ATLAS prospects for physics in the first two LHC years

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- Preparing for physics with test beams, simulations, and cosmics runs
- Detector commissioning with first data
- Physics opportunities in 2008-2009 (examples …)

ATLAS strategy toward physics

Before data taking starts:

- Strict quality controls of detector construction to meet physics requirements
- Test beams (a 15-year activity culminating with combined test beam in 2004) to understand and calibrate (part of) detector and validate/tune software tools (e.g. Geant4 simulation)
- Detailed simulations of realistic detector "as built and as installed" (including misalignments, material non-uniformities, dead channels, etc.) → test and validate calibration/alignment strategies
- Experiment commissioning with cosmics in the underground cavern

now we are here

With the first data:

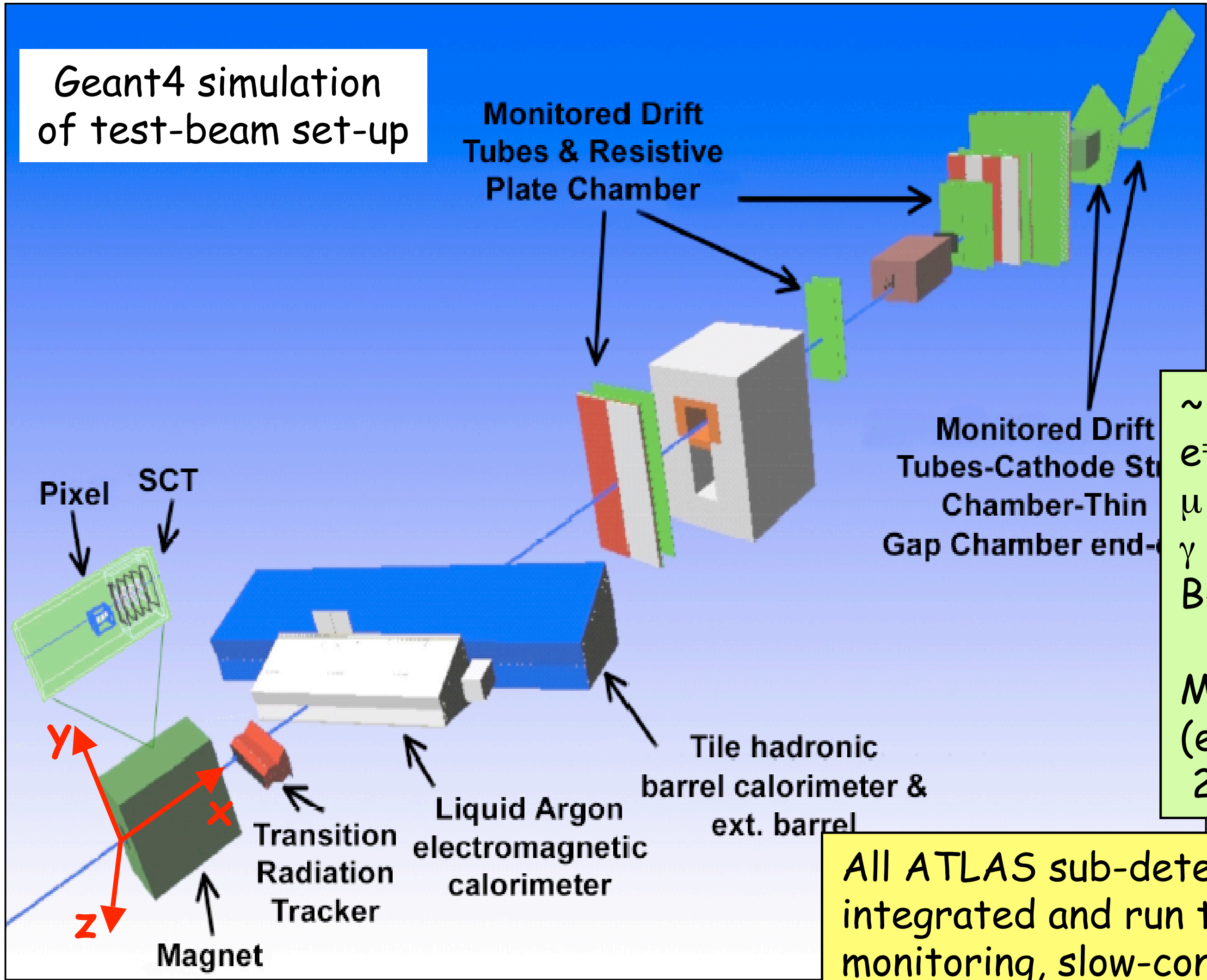
- Commission/calibrate detector and trigger in situ with physics (min.bias, Z→ll, …)
- "Rediscover" Standard Model, measure it at $\sqrt{s}$ =14 TeV (minimum bias, W, Z, tt, QCD jets, …)
- Validate and tune tools (e.g. MC generators)
- Measure main backgrounds to New Physics (W/Z+jets, tt+jets, QCD multijets,…)

↓

prepare the road to discoveries …

The 2004 ATLAS combined test beam

Full "vertical slice" of ATLAS tested in CERN H8 beam line May-November 2004



O(1%) of ATLAS coverage

~ 90 million events collected

$e^{\pm}$, $\pi^{\pm}$ 1 → 250 GeV

$\mu^{\pm}$, $\pi^{\pm}$, p up to 350 GeV

γ 20-100 GeV

B-field = 0 → 1.4 T

Many configurations (e.g. additional material in ID, 25 ns runs, …)

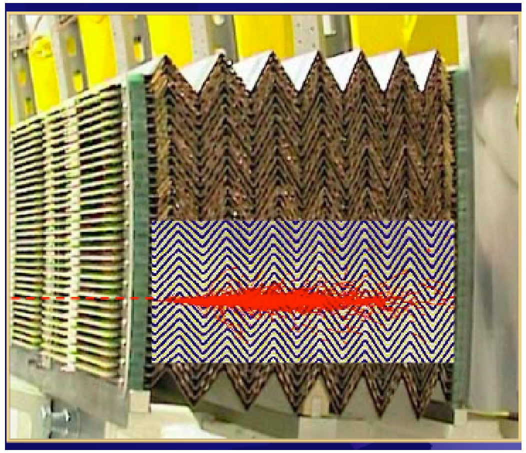
All ATLAS sub-detectors (and LVL1 trigger) integrated and run together with common DAQ, monitoring, slow-control.
Data analyzed with common ATLAS software.
Gained lot of global operation experience during ~ 6 month run.

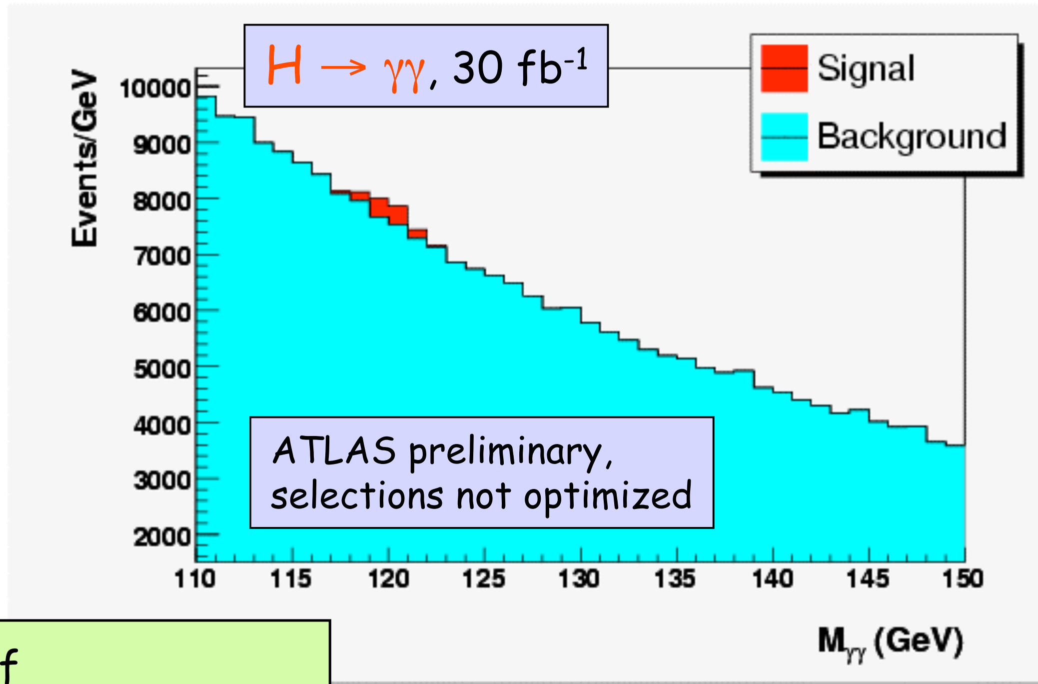
Before data taking starts …

Examples of the preparation strategy for physics
(electromagnetic calorimeter discussed in more detail)

Example 1: electromagnetic calorimeter

Pb-LAr Accordion, covers $|\eta| < 3.2$





$H \rightarrow \gamma\gamma$: to observe signal peak on top of huge background need mass resolution ~ 1%

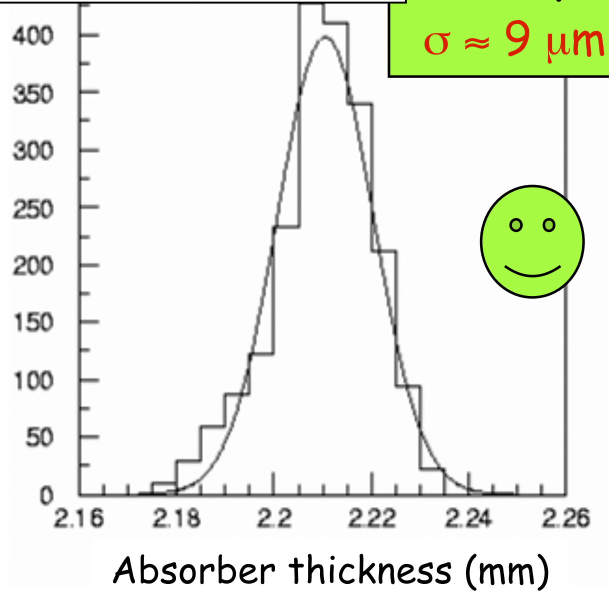
→ response uniformity of ~ 0.7% or better over $|\eta|<2.5$

❶ Construction quality

Thickness of Pb plates must be uniform to 0.5% (~10 μm)

End-cap: 1536 plates

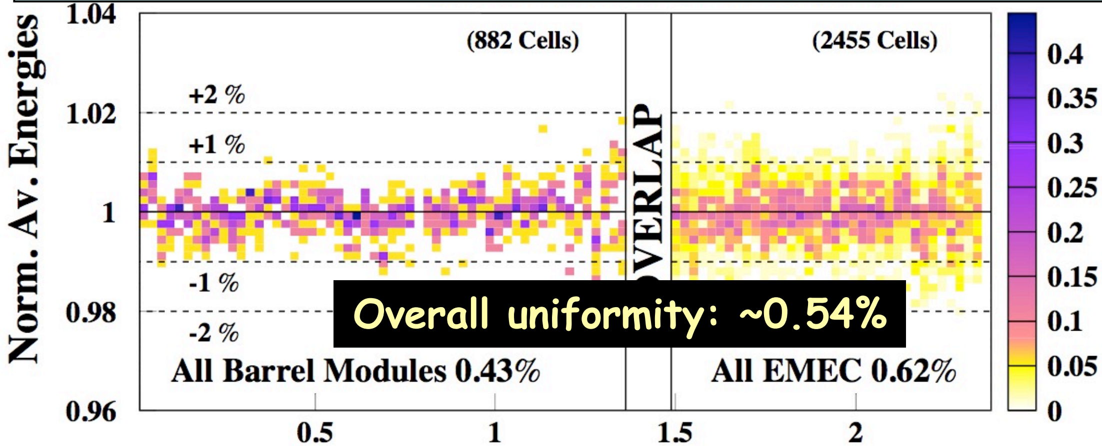
< > ~ 2.2 mm
σ ≈ 9 μm



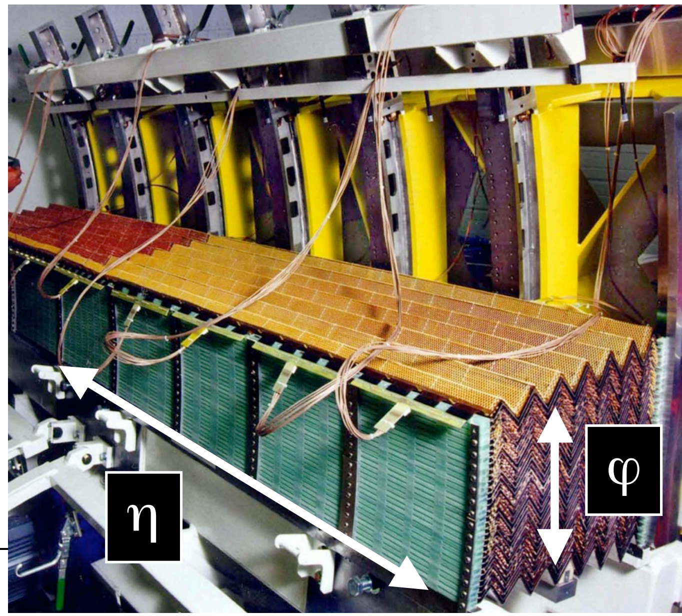
❷ Test-beam measurements

4 (out of 32) barrel modules and 3 (out of 16) end-cap (EMEC) modules tested with beams

Scans with 120-245 GeV electrons (all 7 tested modules)



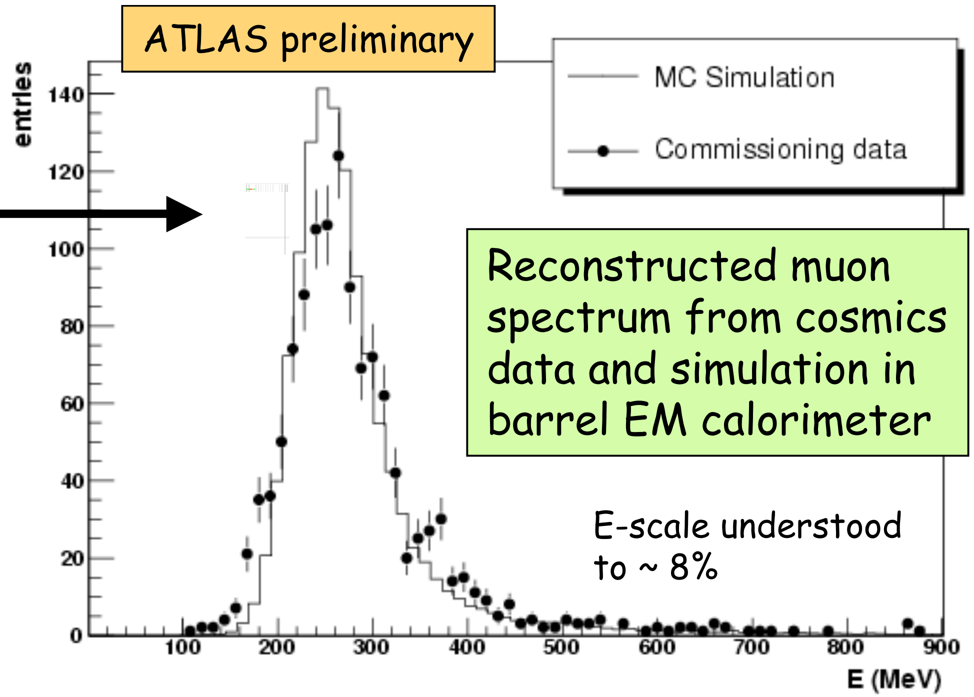
1 barrel module:
Δη x Δφ = 1.4 x 0.4
≈ 3000 channels



❸ Cosmics runs:

~ 170k good cosmic muons collected with EM calorimeter so far (rate in ATLAS cavern is O[10 Hz]) → can record ~ 10^6 events before collisions start

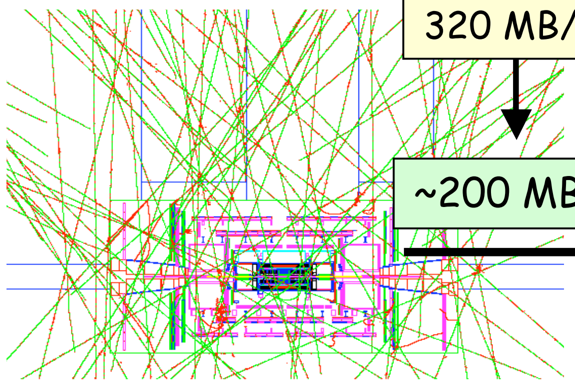
- enough for initial detector shake-down
- enough to check part of calibration vs η to 0.5% in best exposed modules



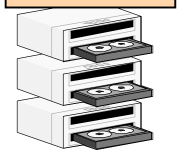
Data collected during last cosmics run (23 Aug.-3 Sept.) processed at CERN (Tier0), distributed to Tiers-1 and some Tiers-2, analyzed at Tiers-2 (following Computing Model)

LHC: 320 MB/s

~200 MB/s

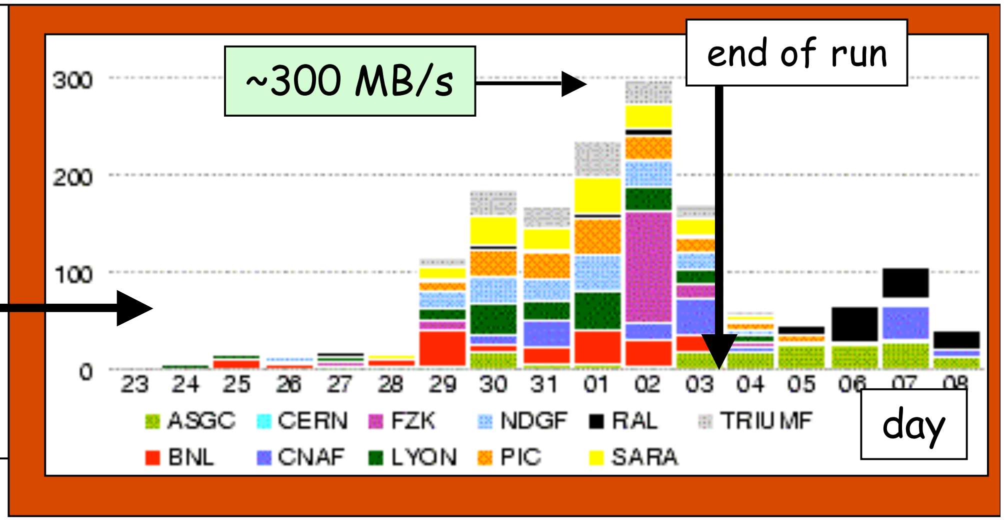


CERN Tier-0



LHC: ~ 1 GB/s

Average throughput (MB/s) from Tier-0 to Tiers-1

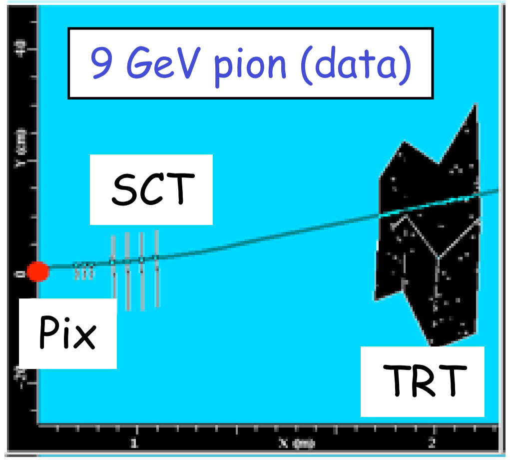


❹ First collisions : calibration with $Z \rightarrow ee$ events

The last step, needed to achieve a uniformity of ≤ 0.7% over the full detector in situ

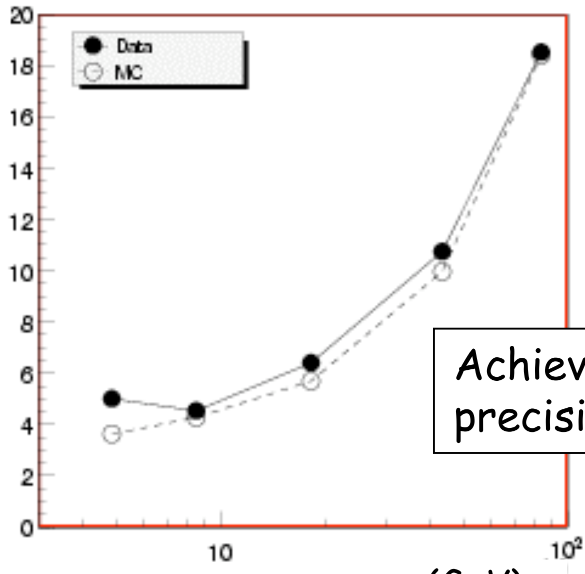
See later …

Example 2: Inner Detector



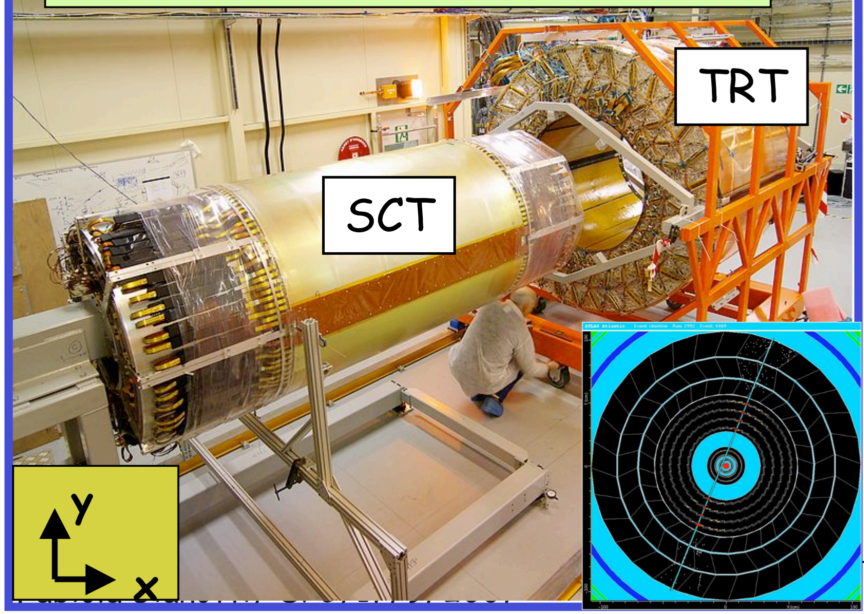
ATLAS preliminary

Pion momentum resolution from 2004 combined test beam using Pixels+SCT



Note:
no TRT,
B=1.4 T

Achieved alignment precision: 5-10 μm

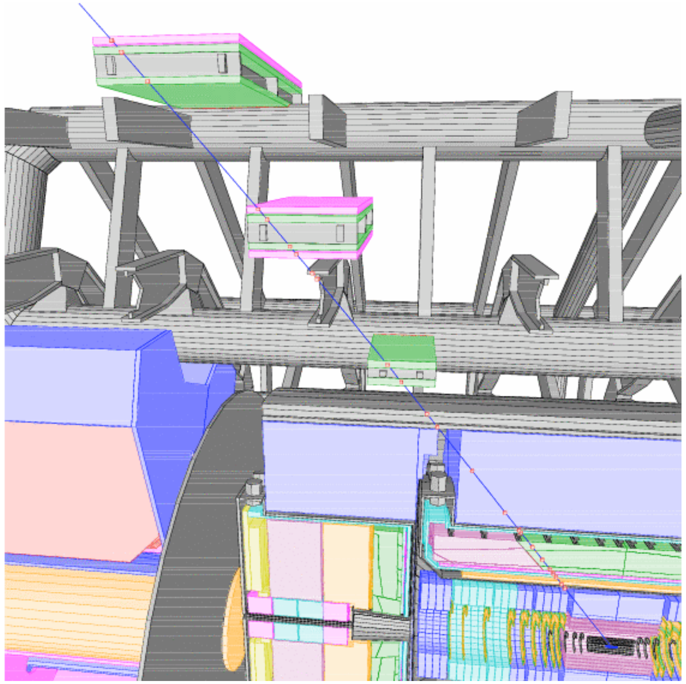


SCT-TRT integration in surface clean room in Feb 2006

Global SCT-TRT barrel misalignments from survey measurements compared to results from reconstructed cosmics tracks after alignment

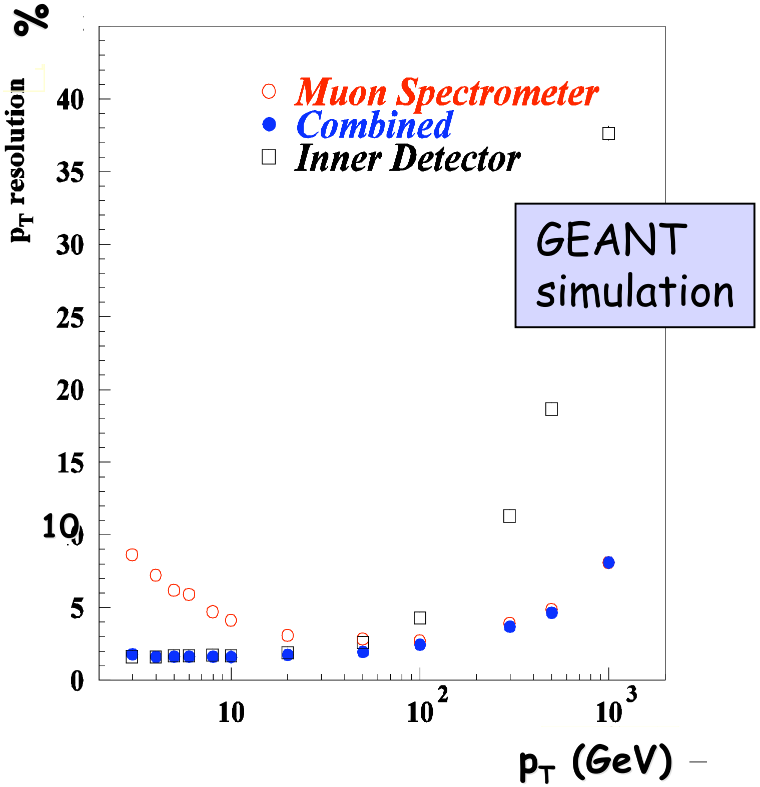
Displacement	Survey	Cosmics
Δx (mm)	-0.300 ±.008	-0.290 ±.007
Δrot-y (mrad)	0.221 ±.006	0.285±.021

Example 3: Muon Spectrometer



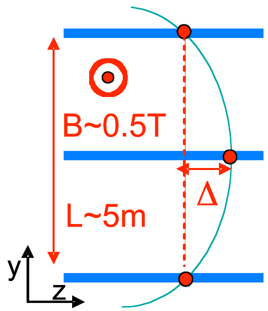
σ/p < 10% for E_μ ~ TeV needed to observe a possible new resonance $X \rightarrow \mu\mu$ as "narrow" peak

ATLAS Muon momentum resolution



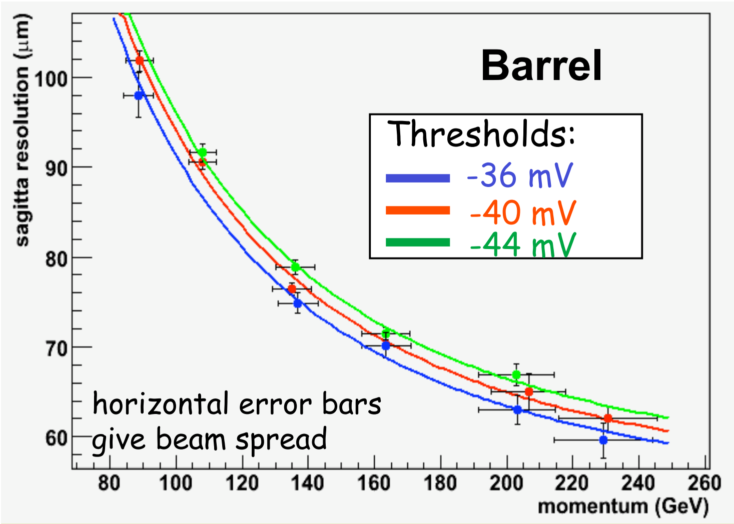
ATLAS Muon Spectrometer:
E_μ ~ 1 TeV $\Rightarrow$ Δ~500 μm

– σ/p ~10% $\Rightarrow$ $\delta\Delta$~50 μm
- alignment accuracy to ~30 μm



Sagitta resolution measured in the 2004 combined test beam

ATLAS preliminary

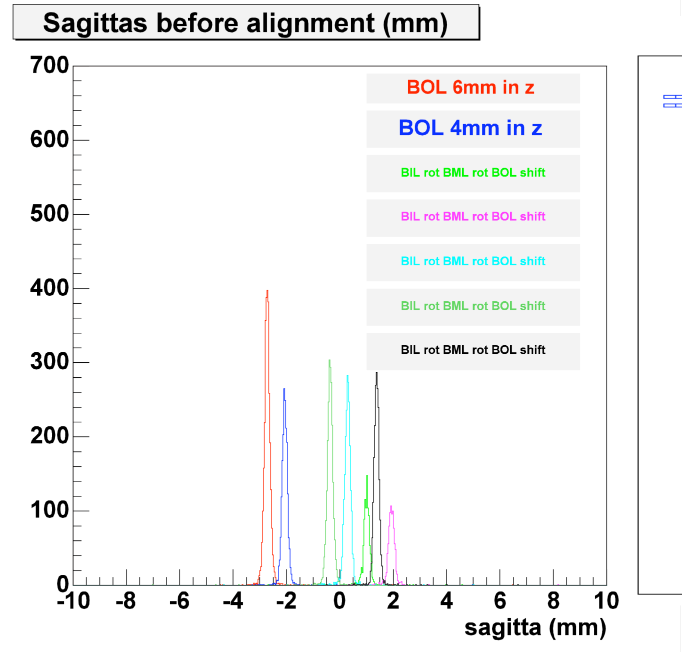


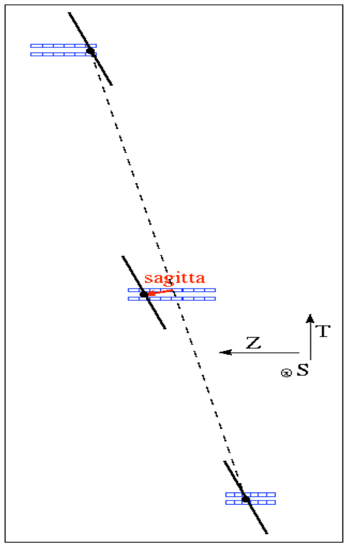
Data fitted with: $\sigma = \sqrt{K_1^2 + (K_2/p)^2}$

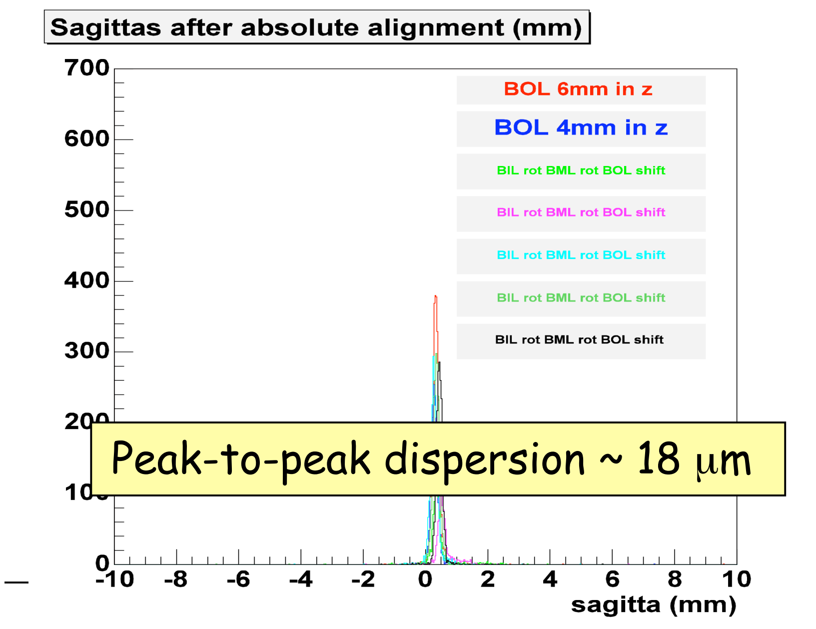
- p = muon momentum from beam magnet
- K_1 = intrinsic resolution
- K_2 = multiple scattering

Data	Simulation	
K_1 = 50.7±1.5 μm	K_1 = 40±3 μm	← intrinsic
0.29±0.01 X_0	0.32 ±0.02 X_0	← multiple scattering

Alignment (optical sensors) tested by moving (rotations, displacements) barrel MDT







Peak-to-peak dispersion ~ 18 μm

With the first data …

How much data at the beginning ?

J.Wenninger
CERN-FNAL HC School
June 2007

Parameter	Phase A	Phase B	Phase C	Nominal
k / no. bunches	43-156	936	2808	2808
Bunch spacing (ns)	2021-566	75	25	25
N (10^{11} protons)	0.4-0.9	0.4-0.9	0.5	1.15
Crossing angle (μrad)	0	250	280	280
$\sqrt{(\beta^*/\beta^*_{nom})}$	2	$\sqrt{2}$	1	1
σ* (μm, IR1&5)	32	22	16	16
L ($cm^{-2}s^{-1}$)	6×10^{30}-10^{32}	10^{32}-10^{33}	(1-2)$\times10^{33}$	10^{34}
Year ? (June schedule)	2008	2009	2009-2010	> 2010
∫ Ldt ? (my guess)	≤ 100 pb^{-1}	1-few fb^{-1}		

Note: at regime, ~ 6×10^6 s of pp physics running per year
→ ~ 0.6 fb^{-1} /year if L= 10^{32}
~ 6 fb^{-1} /year if L= 10^{33}
~ 60 fb^{-1} /year if L= 10^{34}

Expected data samples (examples) with only 100 pb^{-1}

Channels (<u>examples</u> …)	Events to tape for 100 pb^{-1} (ATLAS)	Total statistics from LEP and Tevatron
$W \to \mu\nu$	$\sim 10^6$	$\sim 10^4$ LEP, $\sim 10^{6-7}$ Tevatron
$Z \to \mu\mu$	$\sim 10^5$	$\sim 10^6$ LEP, $\sim 10^{5-6}$ Tevatron
$tt \to W b W b \to \mu\nu + X$	$\sim 10^4$	$\sim 10^{3-4}$ Tevatron
QCD jets $p_T > 1$ TeV	$> 10^3$	---
$\tilde{g}\tilde{g}$ m = 1 TeV	~ 50	---

<u>Goals in 2008-2009:</u>

1) Commission and calibrate the detector <u>in situ using well-known physics samples</u>
   e.g. - $Z \to ee, \mu\mu$ tracker, ECAL, Muon chamber calibration and alignment, etc.
   - $tt \to bl\nu\, bjj$ jet scale from $W \to jj$, b-tag performance, etc.

2) "Rediscover" and measure SM physics at $\sqrt{s}$ = 14 TeV: W, Z, tt, QCD jets …
   (also because omnipresent backgrounds to New Physics)

3) Early discoveries ? Potentially accessible: Z′, SUSY, Higgs, …. surprises ?

will take time … but necessary steps before claiming discoveries

Detector and trigger commissioning with LHC data

First of all: what fraction of ATLAS will be working on day-1 ?

The present situation

Sub-detector	N. of channels	Non-working channels (%)
Pixels	80×10^6	0.2
Silicon strip detector (SCT)	6×10^6	0.3
Transition Radiation Tracker (TRT)	3.5×10^5	1
Electromagnetic calorimeter	1.7×10^5	0.04
Fe/scintillator (Tilecal) calorimeter	9800	0.8 (part of detector)
Hadronic end-cap LAr calorimeter	5600	0.09
Forward LAr calorimeter	3500	0.2
Barrel Muon Spectrometer	7×10^5	0.5
End-cap Muon Spectrometer (TGC)	3.2×10^5	0.02

Based on measurements of full sub-detectors (in most cases) during integration on the surface (Pixels, SCT, hadronic end-cap and forward calorimeters, Muon Spectrometer), or in the pit (TRT, electromagnetic calorimeter, Tilecal)

Commissioning the trigger, trigger for commissioning

Trigger menu for initial $L=10^{31}$ cm^{-2} s^{-1} being prepared
Affordable rate to storage ~ 200 Hz (out of 10^6 Hz interaction rate at $L=10^{31}$)

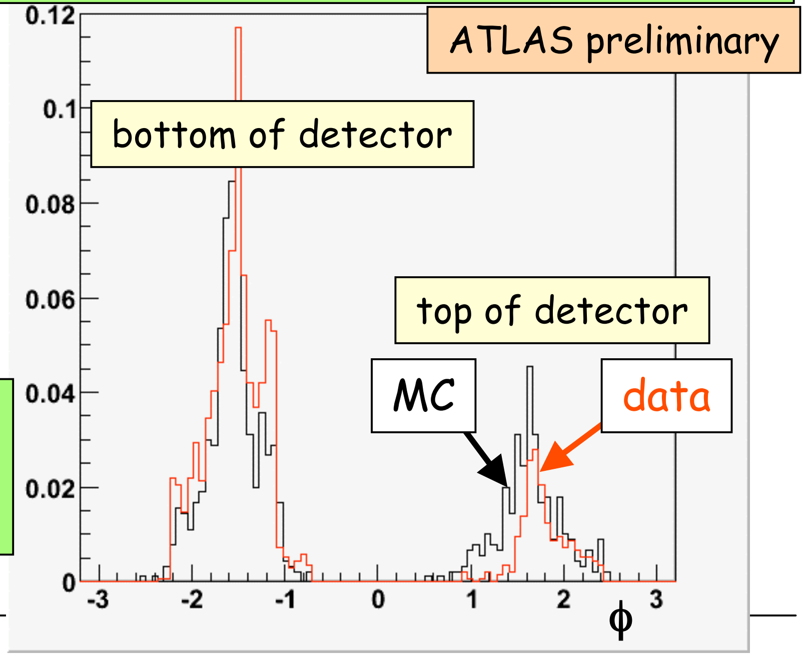
Item (examples)	Trigger output rate 10^{31} (unprescaled)
2e5	5-10 Hz
e15	40
2e15	1
γ20	20
μ6	55
2μ4	15
j70	27
4j23	17
τ25+xE32	7
τ10i+τ25i	5

2e5: 2 $e^{\pm}$ p_T>5 GeV
j70: 1 jet p_T>70 GeV
τ25+xE32: 1 τ p_T>25 GeV+ E_T^{miss}>32 GeV

Preliminary, for illustration

At low initial luminosity can afford: low thresholds w/o prescaling, simple selections, redundant items, several triggers for calibration and sanity checks, run High-Level-Trigger in pass-through mode, etc.
Essential to understand trigger and detector

From last cosmics run (23Aug-3Sept): Muon tracks reconstructed by trigger



Tracks reconstructed online by combining Muon chambers, calorimeters and TRT (all sub-detectors except Pixels and SCT were taking data)

Expected ATLAS performance on day-1 ?

(examples based on test-beam, cosmics and simulation studies)

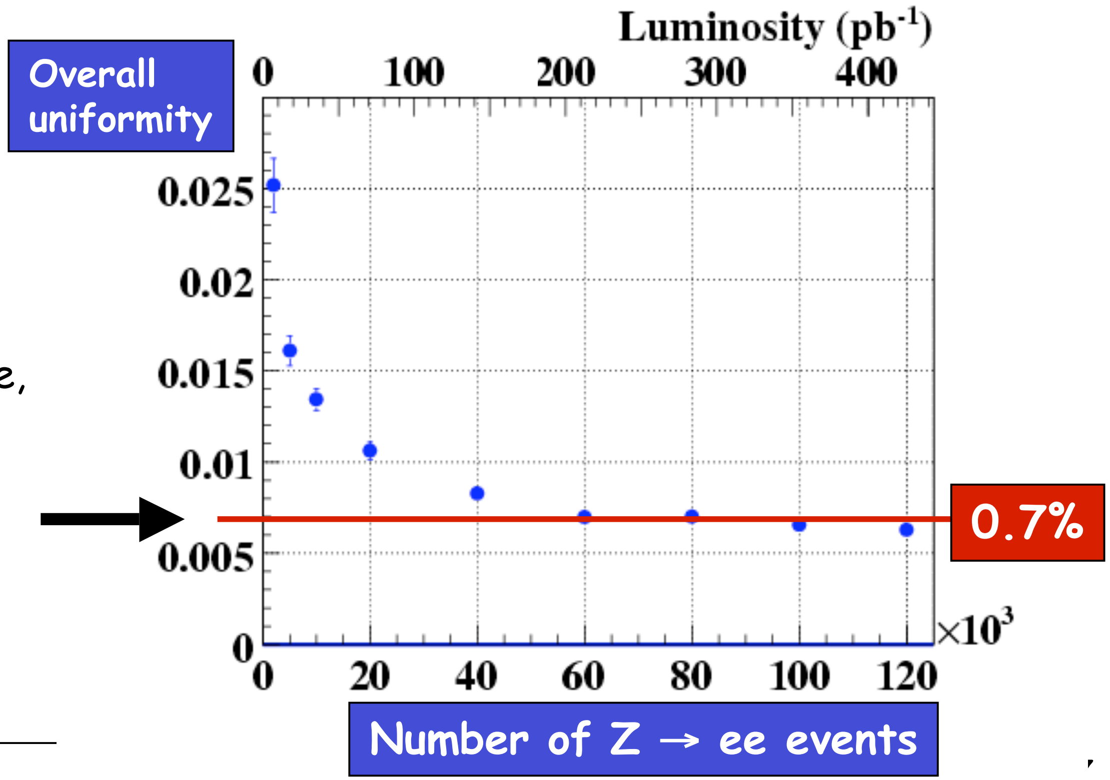
	Expected performance day-1	Physics samples to improve (examples)
ECAL uniformity	1-2% (~0.5% locally)	Isolated electrons, $Z \to ee$
e/γ E-scale	~ 2 %	$Z \to ee$
HCAL uniformity	~ 3 %	Single pions, QCD jets
Jet E-scale	< 10%	γ/Z + 1j, $W \to jj$ in $t\bar{t}$ events
Tracking alignment	10-200 μm in Rϕ Pixels/SCT ?	Generic tracks, isolated μ, $Z \to \mu\mu$

Step ❹ of ECAL calibration:

use Z-mass constraint to correct residual long-range non-uniformities (module-to-module variations, temperature, effect of upstream material, etc.)

~ 10^5 $Z \to ee$ events enough to achieve the goal response uniformity of ~ 0.7%

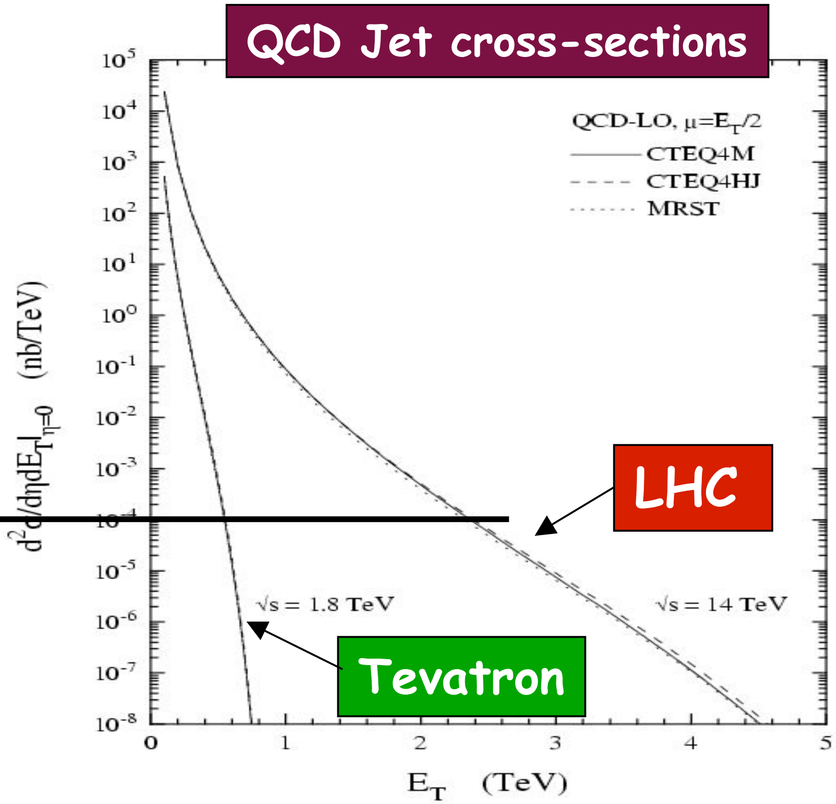
From full detector simulation



Prospects for physics in 2008-2009 (examples …)

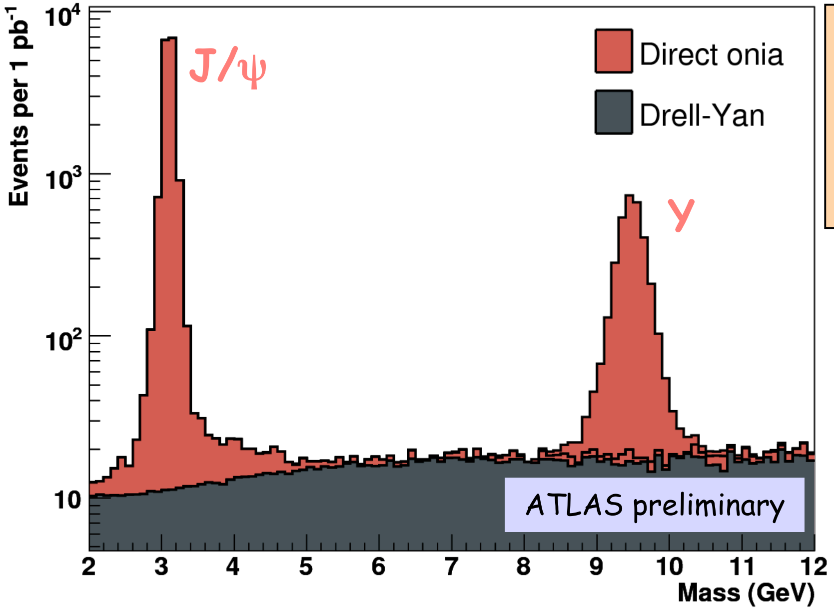
Will jump immediately into a new territory …

10 events with 100 pb^{-1}



The first peaks …

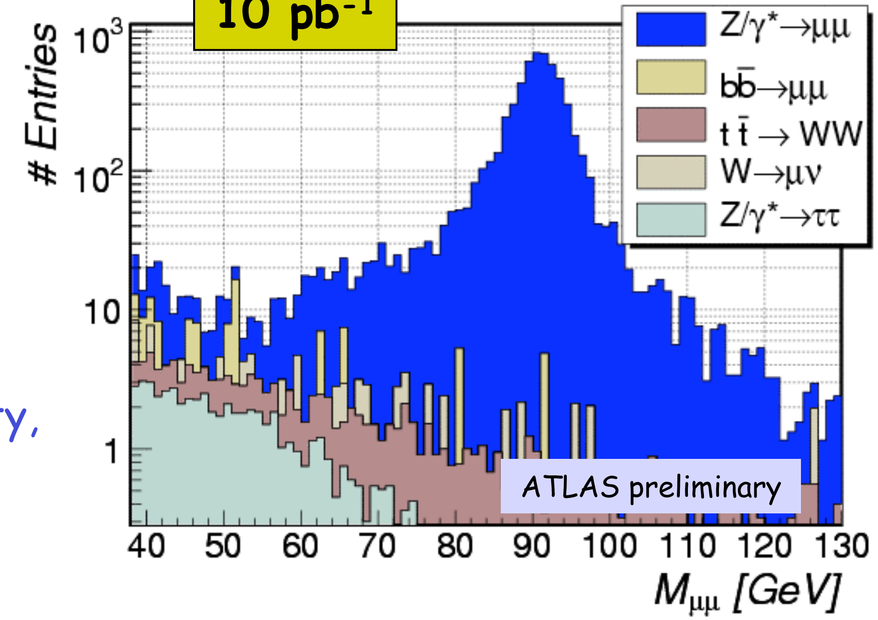
1 pb^{-1} ≡ 3 days at 10^{31} at 30% efficiency



After all cuts:
~ 4200 (800) J/ψ (ϒ) → μμ evts per day at L = 10^{31}
(for 30% machine x detector data taking efficiency)
~ 15600 (3100) events per pb^{-1}

→ tracker momentum scale, trigger performance, detector efficiency, sanity checks, …

10 pb^{-1}



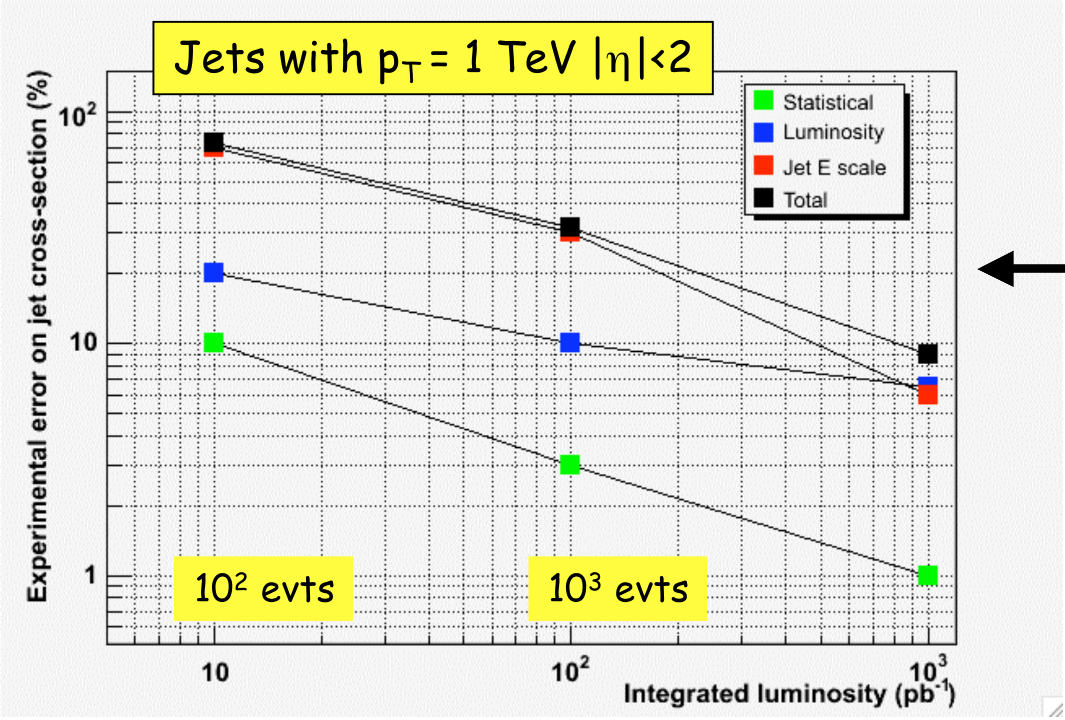
After all cuts:
~ 160 Z → μμ evts per day at L = 10^{31}
~ 600 events per pb^{-1}

→ Muon Spectrometer alignment, ECAL uniformity, energy/momentum scale of full detector, lepton trigger and reconstruction efficiency, …

Precision on σ (Z→μμ) with 100 pb^{-1}: <2% (experimental error), ~10% (luminosity)

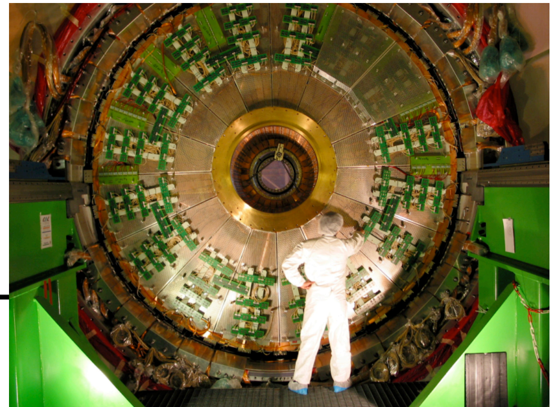
Early measurements of QCD jet cross-section

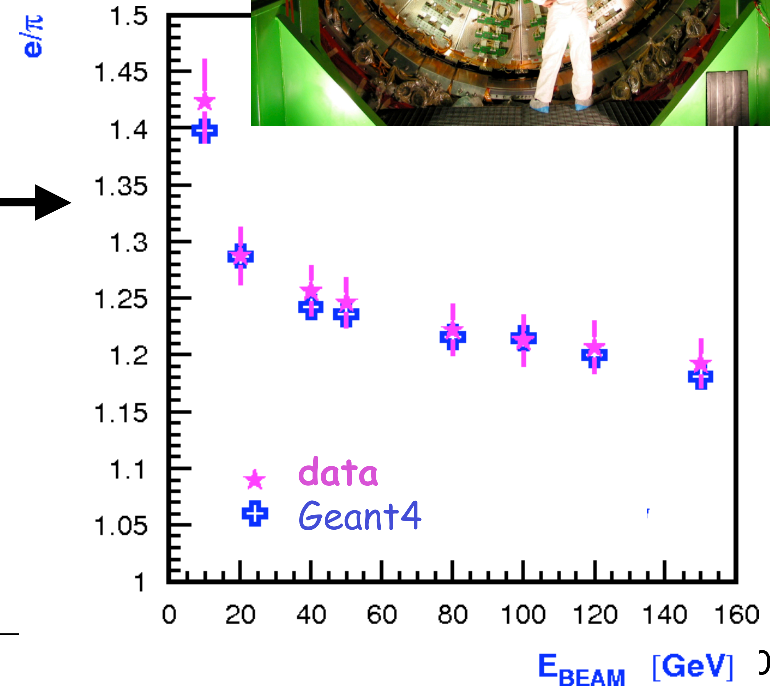
ATLAS preliminary



Jet spectrum at high-p_T sensitive to New Physics (Compositeness, …) → can fake/mask a signal if not well understood

Theoretical error : ~ 20%
(μ_F/μ_R scale, high-x gluon PDF)





e/π from LAr hadronic end-cap calorimeter test beam

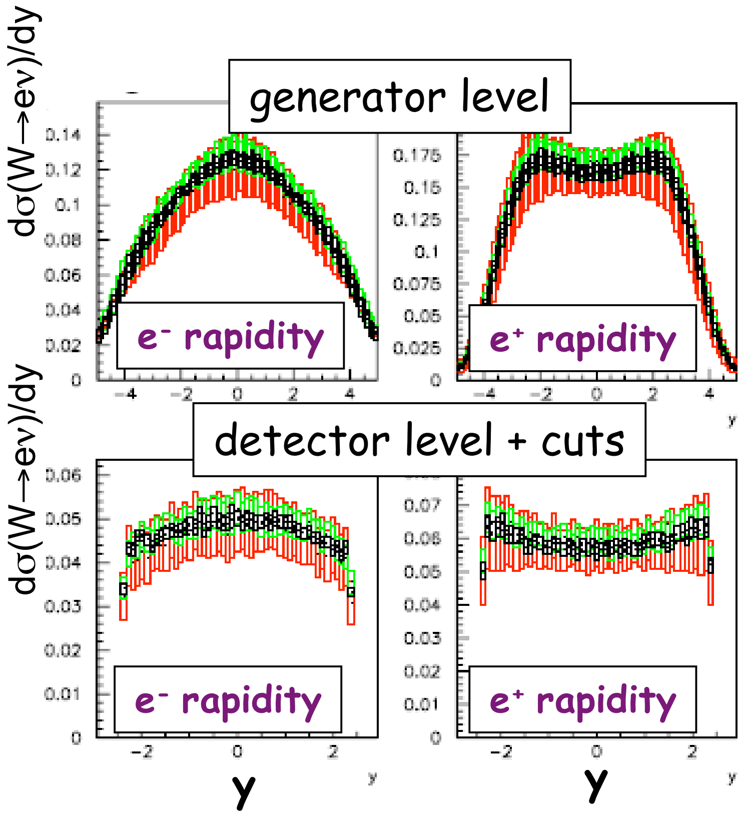
Jet E-scale:

- initially (10%) from test beam + simulation
  (Geant4 reproduces test-beam pion response of hadronic end-cap calorimeter to ~2%)
- then from data (γ/Z+jet, W→ jj in tt evts) + simulation (→ 1%)

Constraining PDF with early data using W → lν angular distributions

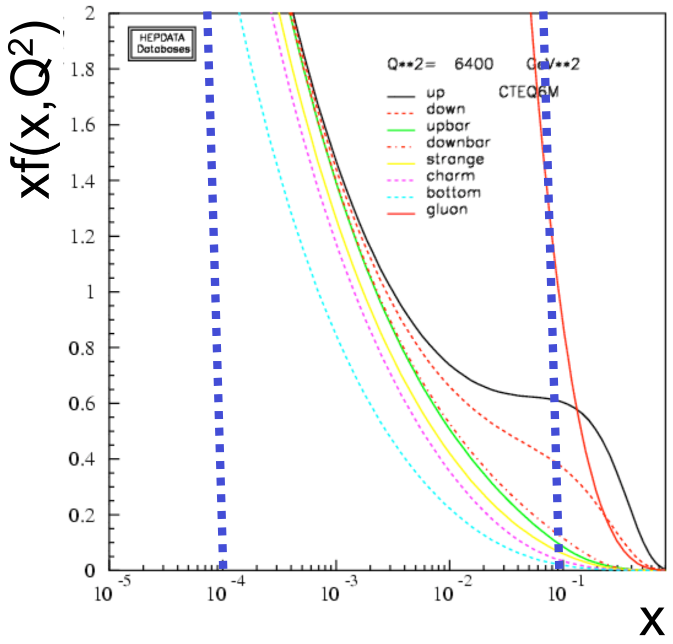
$$x_{1,2} = \frac{M}{\sqrt{s}} \exp(\pm y)$$

⇒ W production over |y|<2.5 at LHC involves $10^{-4} < x_{1,2} < 0.1$
⇒ region dominated by g → qq



HERWIG + NLO K-factor

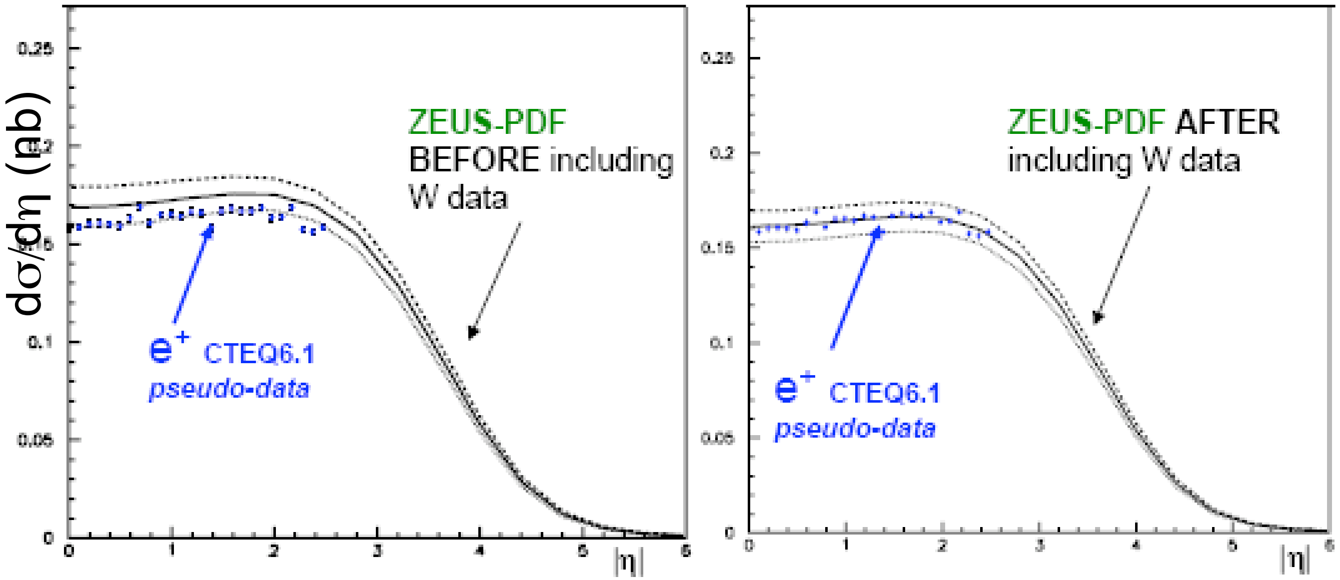
CTEQ61
MRST01
ZEUS-S



Uncertainties on present PDF: 4-8%
→ Early measurements of e± angular distributions at LHC can provide discrimination between different PDF if experimental precision is ~ 4%

Effect of including early ATLAS data on PDF fits

Sample of 10^6 $W \rightarrow e\nu$ generated with CTEQ6.1 PDF and ATLAS fast simulation
Statistics corresponds to ~ 150 pb^{-1}
4% systematic error introduced by hand (statistical error negligible)
Then these pseudo-data included in the global ZEUS PDF fit



Absolute normalization left free in the fit (not to depend on knowledge of luminosity). W^+/W^- relative normalization depends on PDF

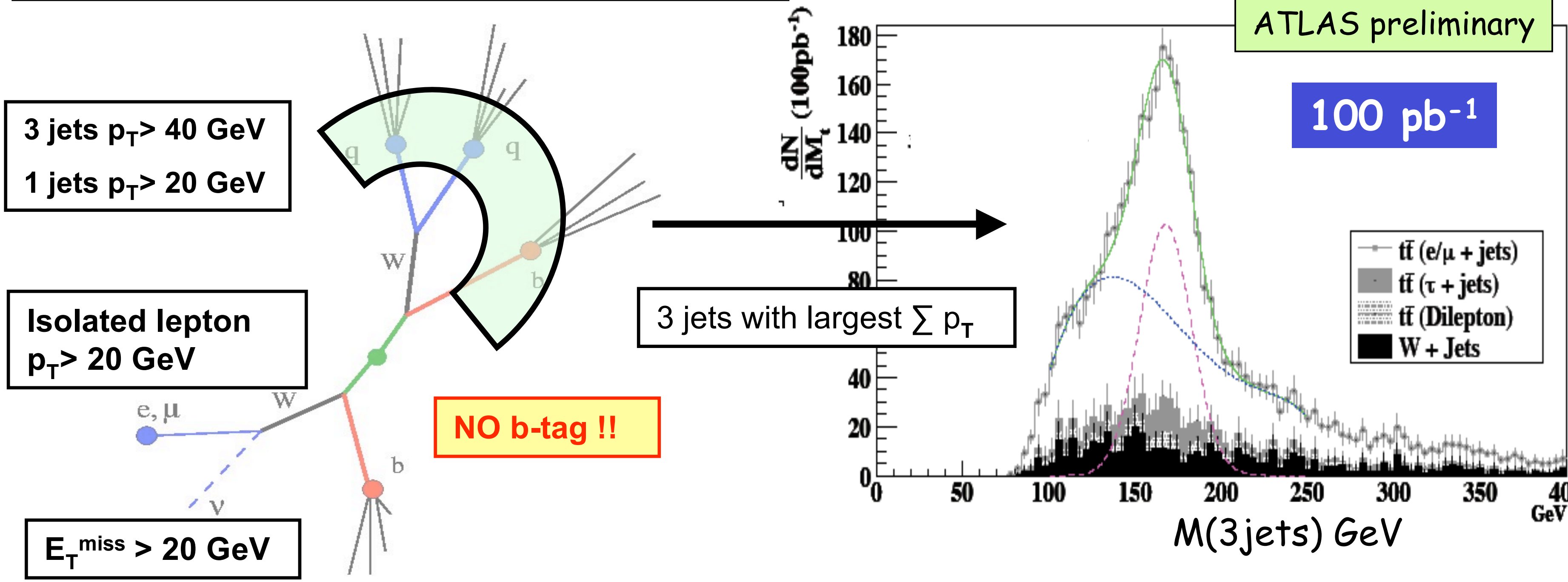
Central value of ZEUS-PDF prediction shifts and uncertainty is reduced
Error on low-x gluon shape parameter λ [$xg(x) \sim x^{-\lambda}$] reduced from 23% to 15%

Systematics (e.g. $e^{\pm}$ acceptance vs η) can be controlled to few percent with $Z \rightarrow ee$
(~ 30000 events for 100 pb^{-1})

The first top quarks in Europe …

A top signal can be observed quickly, even with limited detector performance and simple analysis …. and then used to calibrate the detector and understand physics

$\sigma_{tt} \approx 250$ pb for $tt \rightarrow bW\ bW \rightarrow bl\nu\ bjj$



Top signal observable in early days with no b-tagging and simple analysis (~1000 evts for 30 pb^{-1}) → measure σ_{tt} to ~20%, m_t to <10 GeV with 100 pb^{-1}?
(ultimate LHC precision on m_t: ~ 1 GeV)

In addition, excellent sample to:

- commission b-tagging, set jet E-scale using $W \rightarrow jj$ peak, …
- understand / constrain theory and MC generators using e.g. p_T spectra

What about (early) discoveries ?

A good candidate:

a narrow resonance with mass ~ 1 TeV decaying into e^+e^-

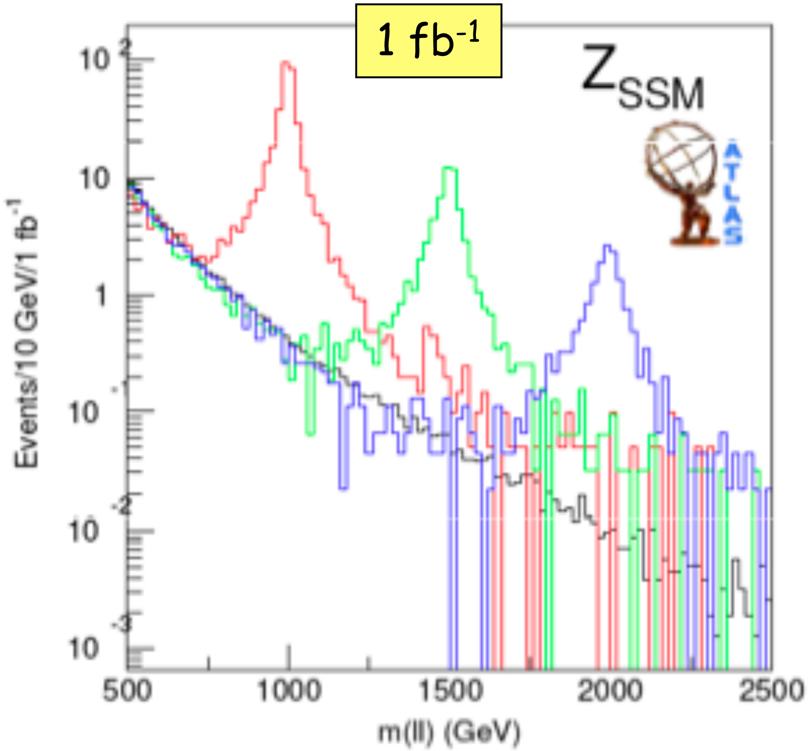
$Z' \rightarrow e^+e^-$ with SM-like couplings (Z_{SSM})

Mass	Expected events for 1 fb^{-1} (after all analysis cuts)	Integrated luminosity needed for discovery (corresponds to 10 observed evts)
1 TeV	~ 160	~ 70 pb^{-1}
1.5 TeV	~ 30	~ 300 pb^{-1}
2 TeV	~ 7	~ 1.5 fb^{-1}

- with 100 pb^{-1} large enough signal for discovery up to m > 1 TeV
- signal is (narrow) mass peak on top of small Drell Yan background
- ultimate calorimeter performance not needed

Is it a Z' or a Graviton ? From angular distribution of e^+e^- can disentangle Z' (spin=1) from G (spin=2). Requires more data (~ 100 fb^{-1})

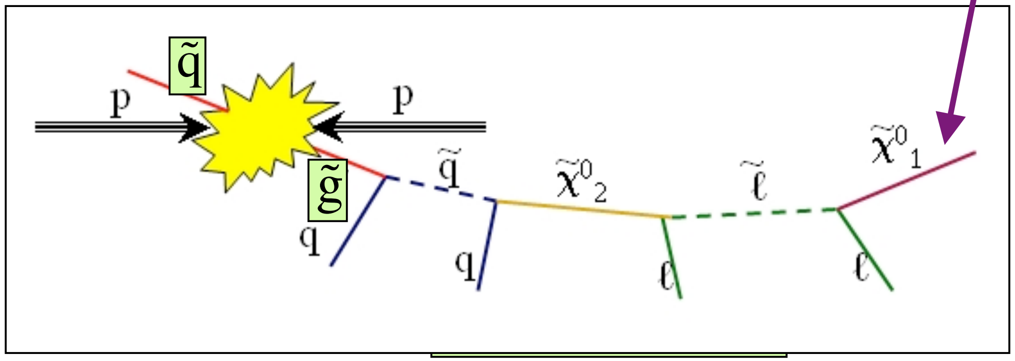
Ultimate ATLAS reach (300 fb^{-1}): ~ 5 TeV



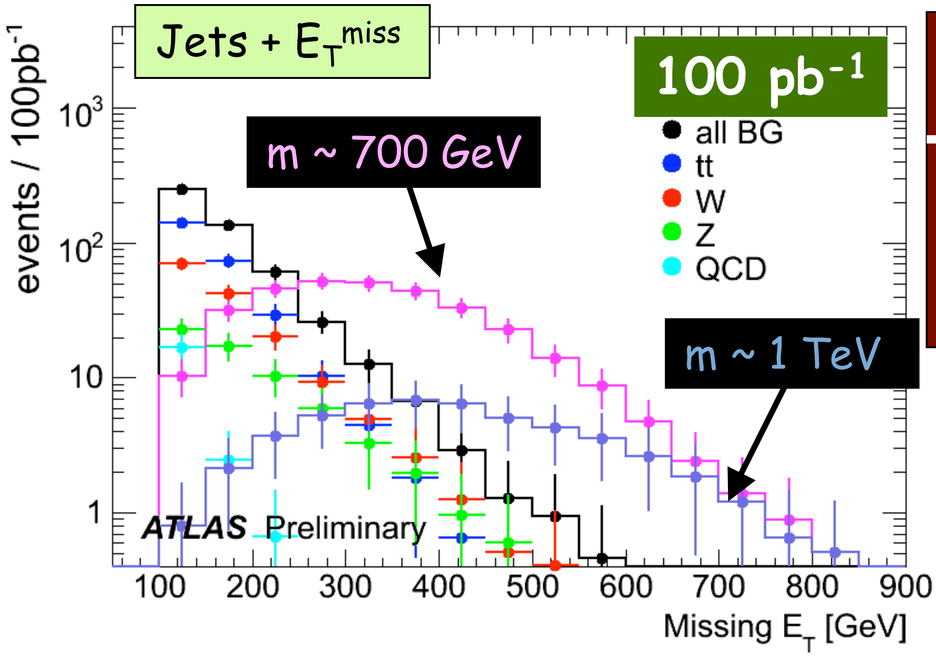
Another example: Supersymmetry

If it is at the TeV scale, it should be found "quickly" …. thanks to:

- large (strong) cross-section for $\tilde{q}\tilde{q}, \tilde{g}\tilde{q}, \tilde{g}\tilde{g}$ production
- spectacular signatures (many jets, leptons, missing E_T)



For $m(\tilde{q},\tilde{g}) \sim 1$ TeV
expect 10 evts/day at $L=10^{32}$



LHC reach for gluino mass

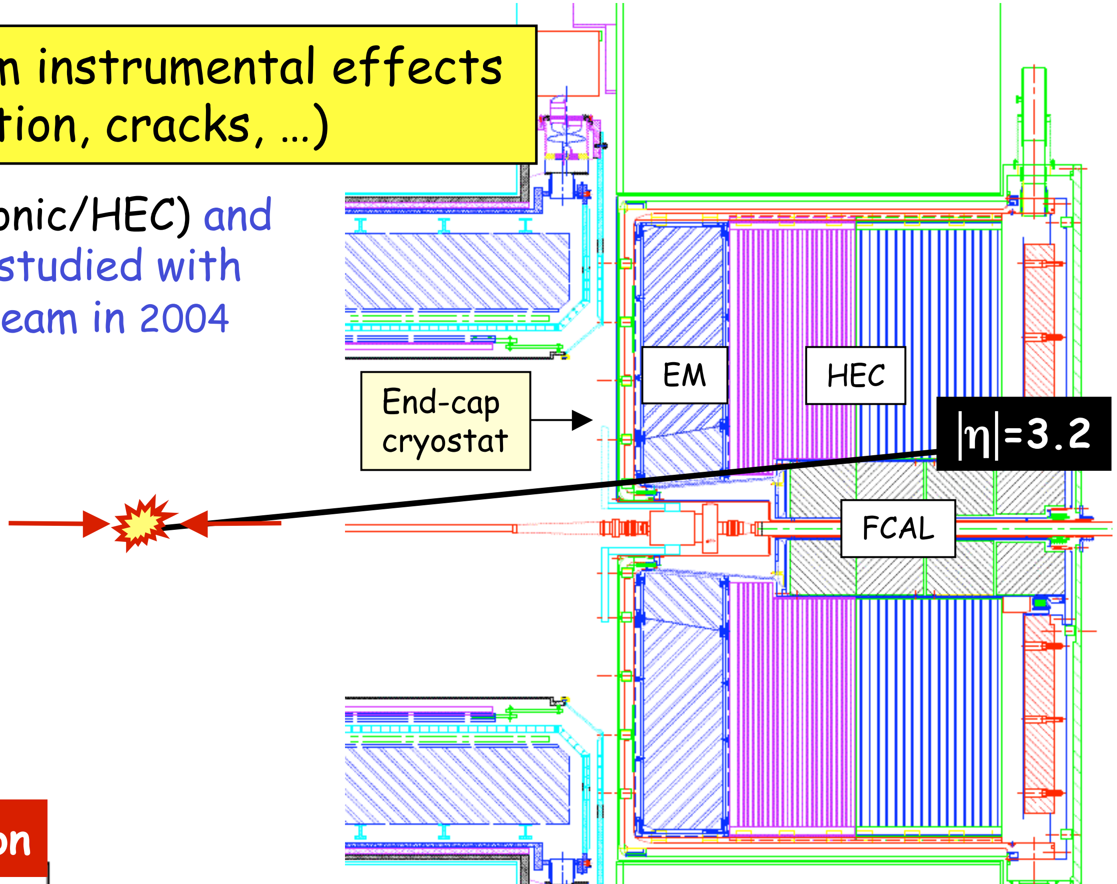
$\int Ldt$ of well understood data	Discovery (95% C.L. exclusion)
0.1-1 fb^{-1} (2009)	~1.1 TeV (1.5 TeV)
≥1 fb^{-1} (2009-2010)	~1.7 TeV (2.2 TeV)
300 fb^{-1} (ultimate)	up to ~ 3 TeV

Hints with only 100 pb^{-1} up to m~1 TeV, but understanding backgrounds requires ~1 fb^{-1}

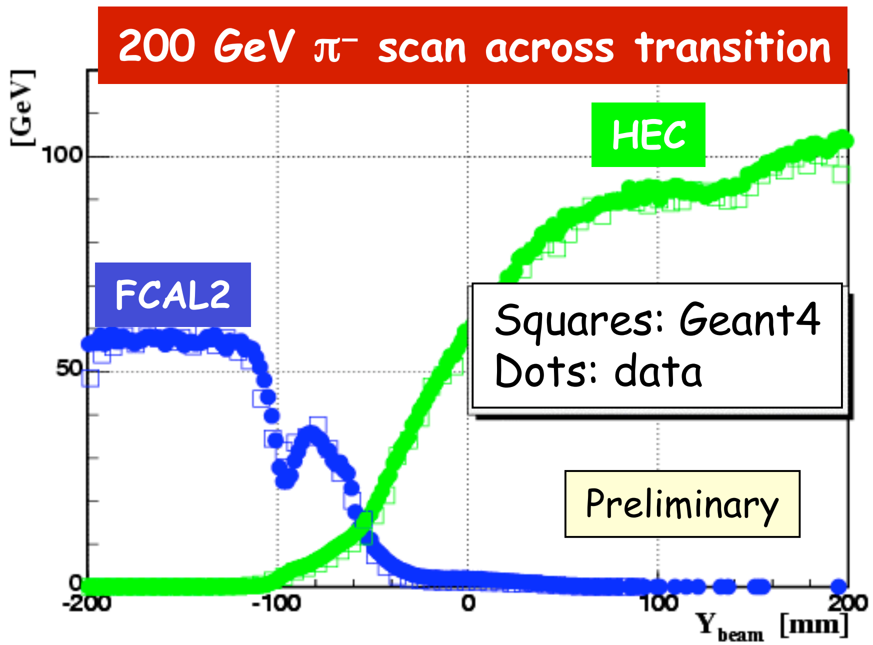
Planning for future facilities would benefit a lot from quick determination of scale of New Physics. With ~ 1 fb^{-1} LHC could tell if "standard" SUSY accessible to $\sqrt{s} \leq 1$ TeV ILC.

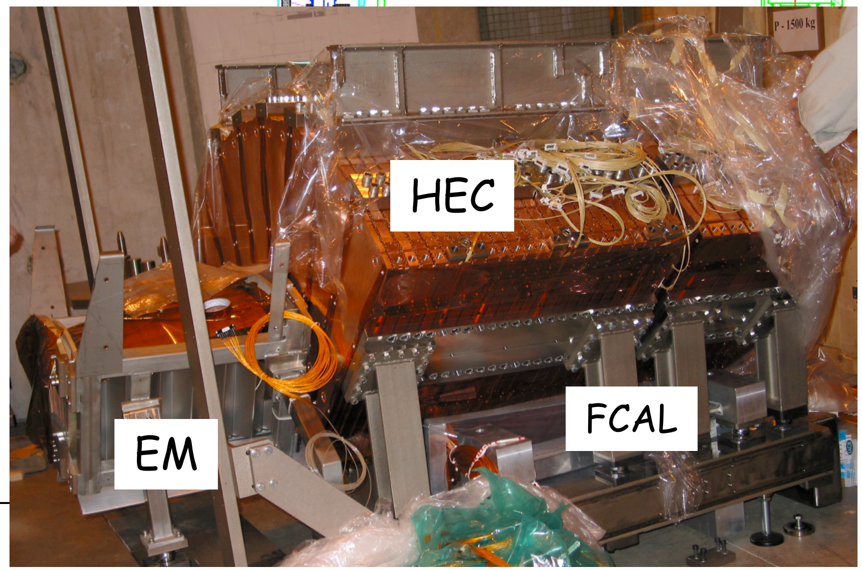
Background 1: fake E_T^{miss} tails from instrumental effects (calorimeter non-linearities, resolution, cracks, …)

Transition between end-cap (EM, hadronic/HEC) and forward (FCAL) calorimeters at η=3.2 studied with dedicated combined test-beam in H6 beam in 2004



Data described well by MC in complex region with 3 different calorimeters and a lot of material



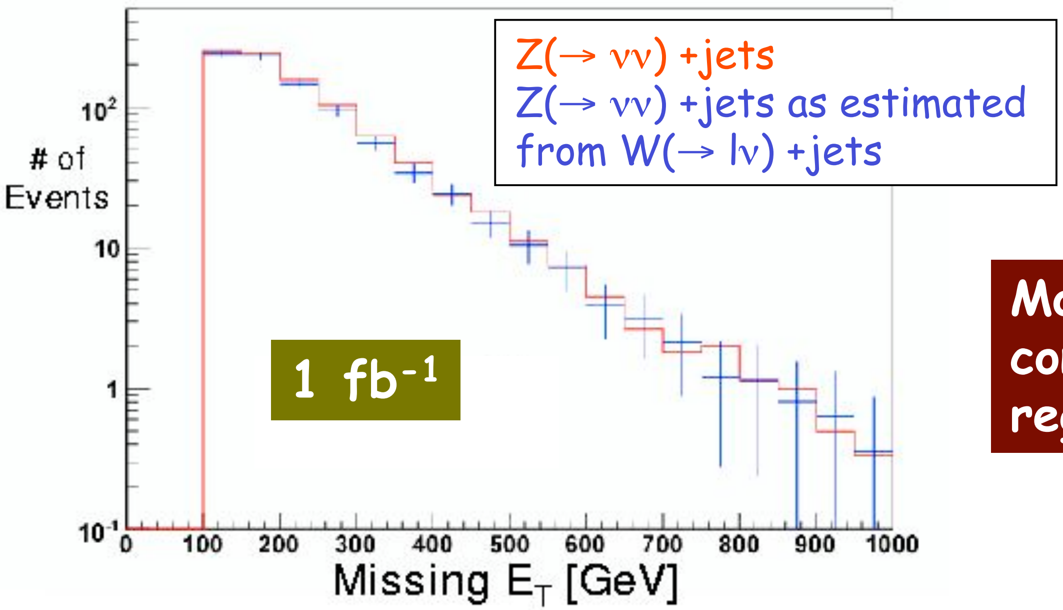


Background 2: genuine E_T^{miss} tails from Standard Model processes

Physics backgrounds will be estimated using as much as possible data (control samples)

Background process (examples ….)	Control samples (examples ….)
Z (→ νν) + jets	Z (→ll),W(→lν) + jets
W (→ τν) + jets	W (→ eν, μν) + jets
tt → blνbjj l=τ or lost	tt → blνbjj l=e,μ
QCD multijets	Extrapolate from low E_T^{miss}

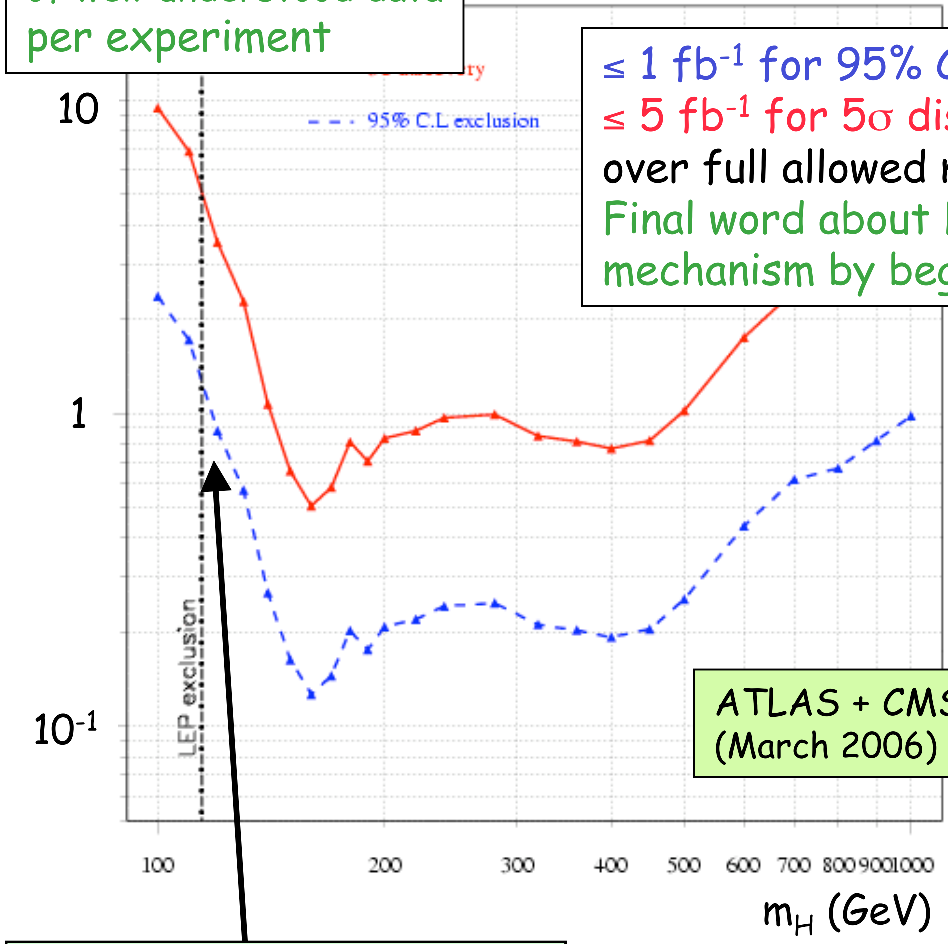
ATLAS preliminary



Most physics backgrounds can be constrained to 10-20% in the region E_T^{miss}>300 GeV with 1 fb^{-1}

A more difficult case: a light Higgs boson

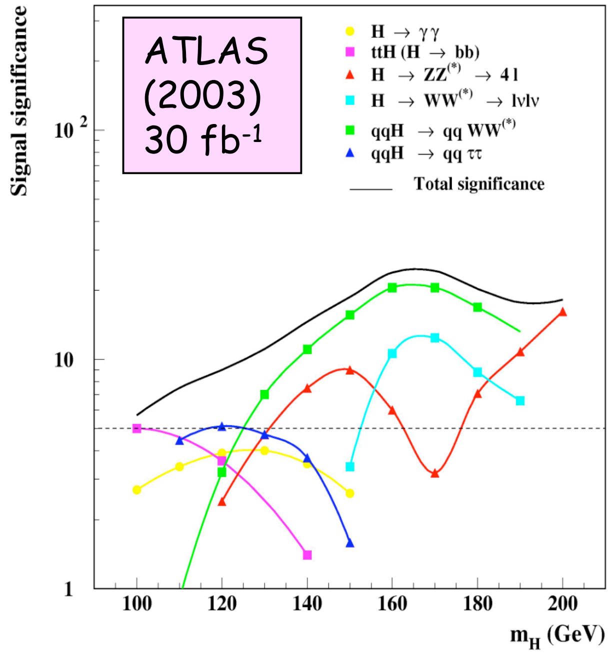
Needed ∫Ldt (fb^{-1})
of well-understood data
per experiment



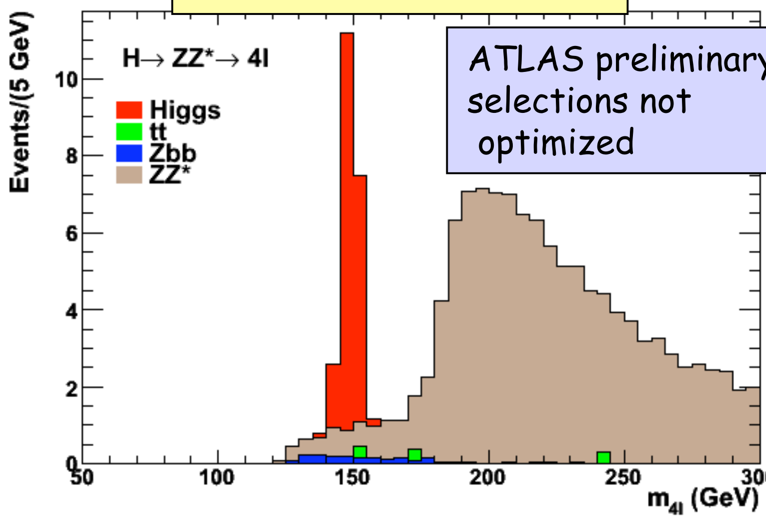
$\leq$ 1 fb^{-1} for 95% C.L. exclusion
$\leq$ 5 fb^{-1} for 5σ discovery
over full allowed mass range
Final word about Higgs
mechanism by beg. 2010 ?

ATLAS + CMS
(March 2006)

Most difficult region:
need to combine many
channels (e.g. $H \to \gamma\gamma$, $qqH \to qq\tau\tau$) with small S/B



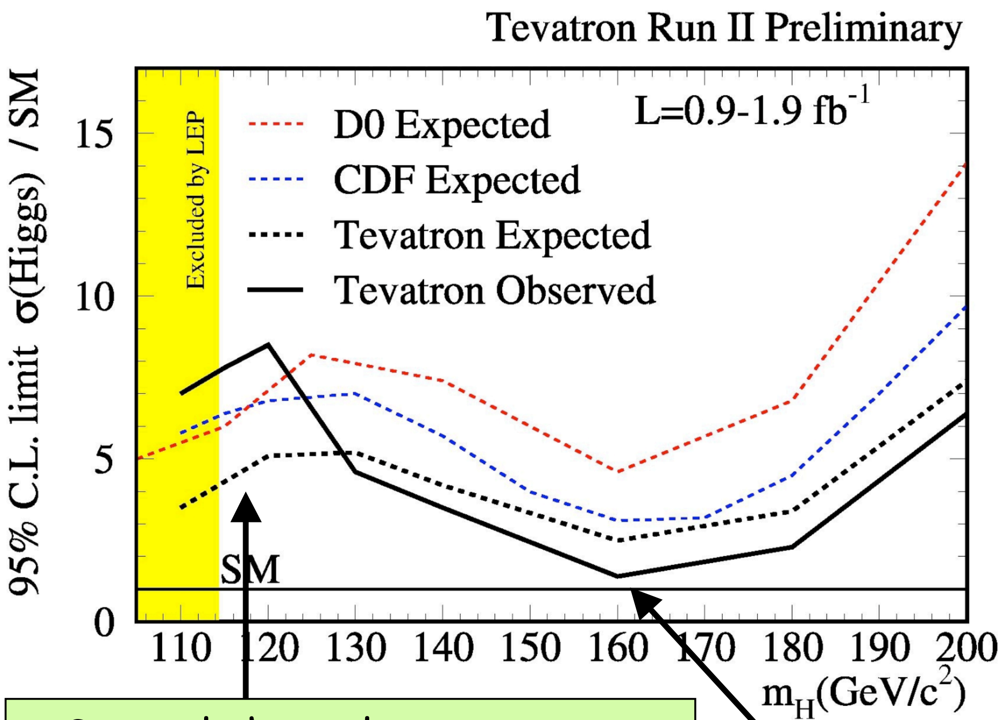
$H \to ZZ^* \to 4l$, 10 fb^{-1}



ATLAS preliminary,
selections not
optimized

For m_H > 140 GeV discovery easier with $H \to ZZ^{(*)} \to 4l$ (narrow mass peak, small B). $H \to WW \to l\nu l\nu$ (dominant at 160-175 GeV) is counting experiment (no mass peak)

What about the "competition" with Tevatron ?



Today : ~2.8 fb^{-1} /expt recorded
End 2009: expect 6-7 fb^{-1} /expt
Operation beyond 2009 being discussed

With 7 fb^{-1}:

- 95% C.L. exclusion 150-180 GeV and <135 GeV (if ~4 analysis improvement)
- 2.5 σ evidence 155-170 GeV
- 3σ evidence up to 128 GeV (if ~10 analysis improvement)
- no 5σ sensitivity

Note: big difference in statistics to go from exclusion to evidence (sophisticated cross-checks required …)

- Several channels: $WH \to l\nu bb$, $ZH \to \nu\nu bb$, etc.
- Expect analysis improvements (b-tagging, mass resolution, ..)
- With 7 fb^{-1} need: ~4 (10) improvement for 95% C.L. (3σ)

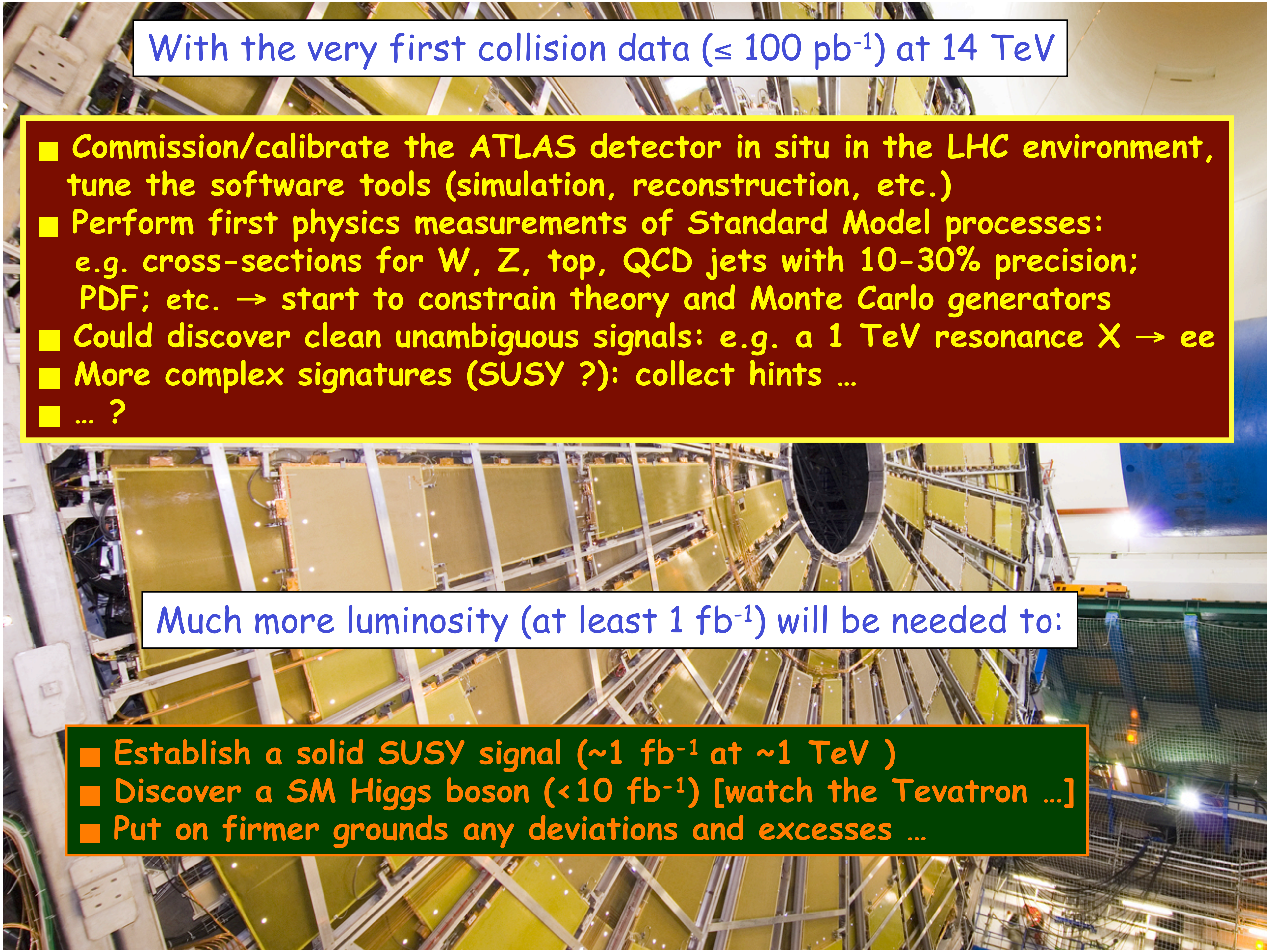
- 1 dominant channel: $H \to WW \to l\nu l\nu$ (counting channel)
- 3.8 fb^{-1}/expt for 95% C.L. exclusion (mid 2008 ?)
- end 2009: 2.5σ (6 fb^{-1}) to 3σ (8.5 fb^{-1}) evidence

Conclusions:

- end 2009: 2.5-3σ sensitivity in some regions (they will not wait 5σ to claim evidence …)
- outstanding machine performance; detectors well understood; sophisticated analyses (see single-top observation) … unlike first 2 years of LHC operation
- every additional delay to the LHC schedule increases the "risk" significantly …

Conclusions

- ATLAS detector installation in underground cavern almost completed → ready to close beam pipe in April 2008
  Software tools and computing infrastructure are also in good shape for data taking.
- Intense test-beam activity over last 15 years has allowed us to demonstrate/understand the detector performance and validate software tools (simulation, reconstruction, etc.) with real data
- Cosmics data taking has now started with the almost complete detector in the underground cavern → this commissioning effort will allow us to save time when first collisions will become available.
- Re-evaluation of the experiment's physics potential with final software and simulation of "as-built, as-installed" detector is going on.
  The large number of channels and scenarios studied demonstrate the detector sensitivity to many signatures → robustness, ability to cope with unexpected scenarios



With the very first collision data (≤ 100 pb^{-1}) at 14 TeV

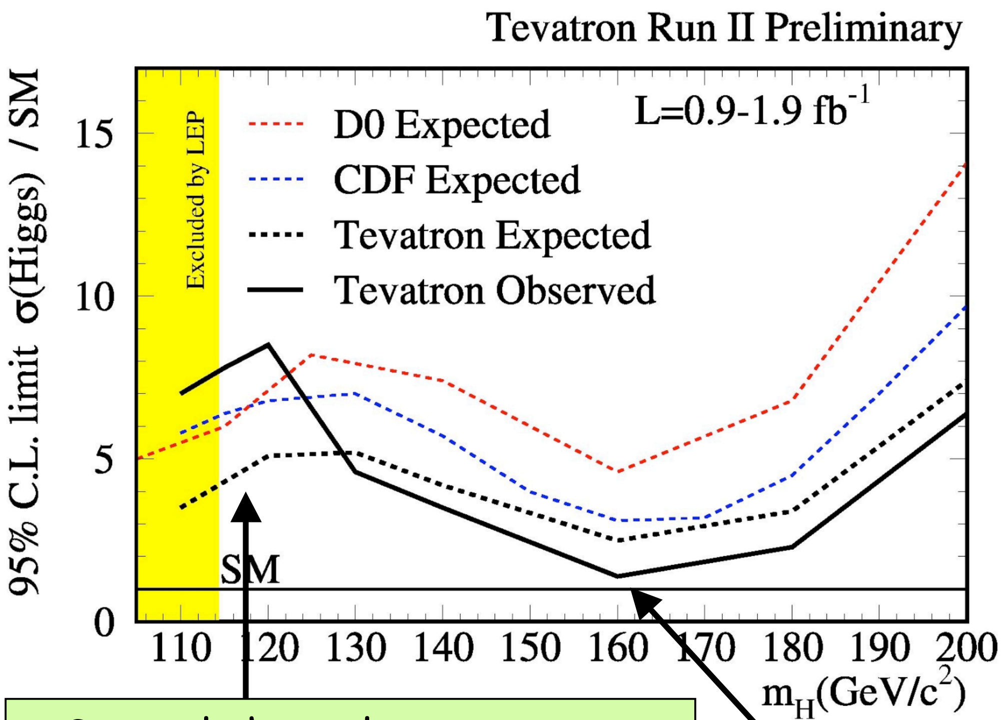
- Commission/calibrate the ATLAS detector in situ in the LHC environment, tune the software tools (simulation, reconstruction, etc.)
- Perform first physics measurements of Standard Model processes: e.g. cross-sections for W, Z, top, QCD jets with 10-30% precision; PDF; etc. → start to constrain theory and Monte Carlo generators
- Could discover clean unambiguous signals: e.g. a 1 TeV resonance X → ee
- More complex signatures (SUSY ?): collect hints …
- … ?

Much more luminosity (at least 1 fb^{-1}) will be needed to:

- Establish a solid SUSY signal (~1 fb^{-1} at ~1 TeV)
- Discover a SM Higgs boson (<10 fb^{-1}) [watch the Tevatron …]
- Put on firmer grounds any deviations and excesses …

Spare slides

What about the "competition" with Tevatron ?



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Conclusions:

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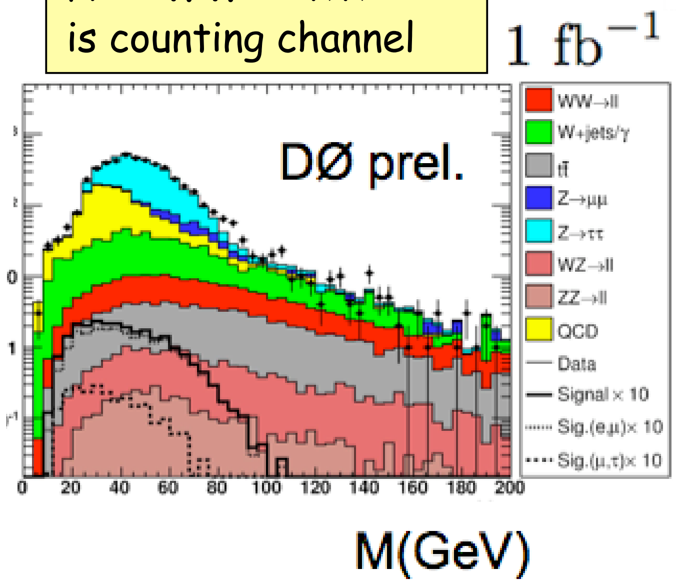
- outstanding machine performance; detectors well understood; sophisticated analyses (see single-top observation) … unlike first 2 years of LHC operation
- every additional delay to the LHC schedule increases the "risk" significantly …

	Main channels Tevatron	Main channels LHC
m_H~115 GeV	$WH \to l\nu bb$ $ZH \to \nu\nu bb$	$H \to \gamma\gamma$ $ttH \to l\nu bbX$ (t.b.c.) $qqH \to qq\tau\tau$
m_H~160 GeV	$H \to WW \to l\nu l\nu$	$H \to WW \to l\nu l\nu$ $qqH \to qqWW \to qql\nu l\nu$ $H \to ZZ^* \to 4l$

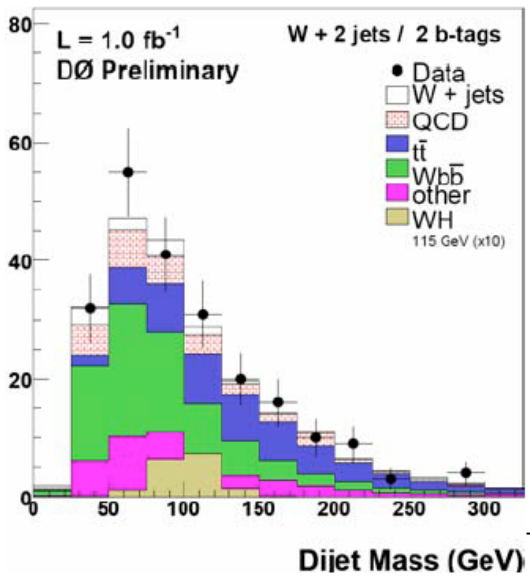
Small S/B at LHC

Cross-section too small at Tevatron

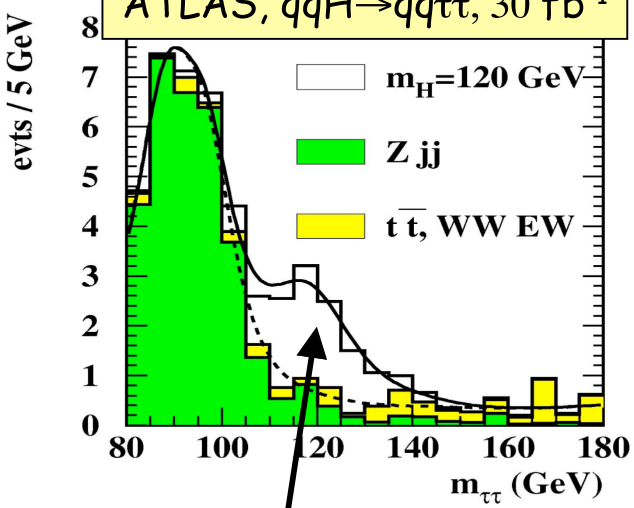
$H \to WW \to l\nu l\nu$
is counting channel



$WH \to l\nu bb$

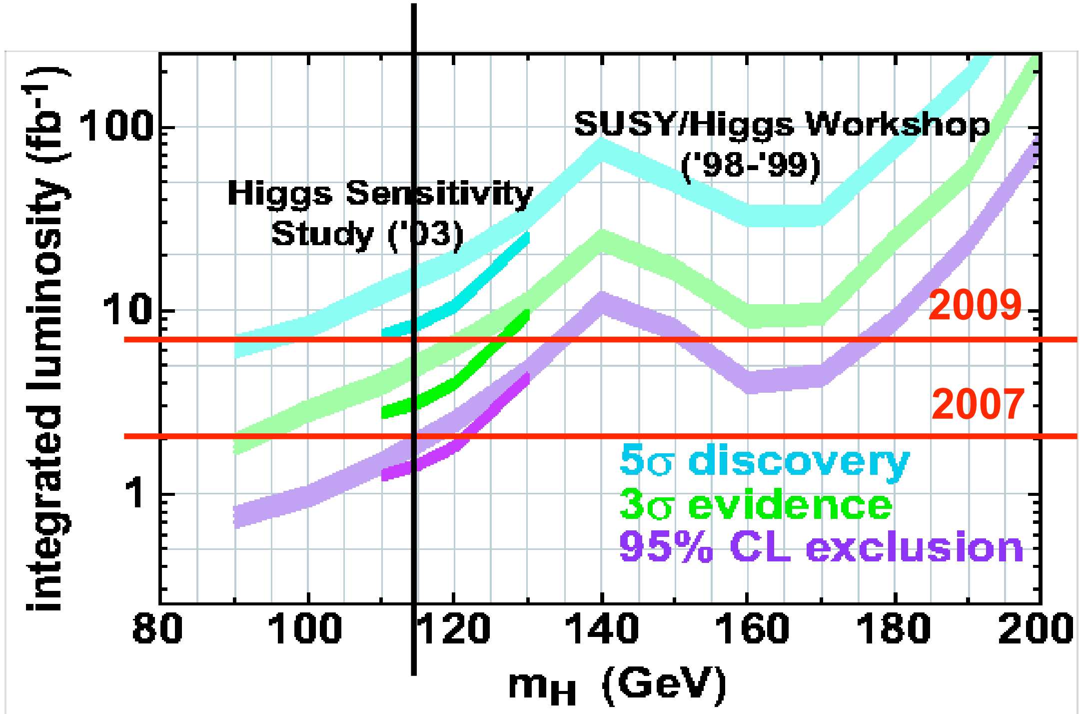


ATLAS, $qqH \to qq\tau\tau$, 30 fb^{-1}



Difficult at the beginning: requires jet veto, fwd jet tag, good E_T^{miss} resolution

What about the Tevatron ?



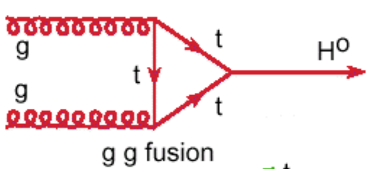
Today : ~ 2.8 fb^{-1} /experiment
2009: expect 6-7 fb^{-1} /experiment
Tevatron operation in 2010 being discussed

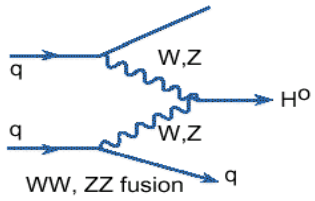
competition between Tevatron and LHC in 2009-2010 if m_H < 130 GeV or 155<m_H<165 GeV ?

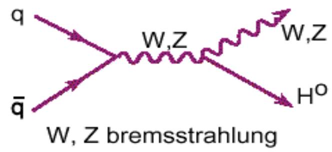
Tevatron vs LHC after kin. cuts	WH → lν bb (m_H=120 GeV)	H → WW(*) (m_H = 160 GeV)
S (14 TeV/ 2 TeV)	≈ 5	≈ 17
B (14 TeV/ 2 TeV)	≈ 25	≈ 6
S/B (14 TeV/ 2 TeV)	≈ 0.2	≈ 3
S/√B (14 TeV/ 2 TeV)	≈ 1	≈ 7

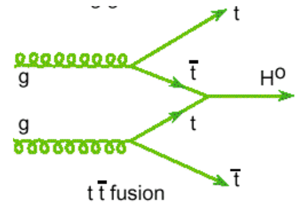
Assuming <u>same</u> integrated luminosity and <u>same</u> detector performance at Tevatron and LHC

Higgs Boson Production at Hadron Colliders



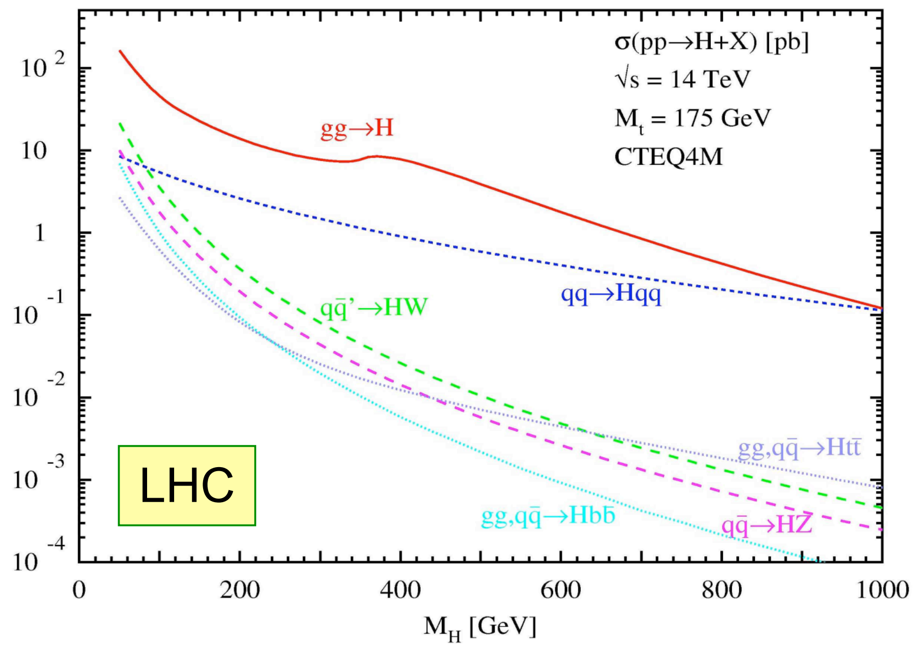




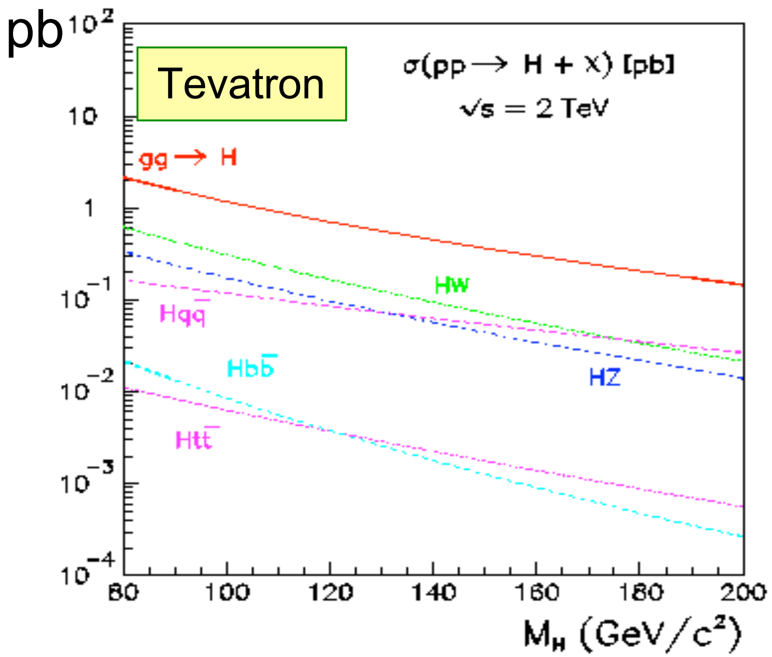


pb

M. Spira et al.



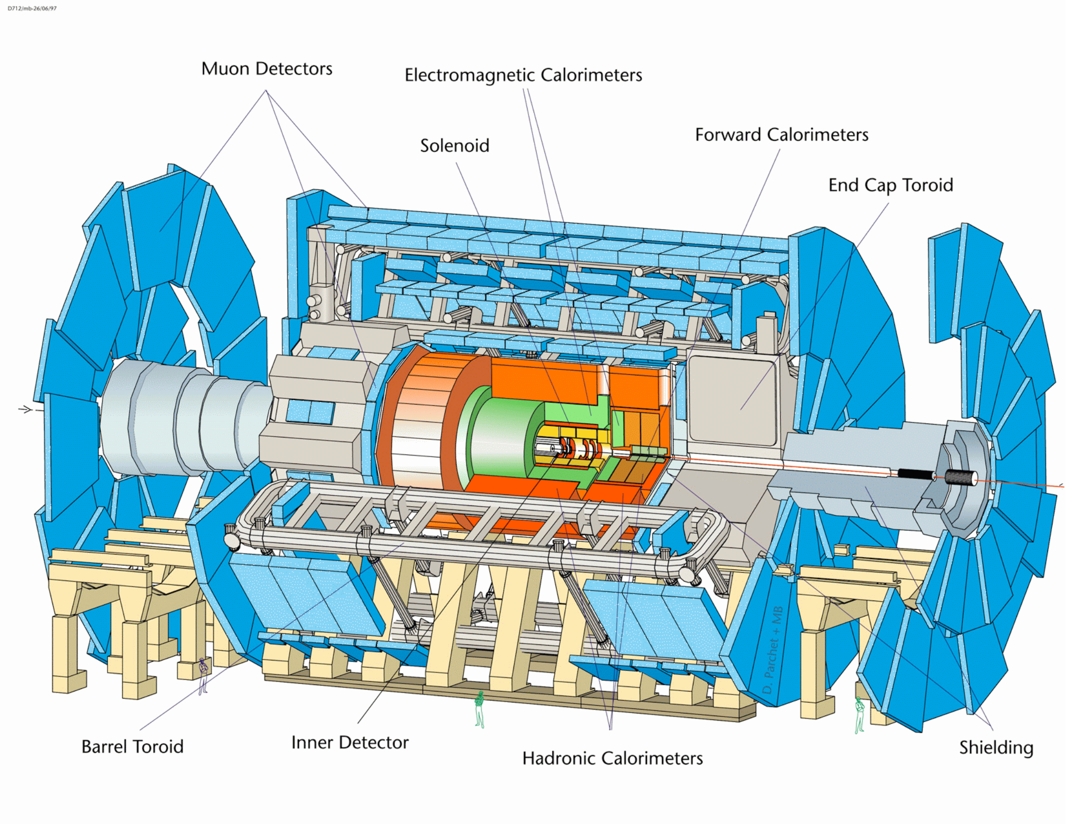
M.Spira et al.



qq → W/Z + H cross sections ~10 x larger at the LHC

gg → H ~70-80 x larger at the LHC

ATLAS



Length : ~ 46 m
Radius : ~ 12 m
Weight : ~ 7000 tons
~10^8 electronic channels
~ 3000 km of cables

- Tracking ($|\eta|<2.5$, B=2T) :
  -- Si pixels and strips
  -- Transition Radiation Detector (e/π separation)

- Calorimetry ($|\eta|<5$) :
  -- EM : Pb-LAr with Accordion shape
  -- HAD: Fe/scintillator (central), Cu/W-LAr (fwd)

- Muon Spectrometer ($|\eta|<2.7$) :
  air-core toroids with muon chambers

And …. 1900 physicists from
165 Institutions from 35 countries
from 5 continents

Trigger: one of the biggest challenges

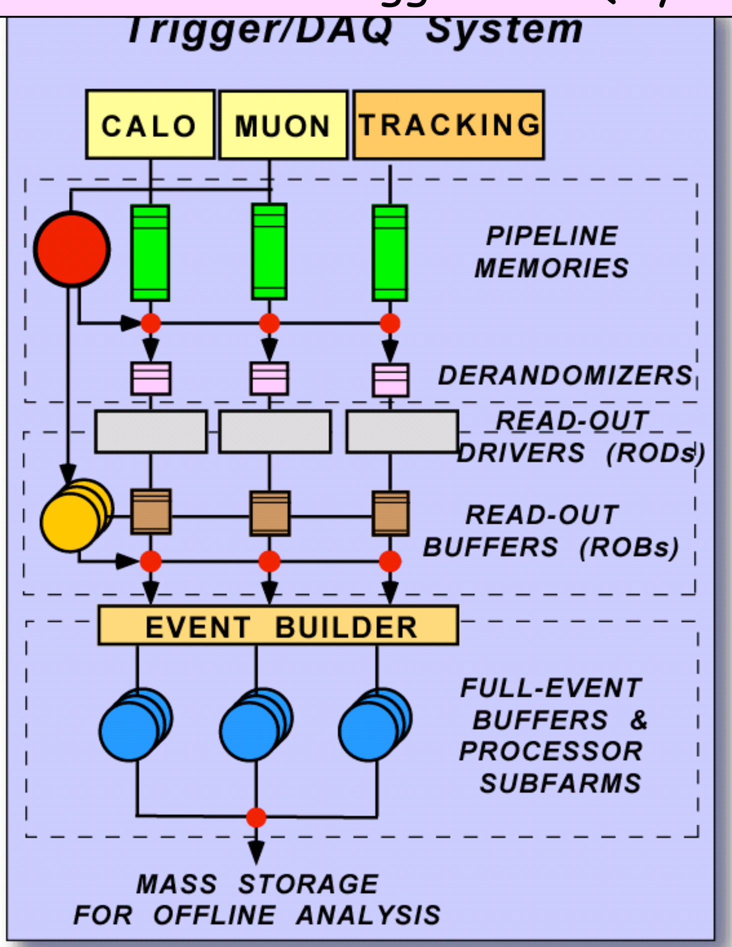
More in S.Dasu's talk

Must reduce rate from 10^9 pp interactions/s (at design luminosity)
to ~ 200 Hz (affordable rate to storage)
Must be very selective and efficient: e.g. 1 H → 4e event every 10^{13} interactions
⇒ multi-level trigger systems

ATLAS 3-level Trigger/DAQ system

RATES

- 40 MHz
- 75 kHz
- 2 kHz
- 200 Hz



LEVEL 1 TRIGGER
- Hardware-Based (FPGAs ASICs)
- Coarse granularity from calorimeter & muon systems
- 2 μs latency (2.5 μs pipelines)

LEVEL 2 TRIGGER
- Regions-of-Interest “seeds”
- Full granularity for all subdetector systems
- Fast Rejection “steering”
- O(10 ms) processing time

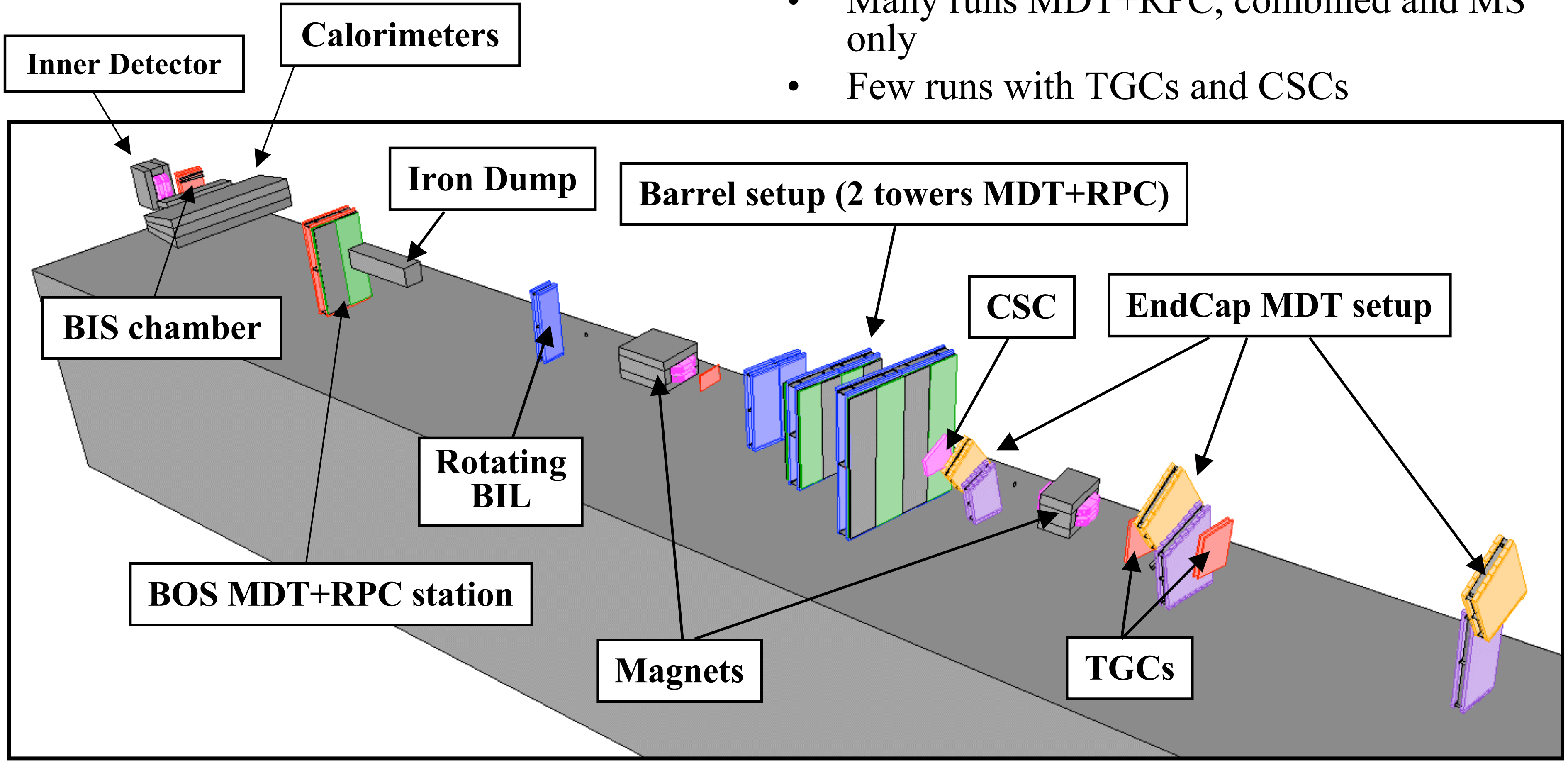
EVENT FILTER
- “Seeded” by Level 2 result
- Potential full event access
- Offline-like Algorithms
- O(1 s) processing time

High Level Trigger

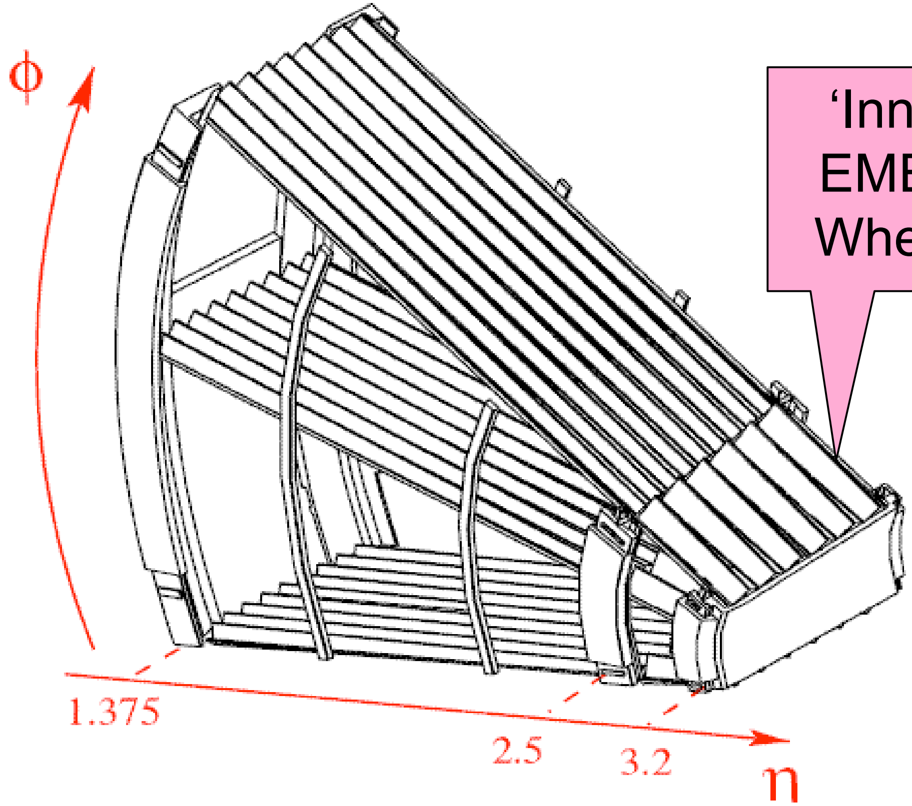
H8 Testbeam final configuration

- Inner Detector (Pixel, SCT, TRT)
- Calorimeters- Liquid Argon e/m and hadronic Tile

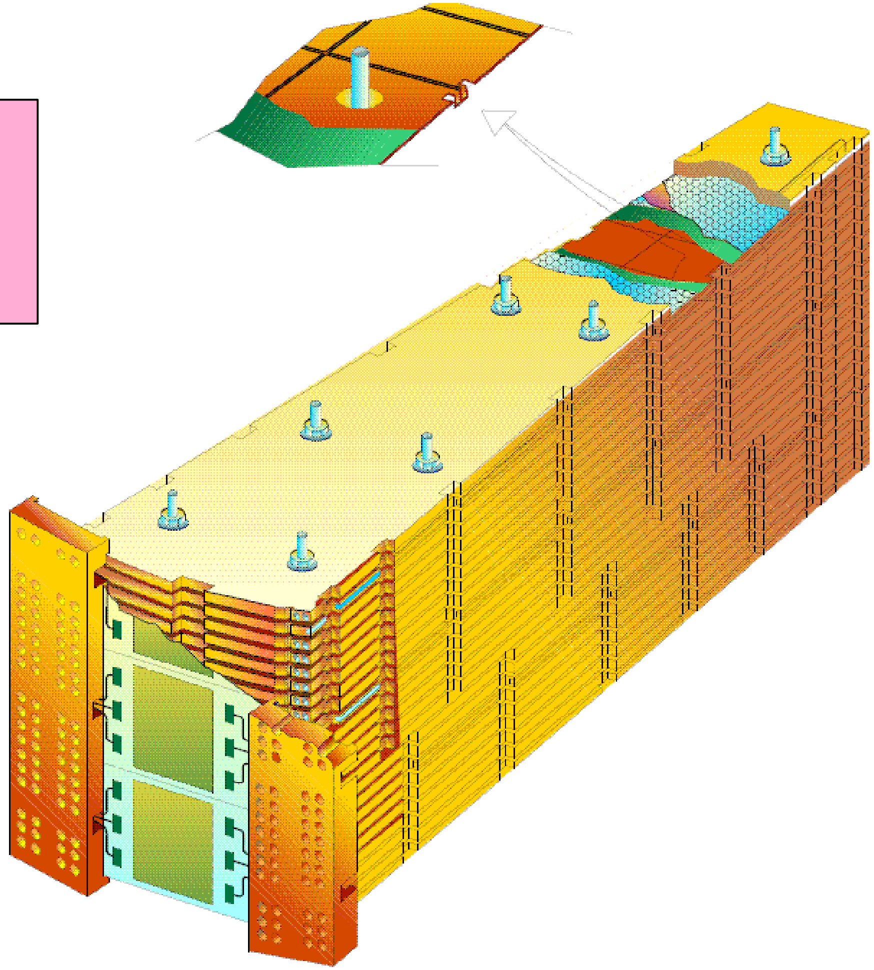
- All muon chambers technologies were tested MDT, RPC, TGC, CSC
- Muon beams at energies ~10 up to 350GeV
- Many runs MDT+RPC, combined and MS only
- Few runs with TGCs and CSCs



LAr Endcap Calorimeter



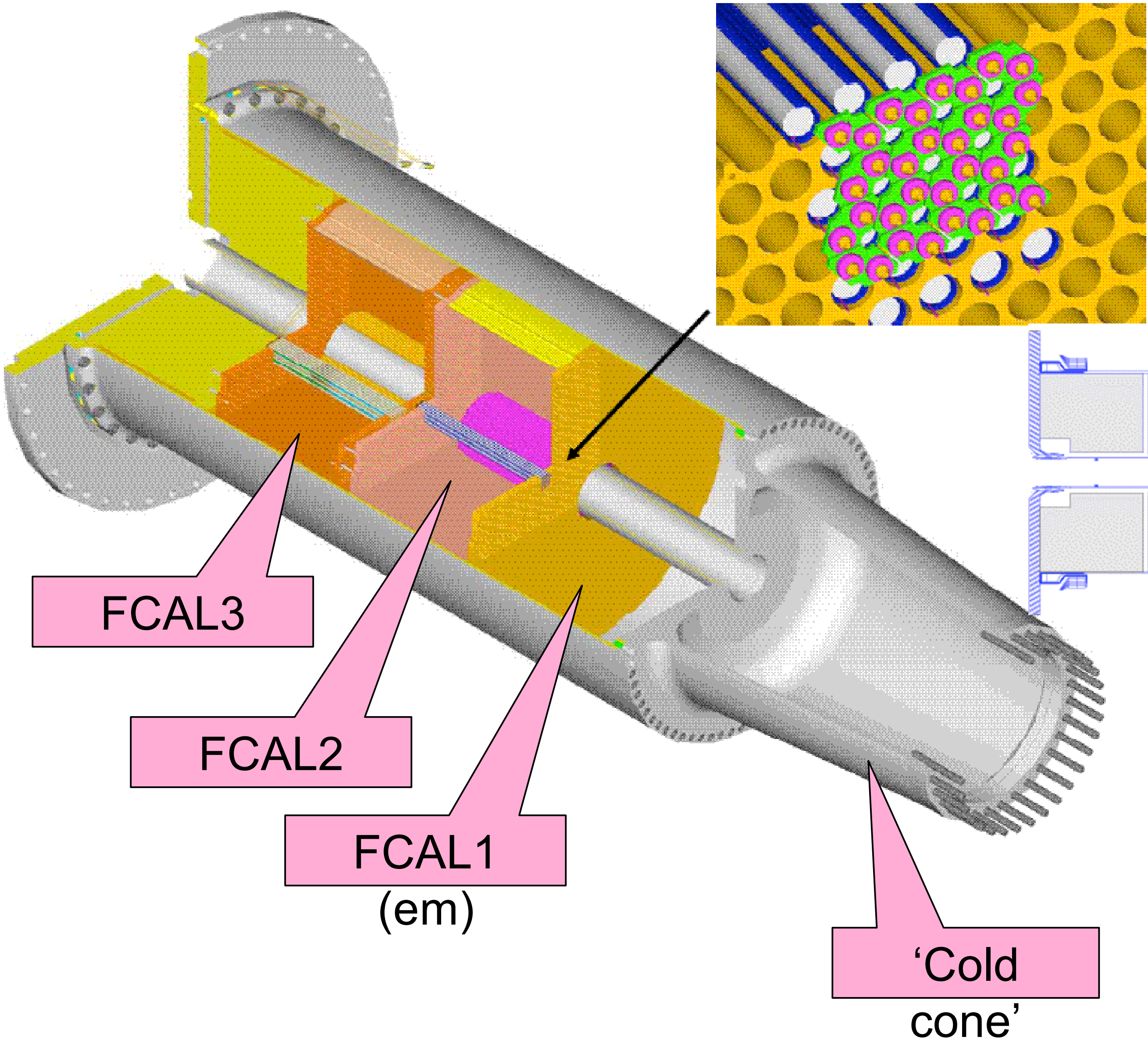
'Inner EMEC Wheel'

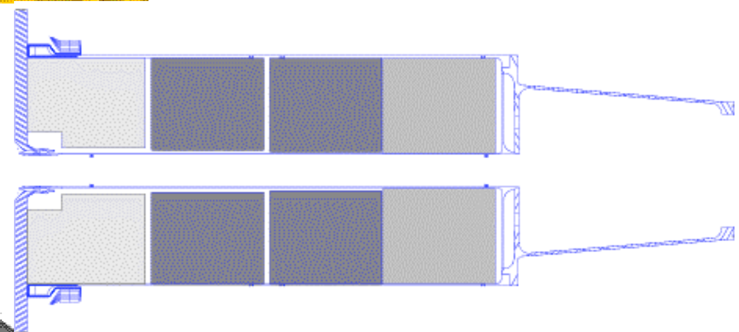


EMEC wheel has 8 modules ..

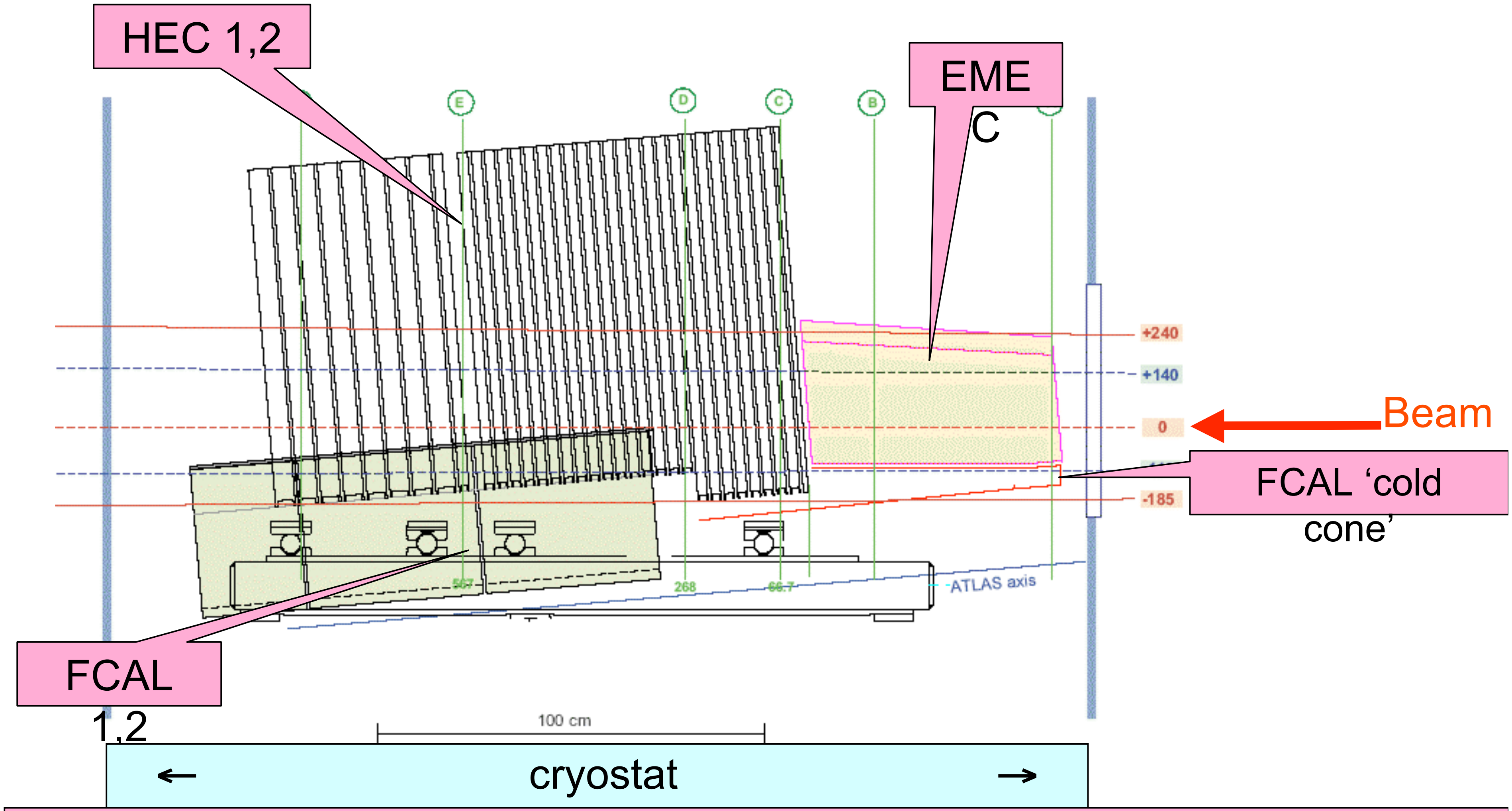
Each HEC (1and 2) wheel has 32 modules ..

LAr Forward Calorimeter



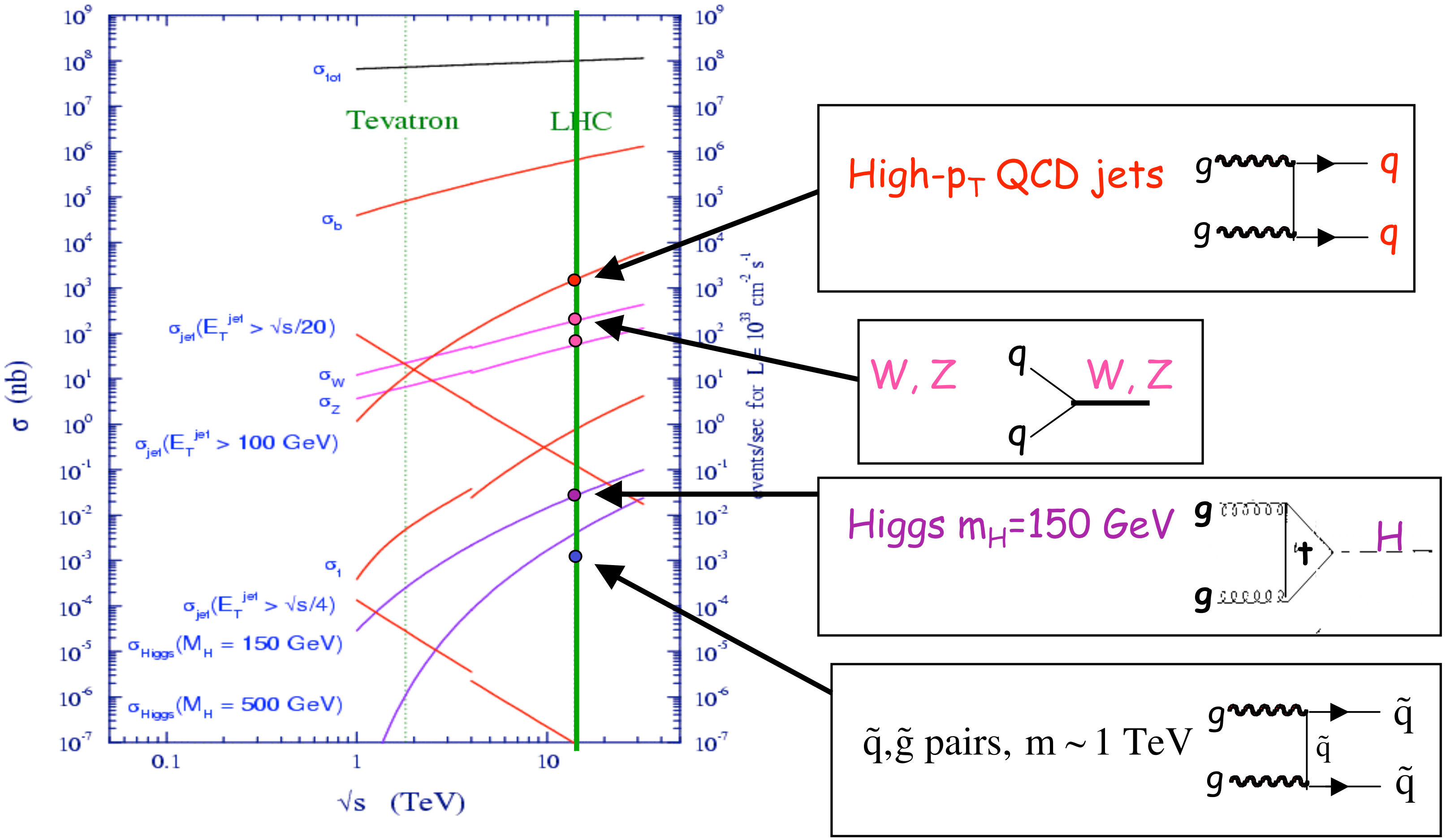


Testbeam Set-up: Side View (CERN, H6 Beam)

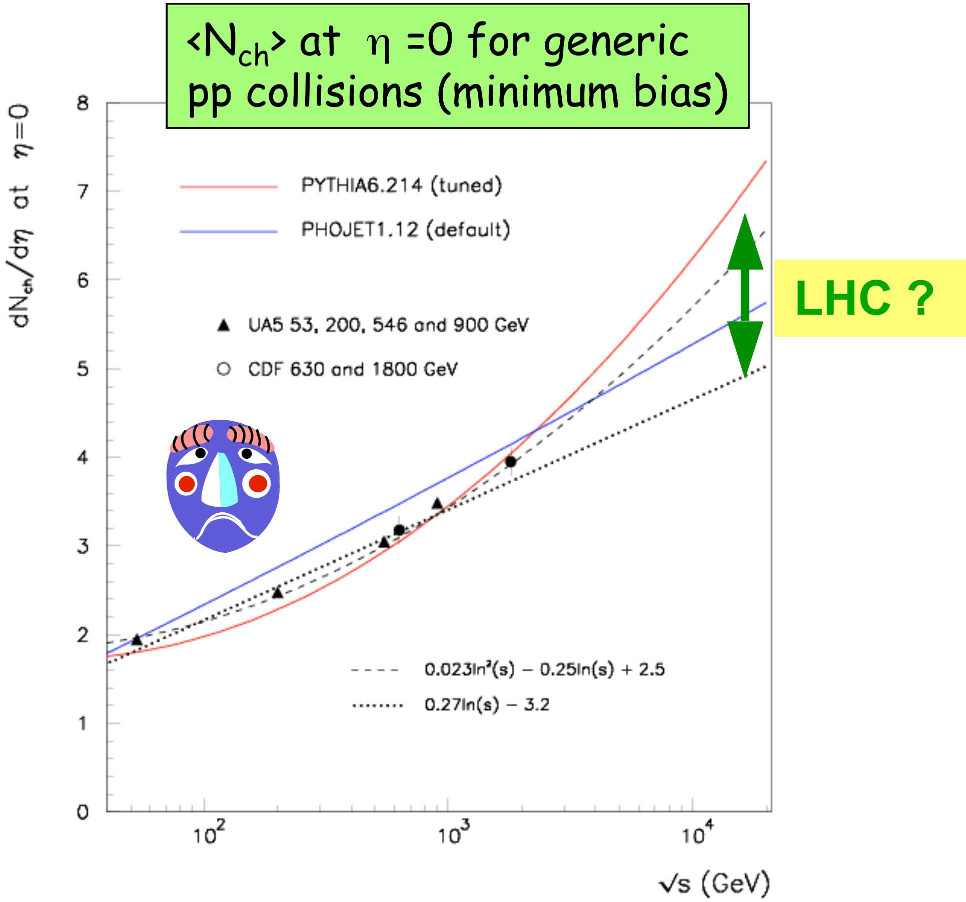


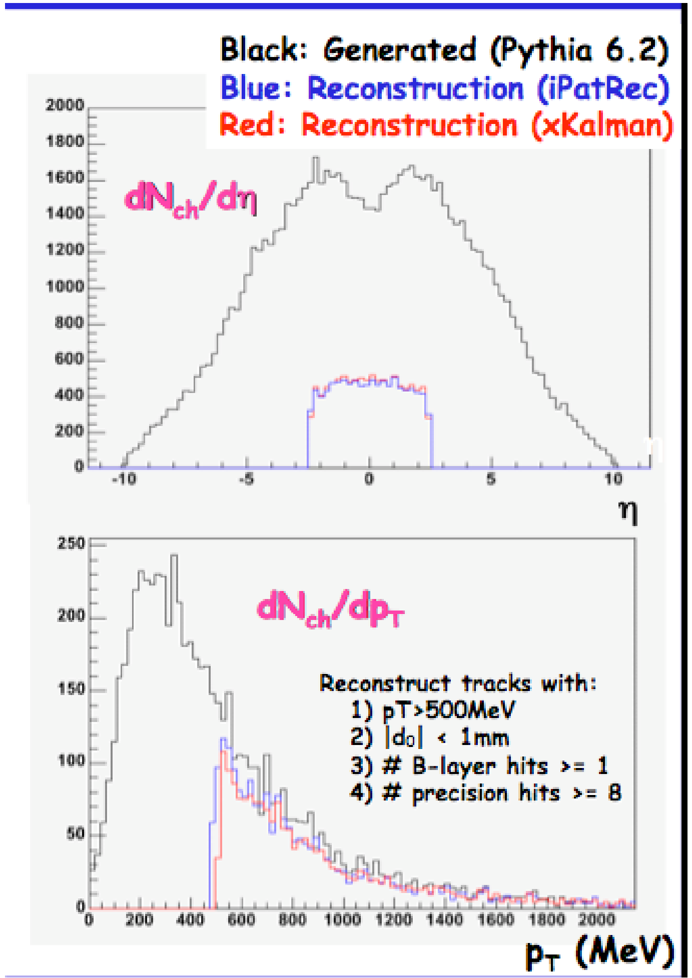
Goal: calibrate complicated region with various dead material zones and 3 different calorimeters

❶ Huge (QCD) backgrounds (consequence of high energy …)



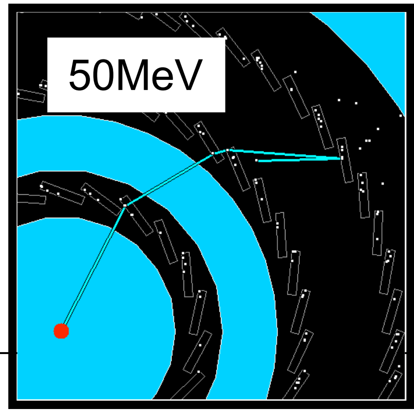
- No hope to observe light objects (W, Z, H ?) in fully-hadronic final states → rely on l, γ
- Mass resolutions of ~ 1% (10%) needed for l, γ (jets) to extract tiny signals from backgrounds, and excellent particle identification (e.g. e/jet separation)
- Fully-hadronic final states (e.g. $q^* \to qg$) can be extracted from backgrounds only with hard O(100 GeV) p_T cuts → works only for heavy objects
- Signal (EW) /Background (QCD) larger at Tevatron than at LHC

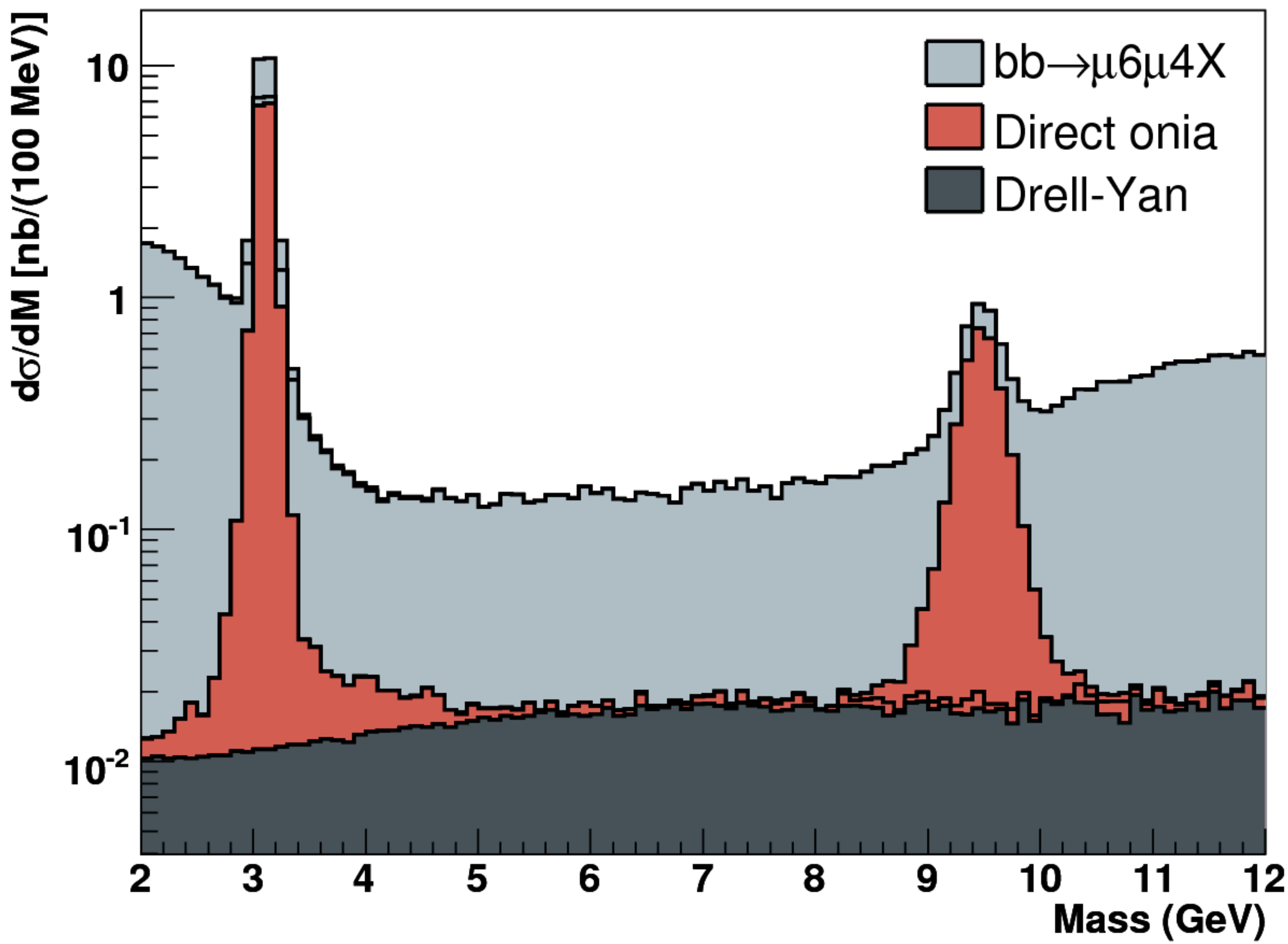




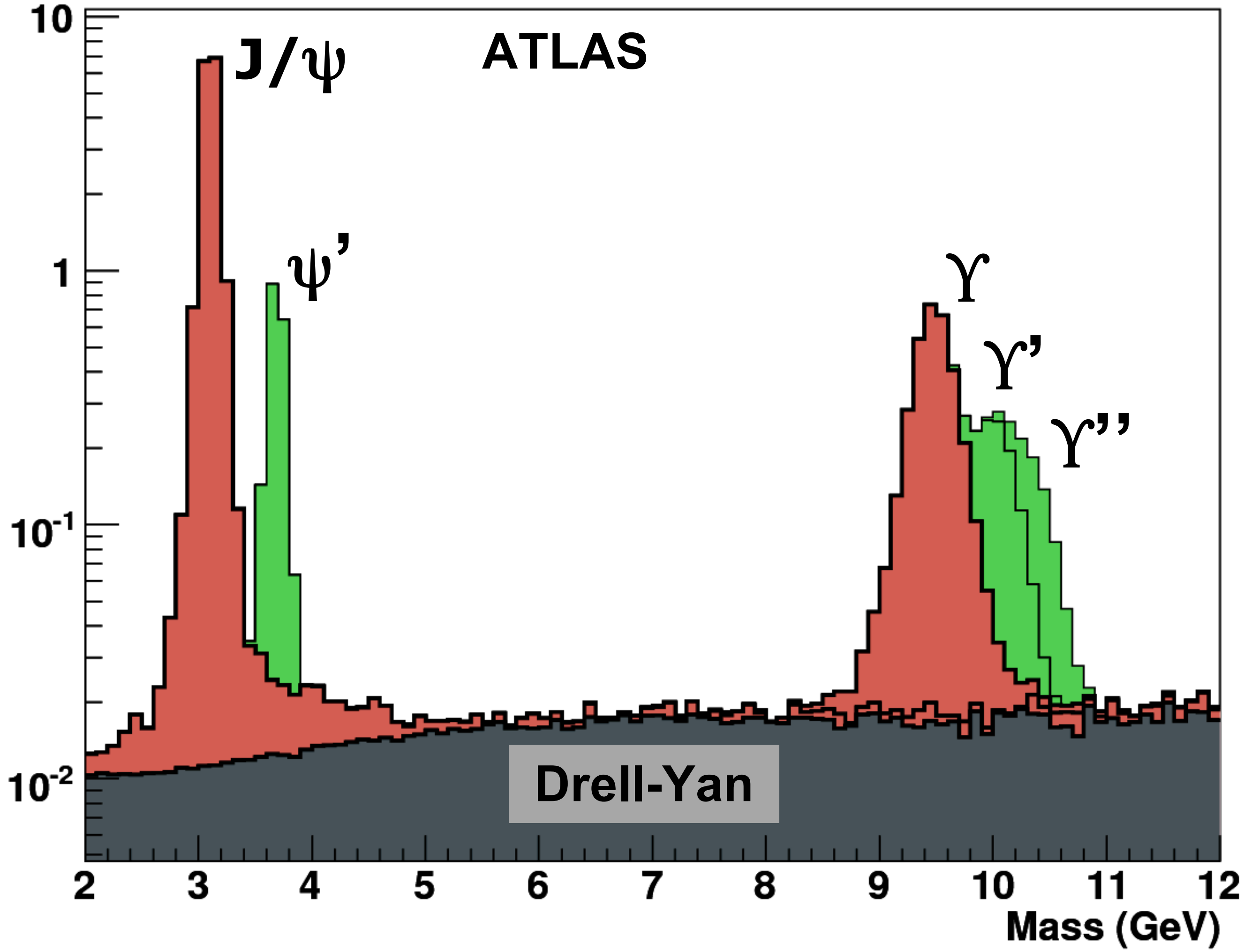
Candidate to very early measurement:
few 10^4 events enough to get $dN_{ch}/d\eta$, dN_{ch}/dp_T
→ tuning of MC models
→ understand basics of pp collisions, occupancy, pile-up, …

Important to measure tracks down to very low p_T
ATLAS tracker: sensitive down to p_T=50 MeV
(tracks reach all Pixel layers)



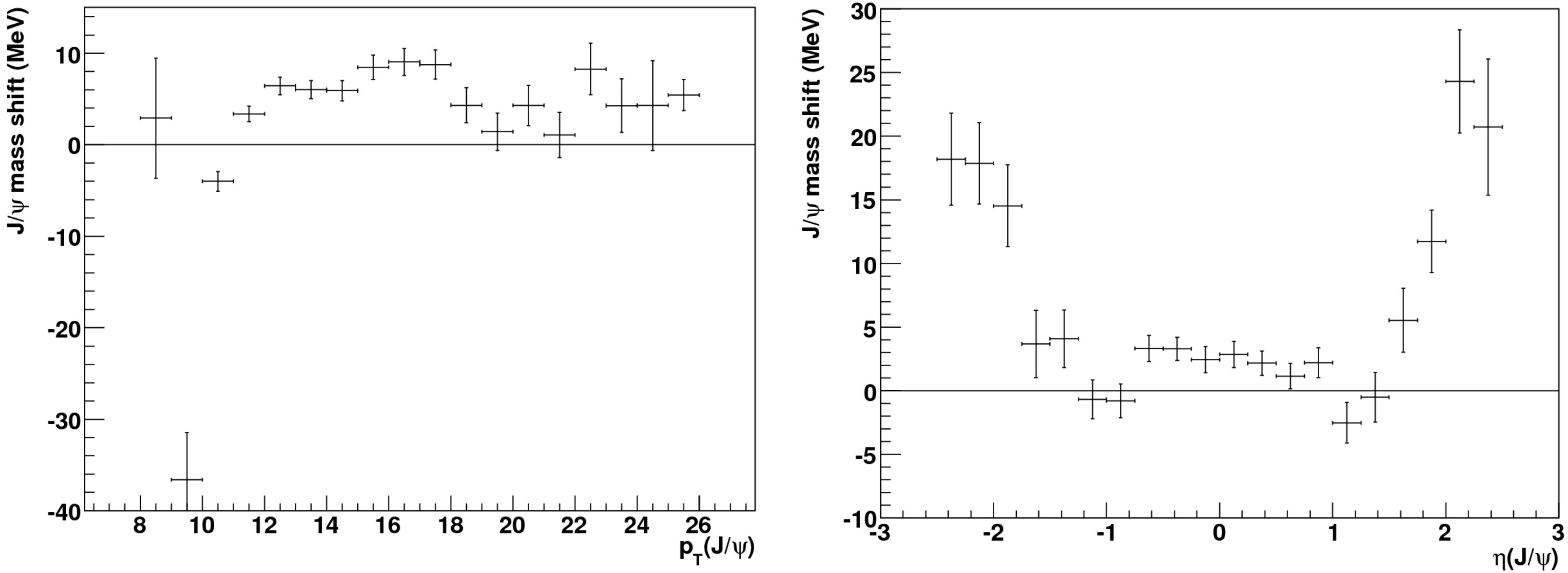

bb→μ6μ4X
Direct onia
Drell-Yan
dσ/dM [nb/(100 MeV)]
10
1
10-1
10-2
2
3
4
5
6
7
8
9
10
11
12
Mass (GeV)

Sources of low invariant mass di-muons



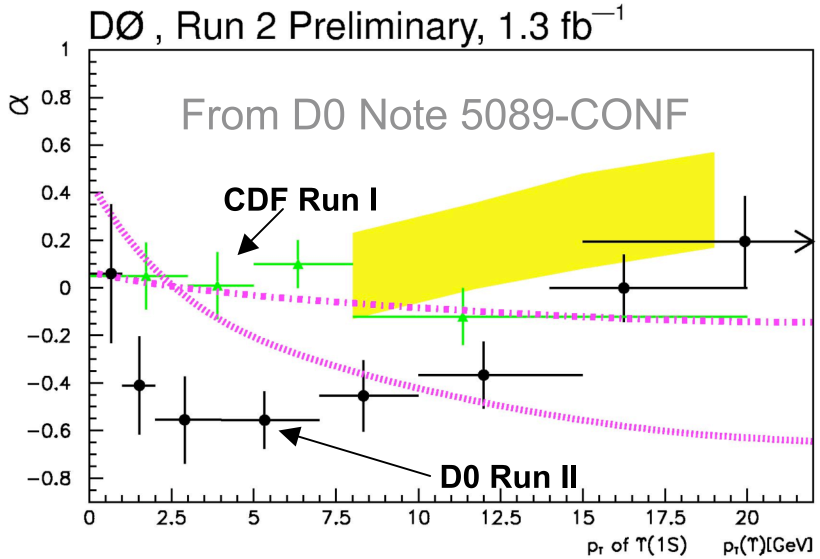
(Higher state contributions have been stacked)

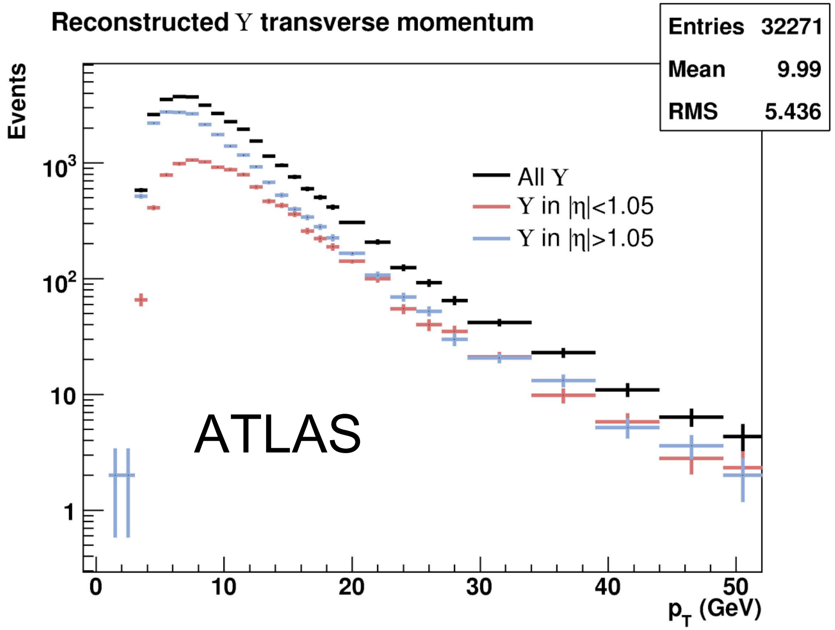
J/ψ mass shift as function of η and p_T



- Plots show the reconstructed J/ψ mass shift from the true value
  [Mass shift defined as reconstructed mass – table mass]
- There is significant variation across the range of J/ψ p_T's and η
- Should be used for alignment and calibration studies
- Statistics corresponds to 3 pb^{-1}

- 100 pb^{-1} should allow for competitive measurement of quarkonium polarisation, with enough statistics in the crucial high p_T region
- Measurement of polarisation provides method of distinguishing between various theoretical production mechanisms
- Latest D0 Run II measurements disagree with all theoretical models *and* CDF Run I results!
- High p_T data important, Tevatron suffers from statistics in this regard
  - ATLAS has same cross-section for Υ above 20 GeV as Tevatron has in total
  - ATLAS has capability to fully test validity of theoretical models for production





Overview: lifetimes with early data
$B \to J/\psi K^*$ $B_s \to J/\psi\phi$ and $\Lambda_b \to J/\psi\Lambda$

		Statistics with 10 pb-1	Life time Statistical error	World today (stat + syst)
B^+	$B^+ \to J/\psi K^+$	1600	2.2 %	0.67 %
B^0	$B^0 \to J/\psi K^{0*}$	900	3.1 %	0.9 %
		Statistics with 200 pb-1		
B^+	$B^+ \to J/\psi K^+$	32000	0.49 %	0.67 %
B^0	$B^0 \to J/\psi K^{0*}$	18000	0.69 %	0.9 %
B_s (single τ fit)	$B_s \to J/\psi \phi$	1800	4.2 %	2.7 %
Λ_b	$\Lambda_b \to J/\psi\Lambda$	520	5.8 %	5%

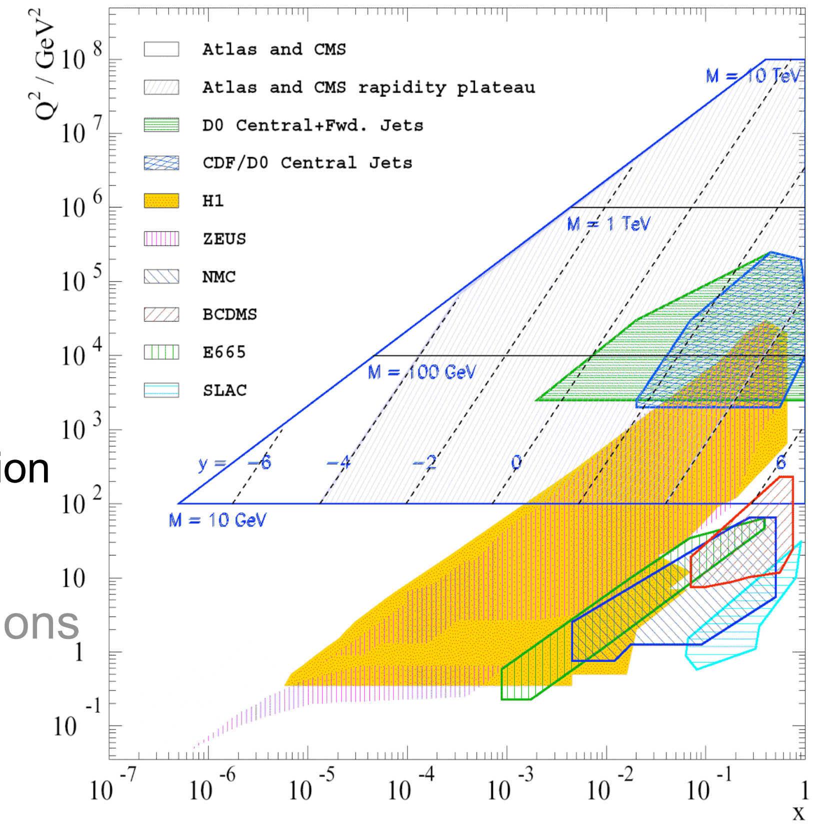
With 10 pb-1 we start to be useful for alignment tests
With 200 pb-1 we improve words precisions

LHC Kinematic regime

Kinematic regime for LHC much broader than currently explored

➡ Test of QCD:

- θ Test DGLAP evolution at small x:
  - θ Is NLO DGLAP evolution sufficient at so small x ?
  - θ Are higher orders $\sim \alpha_s^n \log^m x$ important?
- θ Improve information of high x gluon distribution



$$x_{1,2} = \frac{M}{\sqrt{s}} \exp(\pm y) \qquad Q = M \qquad y = \frac{1}{2}\ln\left(\frac{E+p_z}{E-p_z}\right)$$

At TeV scale New Physics cross section predictions are dominated by **high-x gluon** uncertainty
(not sufficiently well constrained by PDF fits)

At the EW scale theoretical predictions for LHC are dominated by **low-x gluon** uncertainty
(i.e. W and Z masses) => see later slides

How can we constrain PDF's at LHC?

PDF scenario at LHC start up (2007) might be different

- In most of the relevant x regions accessible at LHC
  HERA data are most important source of information in PDF determinations
  (low-x sea and gluon PDFs)

- HERA now in second stage of operation (HERA-II)
  - substantial increase in luminosity
  - possibilities for new measurements

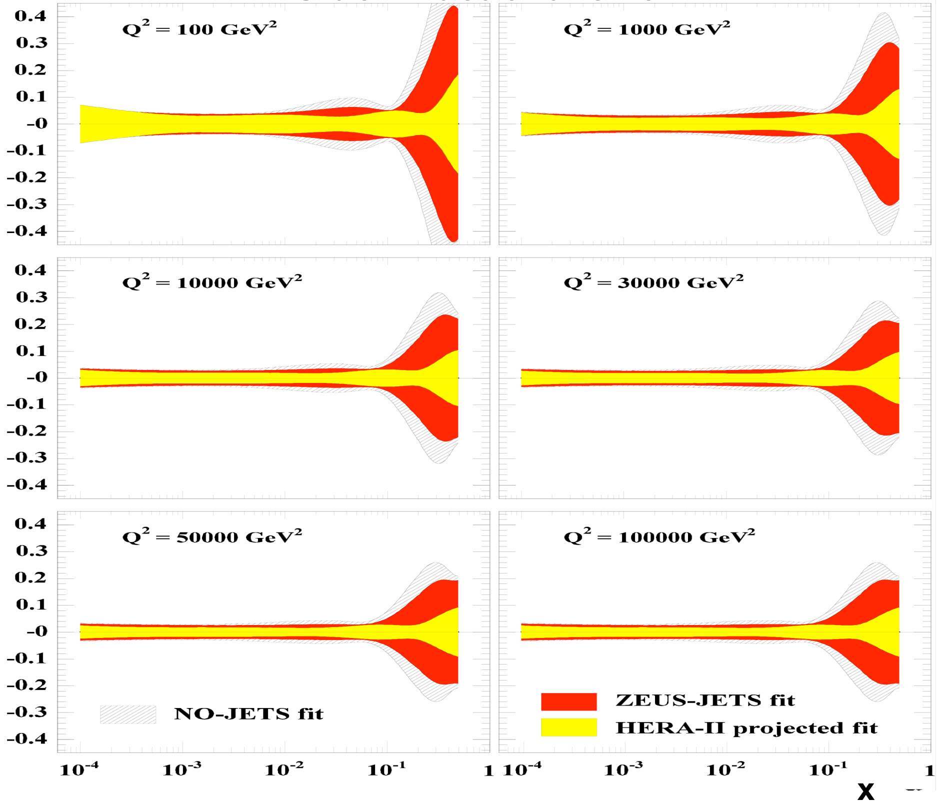
HERA-II projection **shows significant improvement to high-x PDF uncertainties**

⇒ relevant for high-scale physics at the LHC

→ where we expect new physics !!

- significant improvement to <u>valence-quark</u> uncertainties over <u>all-x</u>
- significant improvement to <u>sea and gluon</u> uncertainties at <u>mid-to-high-x</u>
- little visible improvement to <u>sea and gluon</u> uncertainties at <u>low-x</u>

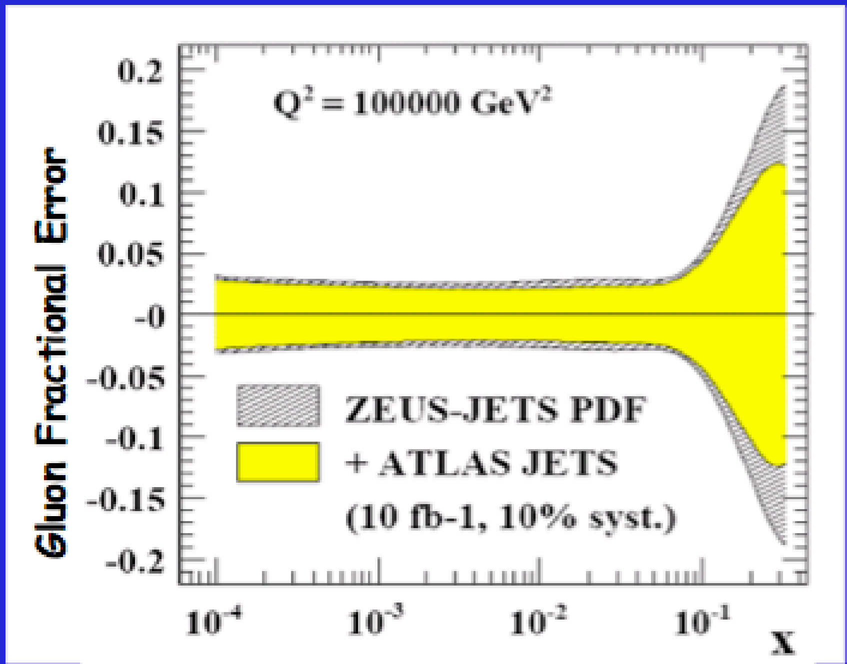
Gluon fractional error



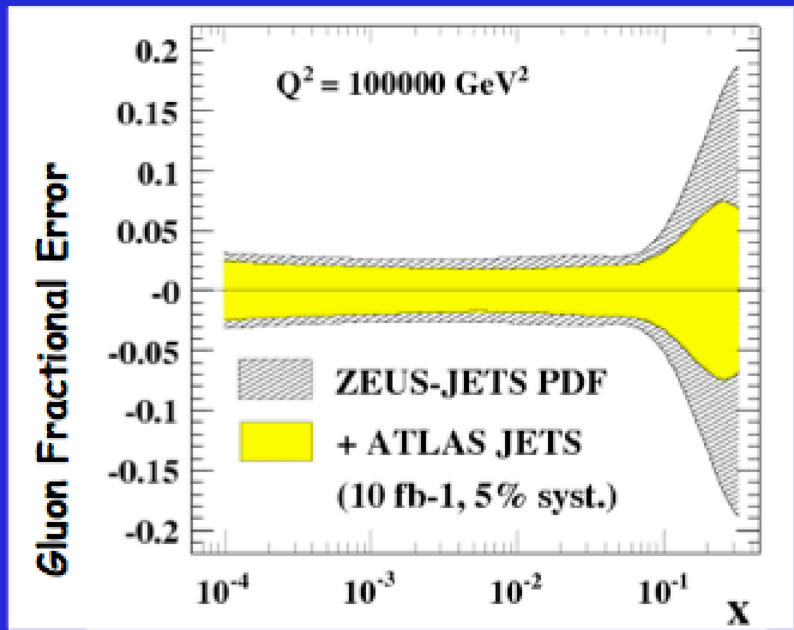
Inclusive jet cross section

- ATLAS pseudo-data for $0<\eta<1$, $1<\eta<2$, $2<\eta<3$ up to pT = 3 TeV was used in a global (ZEUS) fit to assess the impact of ATLAS data on constraining PDFs

- Preliminary results suggest that ATLAS data can constrain the high x gluon.



- Increasing statistics from 1fb-1 to 10 fb-1 (= 1 year of low lumi data taking) leads to small improvements.
- Decreasing systematic errors leads to a significant improvement.



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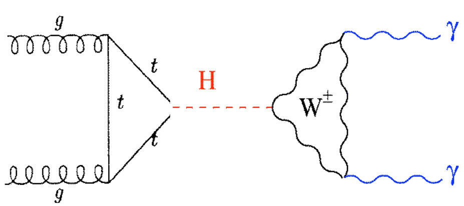
The most difficult low-mass region:

ATLAS : m_H ~ 115 GeV   10 fb^{-1} : $S/\sqrt{B} \approx$ 4-5.5 ← range comes from $H \to \gamma\gamma$: LO vs NLO cross-section, cuts vs likelihood analysis

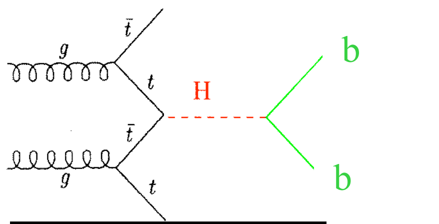
3 (complementary) channels with (similar) small significances:

$H \to \gamma\gamma$



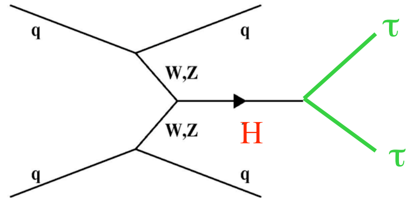
S=130, B=4300, $S/\sqrt{B}$= 2 - 4.4

$ttH \to ttbb \to bl\nu bjjbb$



$S/\sqrt{B}$~2, being re-evaluated

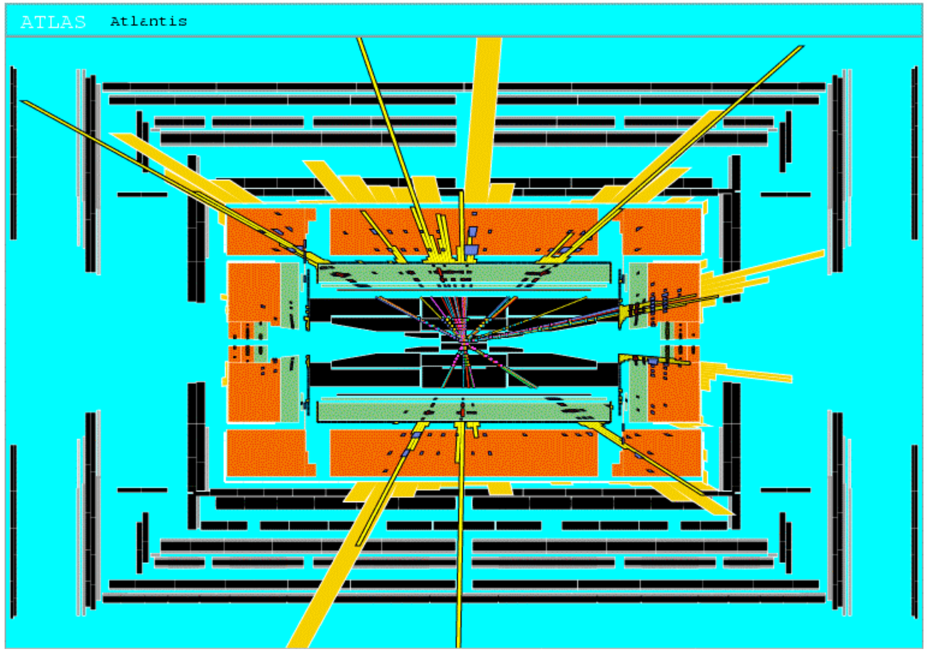
$qqH \to qq\tau\tau$



S=10, B=10, $S/\sqrt{B}$=2.7

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

All three channels require very good understanding of detector performance and background control to 1-10% → convincing evidence likely to come mid-end 2009 …



A black hole event with M_{BH} ~ 8 TeV in ATLAS

Cross-section for M_{Pl}=1 TeV, δ=4:
M_{BH}=5 TeV : 37pb
M_{BH}=8 TeV : 0.3 pb

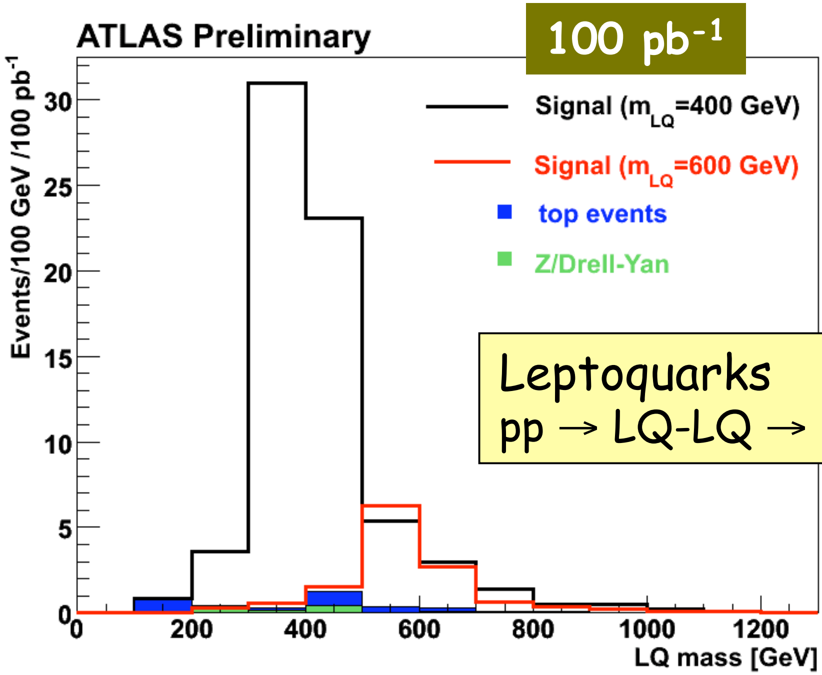
By testing Hawking formula - -> proof that it is BH + measurement of M_D, δ

$$\log T_H = \frac{-1}{\delta + 1} \log M_{BH} + f(M_{Pl}, \delta)$$

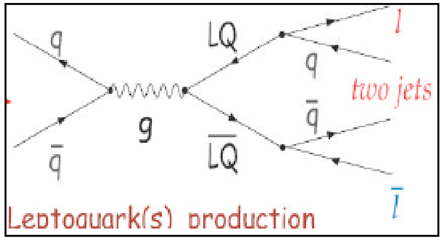
precise measurements of M_{BH} and T_H needed ()

-- T_H from lepton and photon spectra
-- M_{BH} from final-state products
--> get δ; then M_{Pl} from cross-section measurement

What else ?



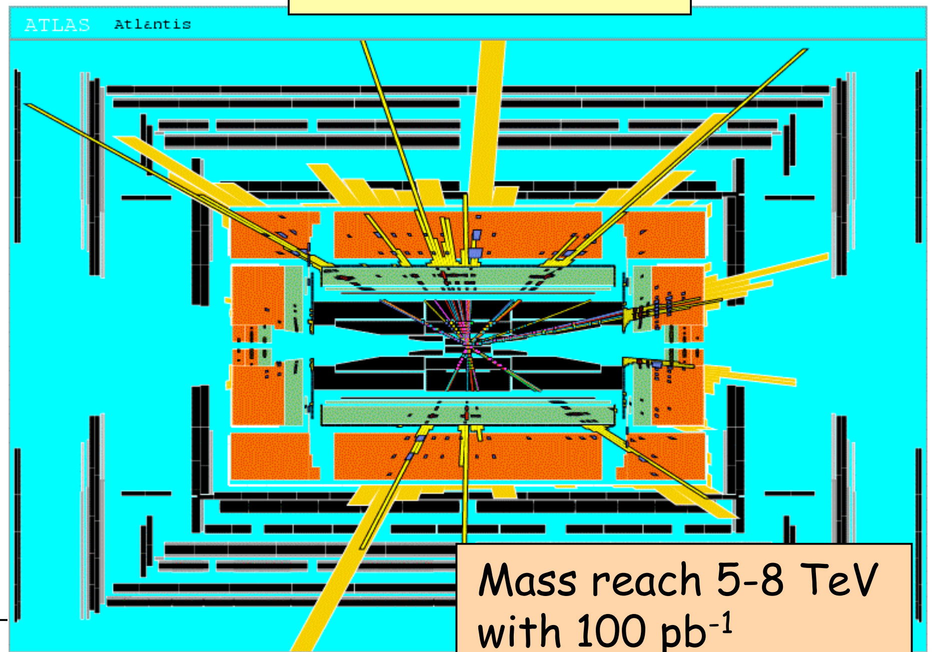
Leptoquarks
pp → LQ-LQ → μjet-μjet



σ ~ pb
m_{LQ} = 400-600 GeV

?

Mini black-holes

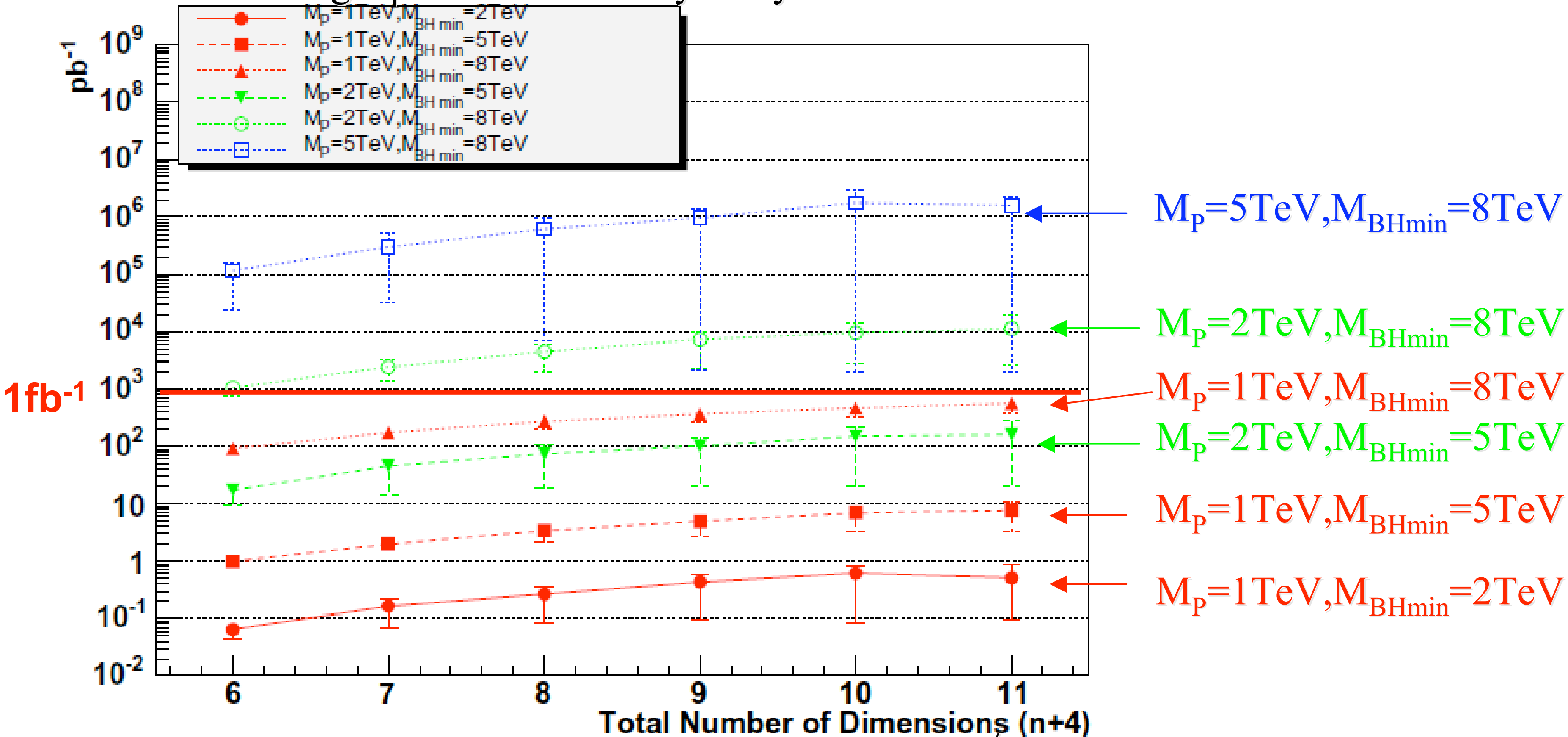


Mass reach 5-8 TeV with 100 pb^{-1}

Discovery potential

Event selection:

- At least 4 objects (e,μ,γ,j) with $P_T > 200GeV$
- At least one lepton is required to have $P_T > 200GeV$
- No Missing E_T cut for Discovery study



The minimum necessary Luminosity for (S>10&&S/√B>5)