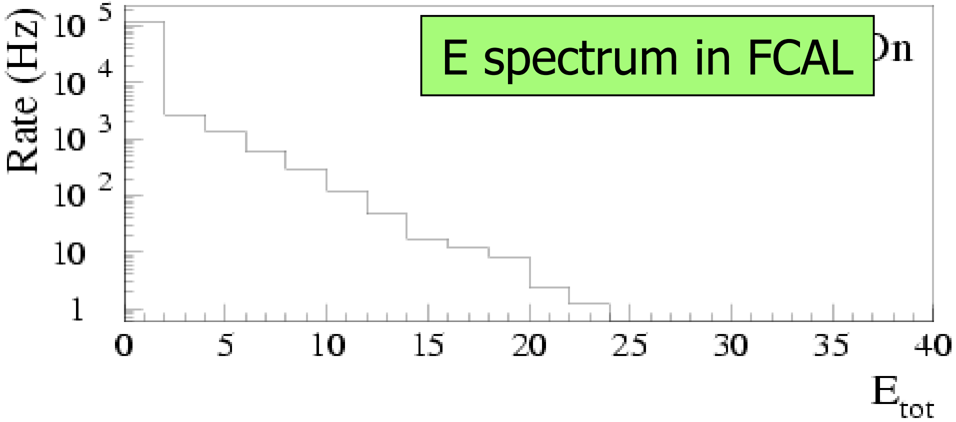


Expected rates of beam-gas events

Vertex z-position	Rate (Hz)	Total (2 months, ε=30%)
±23 m	$1.2\ 10^5$	$2.1\ 10^{11}$
± 3 m	$1.6\ 10^4$	$2.4\ 10^{10}$
± 20 cm	$1.1\ 10^3$	$1.6\ 10^9$
$\pi^\pm$ $p_T > 1$ GeV inside ± 3m	$1.0\ 10^3$	$1.5\ \ 10^9$
γ $p_T > 1$ GeV inside ± 3m	$0.3\ 10^3$	$5.6\ \ 10^8$


E_T charged particles


E_T spectrum in ECAL


E spectrum in FCAL

Expected rates of beam-halo muons

- Rates for initial period scaled from high-luminosity rates by assuming 3×10^{10} p per bunch and 43 bunches → ~ 200 times lower current
- Expected optics and vacuum for commissioning period not included yet (need input from machine people) → these results are very preliminary
- Total rates are for two months of single-beam with 30% data taking efficiency
- Simple definition of "useful tracks" : 2-3 segments in MDT, 3-4 disks in ID end-cap

Very preliminary

Detector	Rate (B-field off)	Total (B-field off)	Rate (B-field on)	Total (B-field on)
MDT barrel	15 Hz	$2.5\ 10^{7}$	72 Hz	$1.5\ 10^{8}$
MDT end-cap	145 Hz	$2.5\ 10^{8}$	135 Hz	$2.5\ 10^{8}$
Pixel/SCT	1.8/17 Hz	$3\ 10^{6}$ / $3\ 10^{7}$	2/19 Hz	$3\ 10^{6}$ / $3\ 10^{7}$
EM E > 5 GeV	2 Hz	$3.5\ 10^{6}$	1 Hz	$1.7\ 10^{6}$
Tile/HEC E > 20 GeV	1.7/1.2 Hz	$2.9/2.1\ 10^{6}$	1.6/0.9 Hz	$2.8/1.6\ 10^{6}$