Preparing for First Physics

Dave Charlton (Birmingham)
11 January 2008

- **LHC status & expectations**
- **Commissioning beyond Point-1: the Full Dress Rehearsal**
- **Some highlights to come...**

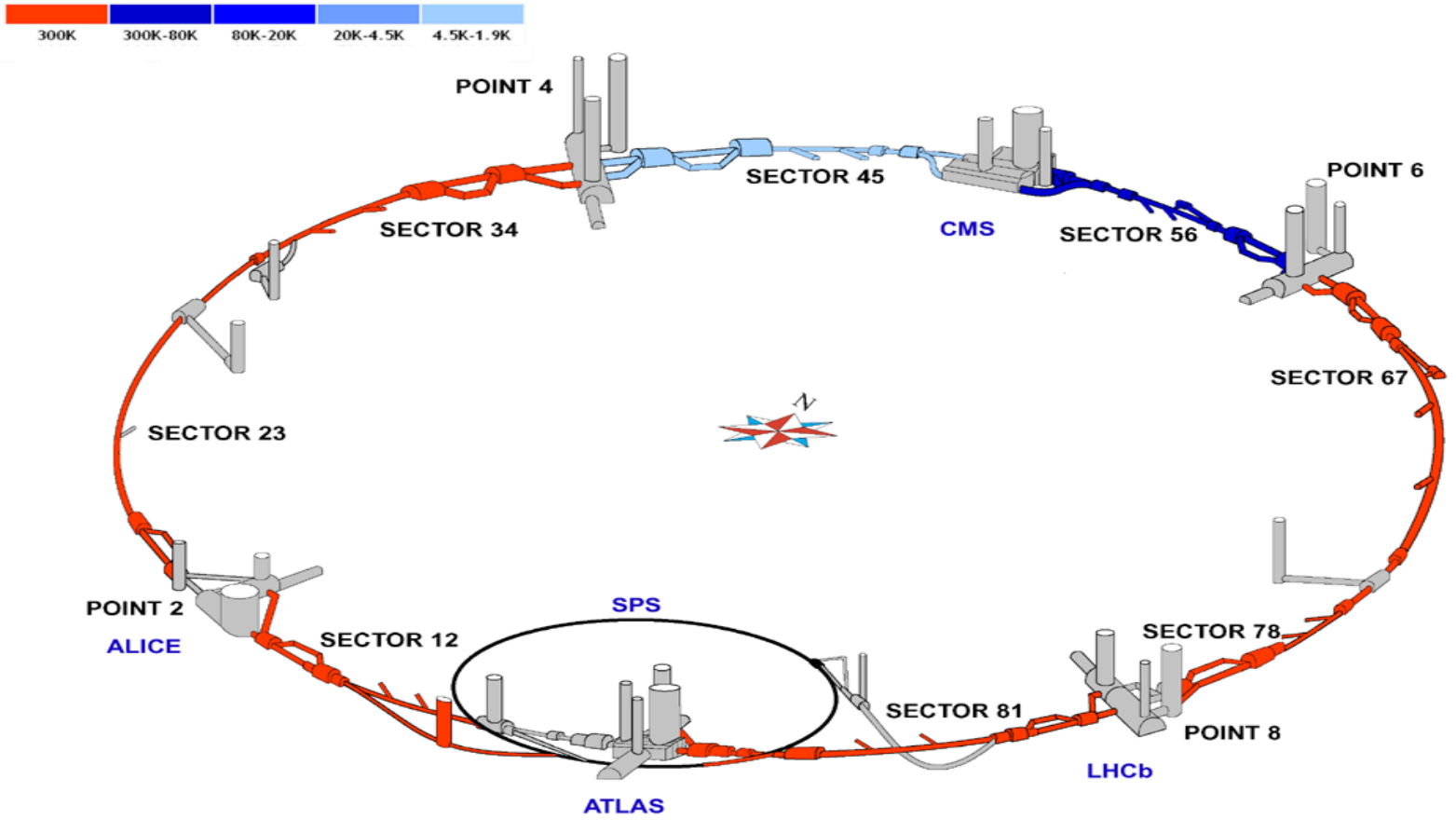
Focus on 2008

I have not credited plots etc from within ATLAS – but you may recognise some of them!

Part I: LHC Status

LHC Status

- LHC machine component installation is essentially complete
  - Major time factor is cool-down to 1.9K
    - takes ~8 weeks per sector
- Now: one sector (45) is cold (1.9K) and effectively commissioned



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- Now: one sector (45) is cold (1.9K) and effectively commissioned
- Plan (October) was to have 4 sectors cold before Xmas break
  - achieved 1
  - ~4 week delay?
- The October schedule foresaw first injection late May

News from CERN Council

From the December press release, R. Aymar...

"Today, we're on course for start-up in early summer 2008, but we won't be able to fix the date for certain before the whole machine is cold and magnet electrical tests are positive. We're expecting that in the spring."

Any difficulties encountered during this commissioning that require any sector of the machine to be warmed up would lead to a delay of two to three months.

Let's be optimistic...

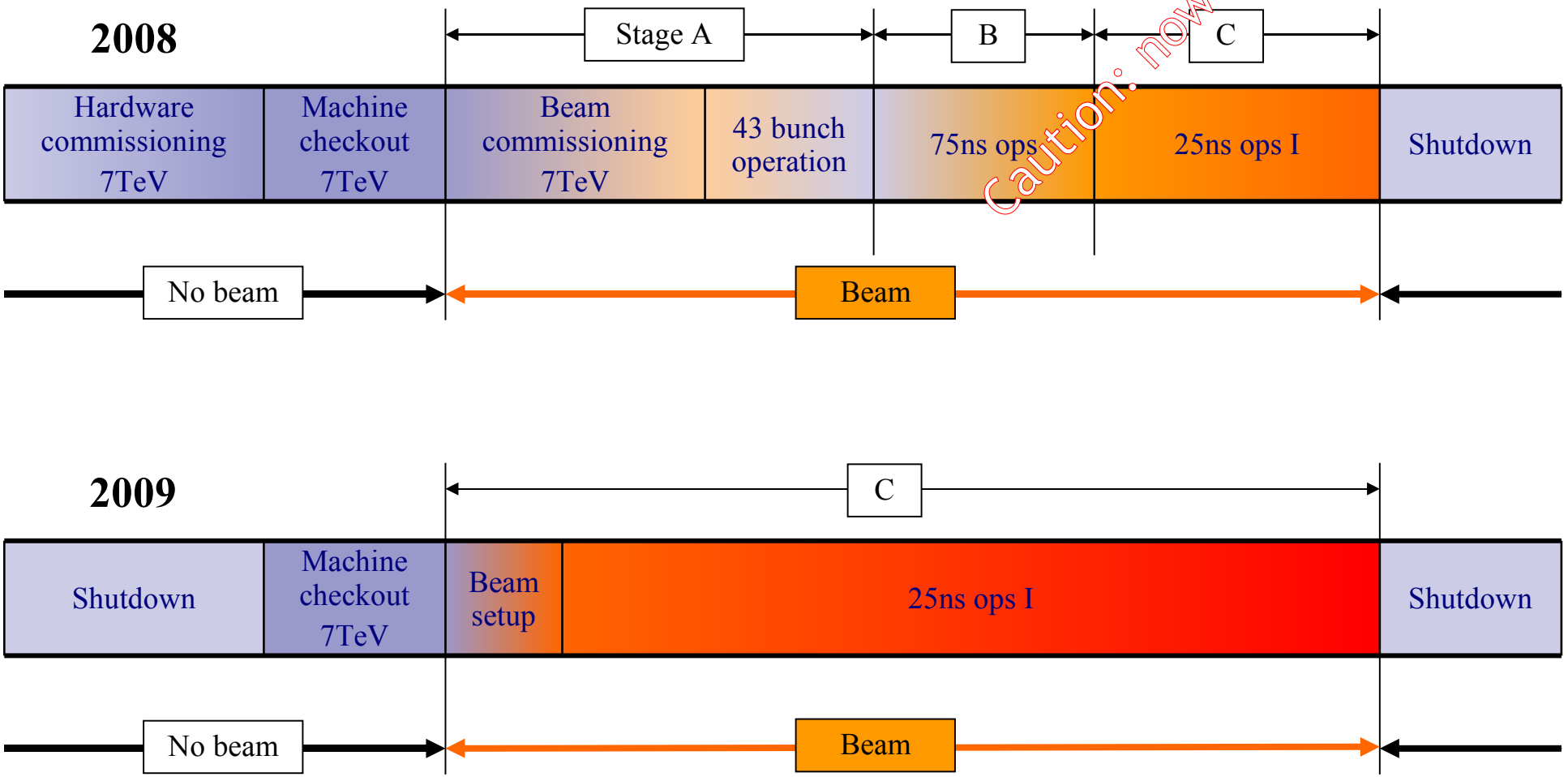
Commissioning to 7 TeV

- Start of commissioning with beam was planned for late May → June/July?

- Four commissioning phases:

  - Stage A: establish collisions; first 1-1, then 43-43 to 156-156
    - ~2 months before collisions (if ~50% LHC availability)
    - ~1 month with collisions "pilot physics"
    - limited to 156 bunches because no crossing-angle

Staged commissioning plan for protons



Slide from M Lamont, ATLAS TMB Oct 07

Commissioning to 7 TeV

		Rings	Total [days]
1	**Injection and first turn**	**2**	**4**
2	**Circulating beam**	**2**	**3**
3	**450 GeV - initial**	**2**	**4**
4	**450 GeV - detailed**	**2**	**5**
5	**450 GeV - two beams**	**1**	**1**
6	**Snapback - single beam**	**2**	**3**
7	**Ramp - single beam**	**2**	**6**
8	**Ramp - both beams**	**1**	**2**
9	7 TeV - setup for physics	**1**	**2**
10	Physics un-squeezed	**1**	**-**
	TOTAL TO FIRST COLLISIONS		**30**
11	Commission squeeze	**2**	**6**
12	Increase Intensity	**2**	**6**
13	Set-up physics - partially squeezed.	**1**	**2**
14	Pilot physics run		

Caution: LHC operating efficiency <100%

Estimate ~ factor 2

i.e. ~2 months from 1st turn to 14 TeV collisions

Table from M Lamont, ATLAS TMB Oct 07

Luminosities in Stage A

Bunches	β^*	I_b	Luminosity	Event rate
1 x 1	18	10^{10}	10^{27}	Low
43 x 43	18	3×10^{10}	3.8×10^{29}	0.05
43 x 43	4	3×10^{10}	1.7×10^{30}	0.21
43 x 43	2	4×10^{10}	6.1×10^{30}	0.76
156 x 156	4	4×10^{10}	1.1×10^{31}	0.38
156 x 156	4	9×10^{10}	5.6×10^{31}	1.9
156 x 156	2	9×10^{10}	1.1×10^{32}	3.9

Table from M Lamont, ATLAS TMB Oct 07

Integ. luminosity accumulated depends how long we stay in stage A

- "first fills" lumi ~ 2 nb^{-1} at ~10^{28} cm^{-2} s^{-1} in a few days
- canonical "10h fill" around 10^{32} ~ 2-3 pb^{-1}

Suggests if we spend 1-2 months, can accumulate a few tens pb^{-1}

Luminosities in Stage A

per crossing!

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PILE-UP!

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    realistically: to Oct or end 2008
  - Stage B: move to 75ns bunch spacing
    - up to 936-936

    potential to deliver substantially more lumi if we get there in 2008
  - Stage C: move to 25ns bunch spacing, up to 4×10^{10} p / bunch

    not in 2008

    (long shutdown for additional collimation/beam dump infra.)
  - Stage D: move to 25ns full current

Beyond 2008

One guess...

- 2008: a few to a few 10's of pb^{-1}
- 2009: one to a few fb^{-1}
- 2010: O(10 fb^{-1})
- ...

“Same bunch” pileup will be an issue already in the early days

In what remains I'll talk about a few to 100 pb^{-1}

Part II: the FDR

Full Dress Rehearsal

The FDR aims to stress test as much possible of the full data processing and analysis chain from point-1 to the end-user

Think of it as the “offline & Grid” analogue of the commissioning runs that Jamie has been talking about

Aims are very much complementary: we don't re-test that which the commissioning runs test

Full Dress Rehearsal

Concretely, the FDR will:

- Use a sample which looks like real raw data, put it at point-1
  - mixed events, misaligned, imperfect detectors, no truth!
- Make that sample appear on the point-1 output disks “just like data” (bytestream (BS) =RAW format)
- Run calibration and data quality procedures on express stream and calibration streams
- Run bulk reconstruction after 24-48h at Tier-0
- Distribute ESDs and AODs to Tier-1s and (AODs) Tier-2s
- Make TAGs and DPDs, and analyse data!

- Reprocess data at Tier-1s after a certain time
- Do all in parallel with usual MC prod at the Tier sites (~100k jobs/day)

Run the whole computing system “as for real data”'; try to find early the problems we'll have with data

FDR Timing

In practice there is a lot of setting up...

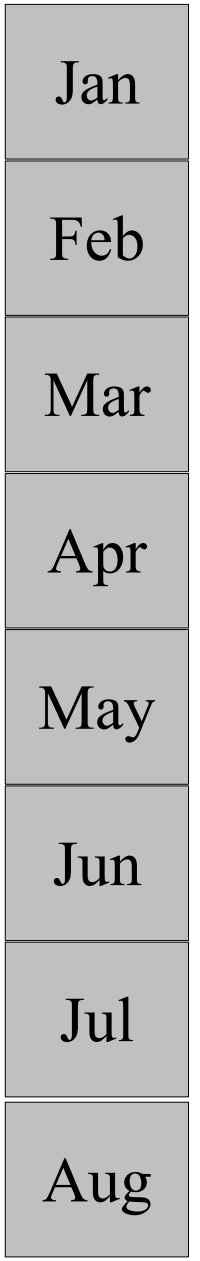
Therefore we plan two "FDR runs" at different times, with different levels of sophistication:

FDR-1

- A few fills of 10^{31} and a short period of 10^{32} luminosity data ~ 0.5-1 pb^{-1} of data
- "FDR run" will be week of 4 February

FDR-2

- A few fills of 10^{32} or 10^{33} data
- Aiming for start of May for the "run"
  - but need to allow enough time to feed back lessons learnt into the system!
  - potential clash with "routine running" at pt. 1



Now

FDR-1

M6

FDR-2?

First beam?

Collisions?

Data Sample

Made by mixing simulated events (RDO)

- take events randomly in proportion to cross-section
- run trigger simulation and keep only triggered events
- convert to bytestream, include trigger output info
- make “physics stream” files
- ~70M input events, ~8M output events

Simulated data is release 12, use CSC-misaligned samples for FDR-1, trigger run from release 13.0.40

Physics processes include:

- minimum bias, single and doubly diffractive events
- random beam crossings
- QCD jet events, photon-jet events
- Drell-Yan, W and Z
- b physics samples
- ttbar and single top
- etc...

Collation of these samples is not trivial, done previously for streaming test

Streaming for FDR-1

Data streaming:

- physics streams defined by trigger bits
  - muon + b-physics
  - e/γ
  - jets/tau/E_t^{miss}
  - minbias
- express stream (no lumi block structure)
- one calibration stream (ID alignment – high-p_t tracks, partial readout)

The physics streams will persist through the data processing to the AOD

Stream definitions can be expected to change before data-taking

Also will have a “between-fill cosmics” sample for alignment studies

Calibration Loop

Plan for first-pass reconstruction of **real data**
- express stream is processed immediately
- bulk physics streams after 24-48h

*Re*processing of physics streams happens later, at Tier-1s

1-2 day delay allows calibration/alignment to be checked, and updated if needed – but a fast turn-round is essential (shifts, automation)

Two classes of sample for first-pass calibration:
- Express stream (ES)
- Calibration streams

Calibration streams are normally special streams
- either selected subevent data or events from special triggers

Readiness of subsystems for this process is variable...
- in best cases we can start to test in FDR-1
- most cases will have to wait for FDR-2

Express Stream (ES)

The express stream is solely for data quality purposes – it's not for physics analysis

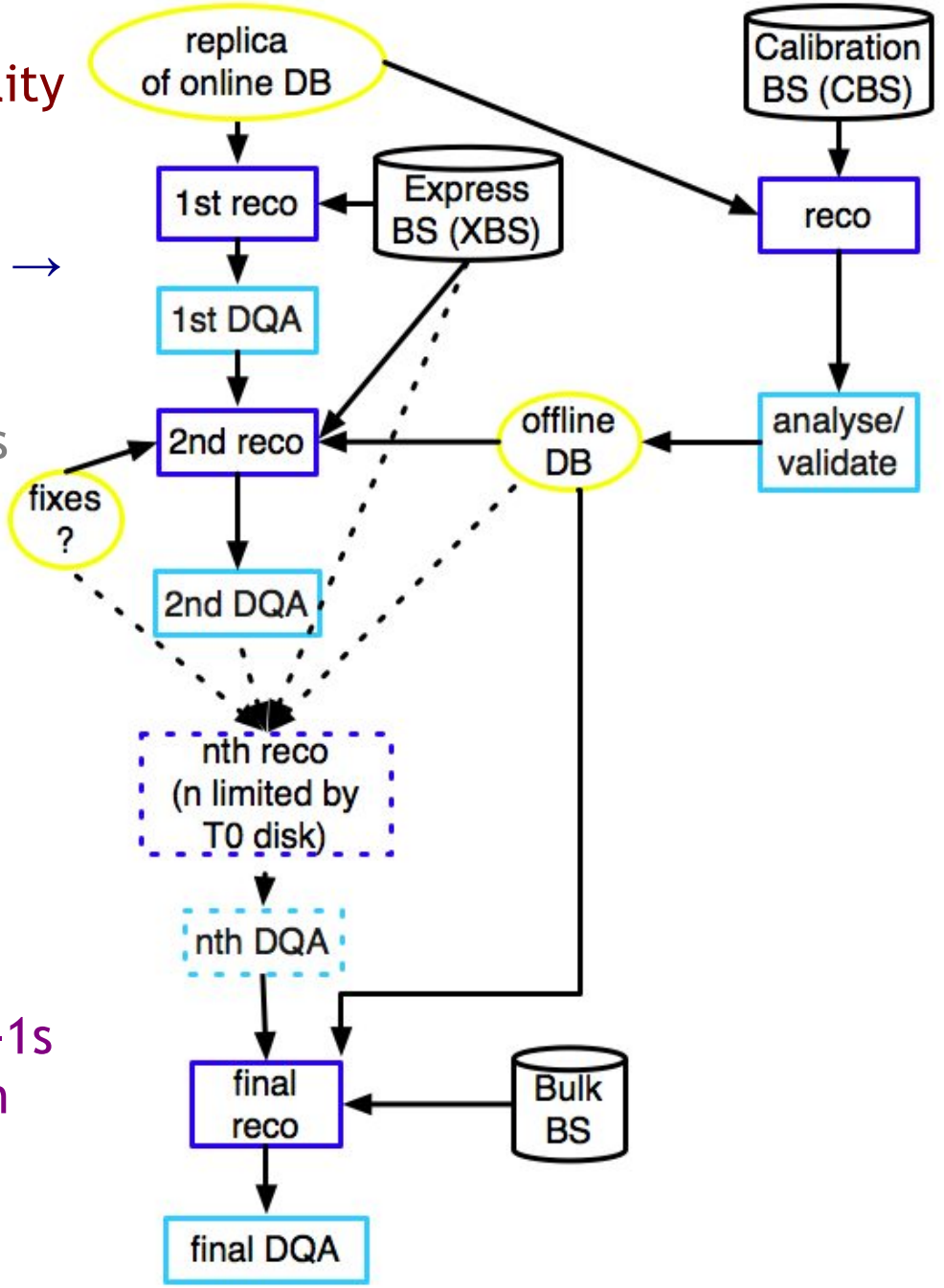
Express stream processing is complicated →

If calibrations change, need to reprocess (some of) the ES potentially several times

At each ES processing, run offline data quality monitoring checks

- expect to need DQ shifts during FDR
- in order to test DQ non-trivially, may insert occasional "small problems"

Not expecting (ever) to export ES to Tier-1s – unless it will be used for fast calibration there



Data Processing

Tier-0

- Bytestream file merging and archival in Castor
- Bytestream file export to Tier-1s
- Express stream processing
- Most initial calibration stream processing
- First-pass reconstruction: RAW – ESD – AOD and TAG
- ESD export to Tier-1s
- AOD merging before export to Tier-1s
- TAG file merging and transfer into TAG database, export

Tier-1

- Archives the fraction of bytestream it receives
- Receives & makes available fraction of ESD
- Has full AOD sample
- Will host central "DPD" production (from AOD and/or ESD?)
  - Expect this will iterate frequently with early data
- Eventually re-reconstruction done here

Tier-2

- Has full AOD sample, plus DPDs as requested

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Tier-2

- Has full AOD sample, plus DPDs as requested

We want to test ALL of this in FDR-1

Analysis Preparation

The AODs should arrive at Tier-1s soon after main processing
- a couple of days after data is “taken”
- copying of AODs to Tier-2s can happen in parallel

For analysis, many physics groups/subgroups use “DPDs” already – these must evolve as we get closer to data (new distilled-AOD style)

For FDR, want to make some new-style DPDs in the production system

Also will exercise:
- Analysis from TAGs
- Analysis from AODs and from DPDs
- Analysis at all Tier-1s – and all Tier-2 clouds!

- Remaking DPDs after some time
- Re-reconstruction after a time
  - shouldn't take longer than first-pass reco!

Improvements for FDR-2

FDR-2 is planned to have a higher luminosity (~10 pb^{-1}?), and should also have significant technical improvements

Some items on the wish-list...

- final metadata passing mechanism between SFO and Tier-0
- more calibration streams, including the L2-muon stream
  - calibration processing at Tier-2s!
- release 13 simulation and release 14 reconstruction
  - requires release 13 simulation to be validated
- full(er) set of DPDs
  - requires more involvement of physics groups
- all sites that want to look at the early data should look at the data

- pileup to simulate the higher lumi “Stage A” LHC setup

Why You Should Look...

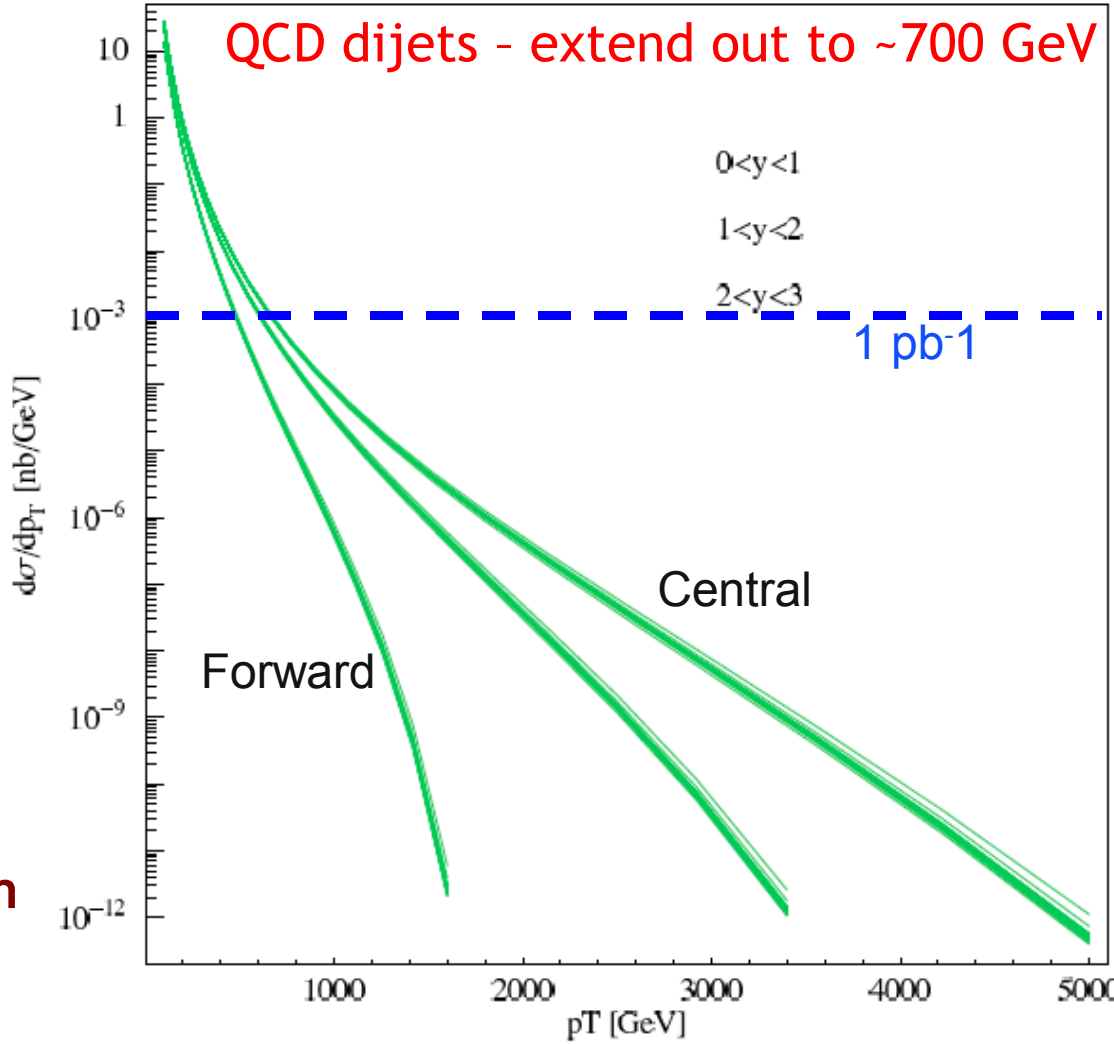
Although the integrated luminosity is low, there are still substantial numbers of events to be found...

Even in FDR-1:

- QCD dijets, γ+jets
- b physics, J/ψ
- minimum bias
- W's and Z's
- (ttbar)

And for this meeting:

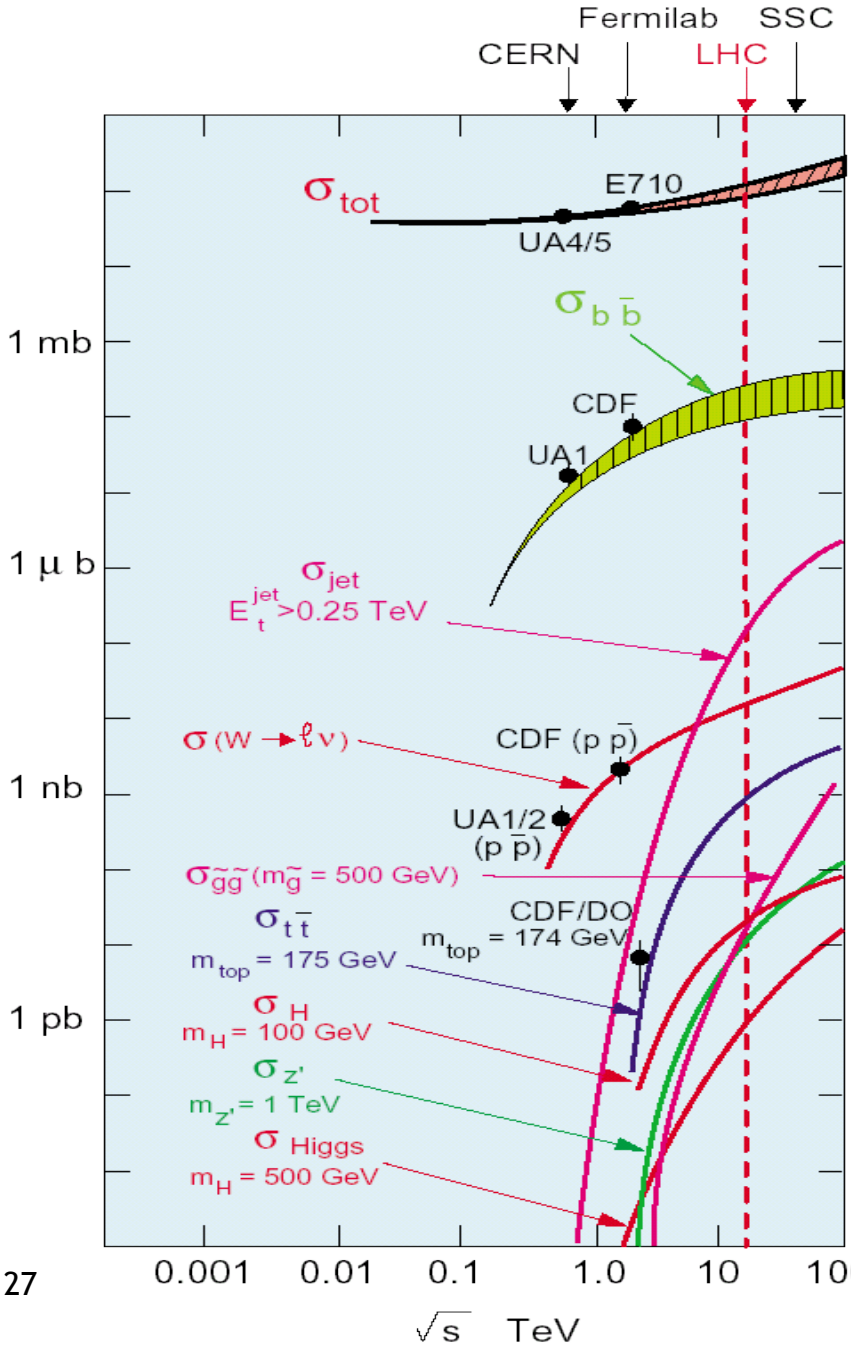
- **are the UK sites subscribed?**
- **does the UK computing system allow you to do physics with this?**
- **should we have a UK FDR effort as such - cloud-related analysis issues?**



Plot from Campbell, Huston & Stirling

Part III: Data

Early Physics Landscape



Minimum bias (non-diffractive) cross-section ~ 70 mb

With 100 pb^{-1} (on tape):

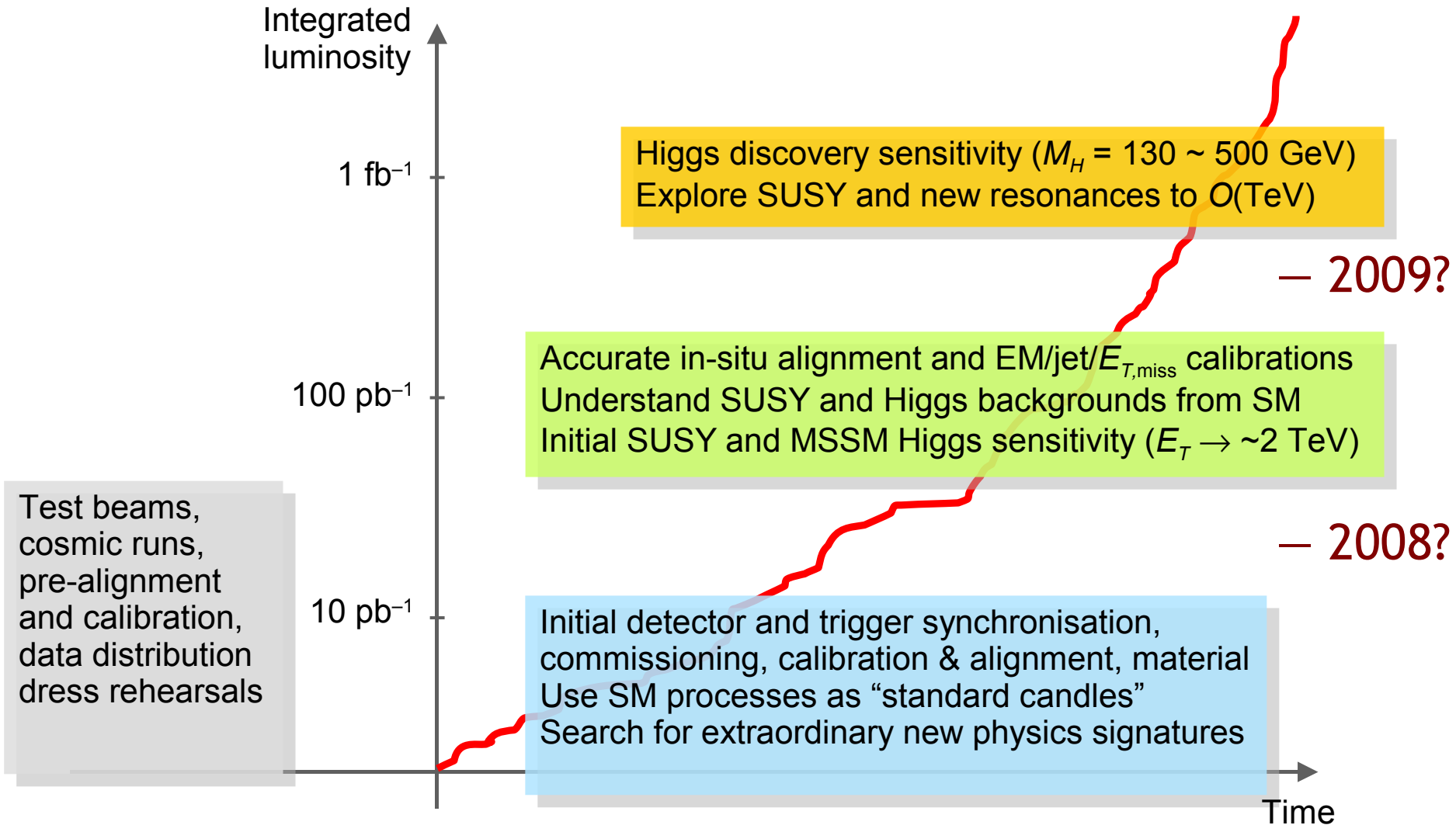
- 10^6 $W \rightarrow \mu\nu$
- 10^5 $Z \rightarrow \mu\mu$
- 10^4 $tt \rightarrow qqb\mu\nu b$

Comparable to Tevatron

Understanding the detector will be one major goal with these events

Discoveries are possible – but only when we understand the data and detector properly

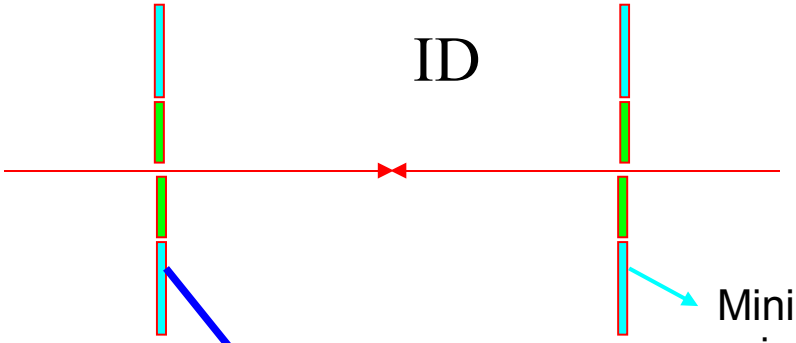
A Roadmap

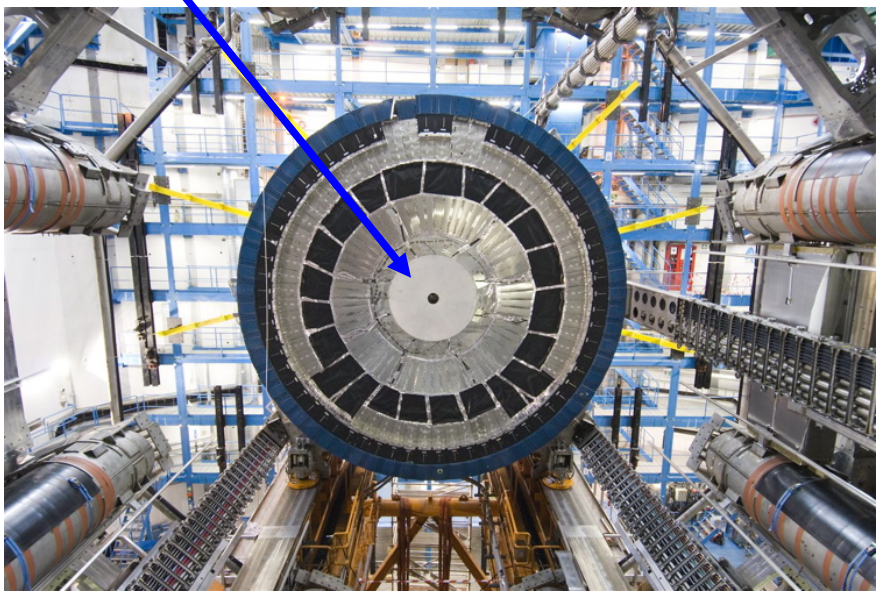

Integrated luminosity
1 fb⁻¹
100 pb⁻¹
10 pb⁻¹
Time
Higgs discovery sensitivity (M_H = 130 ~ 500 GeV)
Explore SUSY and new resonances to O(TeV)
– 2009?
Accurate in-situ alignment and EM/jet/$E_{T,\mathrm{miss}}$ calibrations
Understand SUSY and Higgs backgrounds from SM
Initial SUSY and MSSM Higgs sensitivity ($E_T \rightarrow$ ~2 TeV)
– 2008?
Initial detector and trigger synchronisation, commissioning, calibration & alignment, material
Use SM processes as “standard candles”
Search for extraordinary new physics signatures
Test beams, cosmic runs, pre-alignment and calibration, data distribution dress rehearsals

From Collisions to Physics

With beam, much to do before we can start extracting physics...

- timing in (starts with beam-gas, needs collisions to complete)
- trigger commissioning
  - Minimum-Bias Trigger Scintillators (MBTS)
  - level-1
  - level-2 and event filter
- first: see minimum bias events
  - ~80Hz at 10^{27} $cm^{-2}s^{-1}$ (first collisions?)
  - this is great for trigger commissioning...





From Collisions to Physics

After this, still a huge amount to do to understand the data well enough for physics results

Build on test-beam data – but much has changed since then

- commission & tune tracking
- commission & tune jet reconstruction
- align & calibrate muon system
  - needs a lot of muon segments (L2 calibration stream)
- establish lepton signatures
- etc. etc. etc.
- (Missing E_t will probably take a while...)

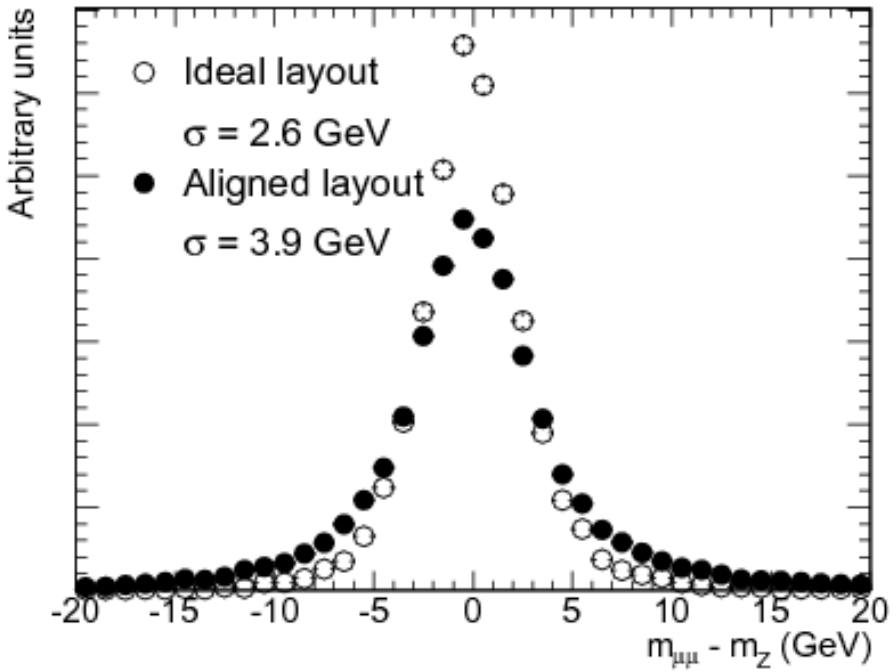
We saw excellent summaries on Wednesday of how we can understand performance of object reco and ID with ~100 pb^{-1}

But this will not happen straight away...

we'll start when we have <1 pb^{-1} !

Tracking

2007 saw a big step forward in implementing alignment procedures



$Z \rightarrow \mu\mu$
ideal geometry and misaligned geometry after alignment

Caution: the CSC misalignment did not test all degrees of freedom – real data will be misaligned in other ways too...

Needs substantial samples of high-p_t tracks (ID alignment stream)

Tracking

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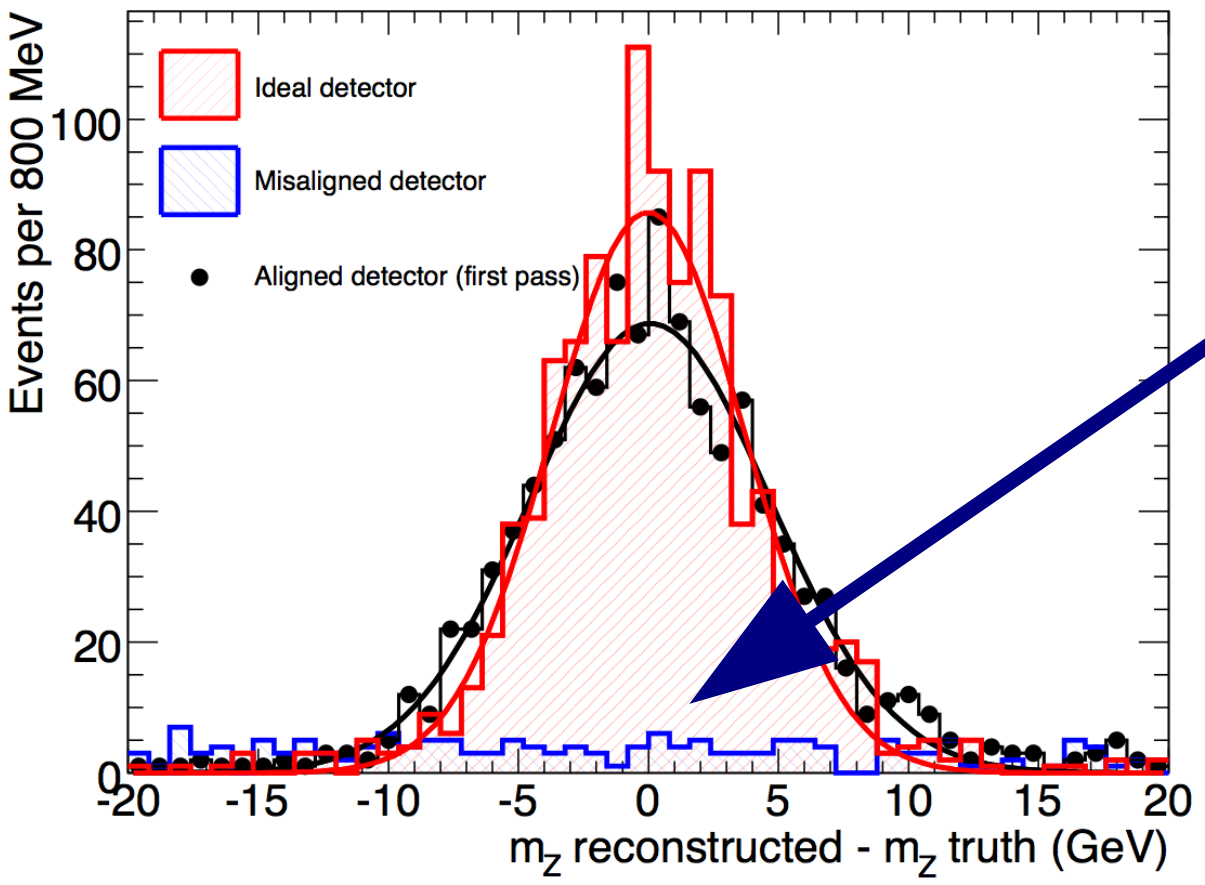


This is what it looked like before aligning – closer to what we should expect at the start..!

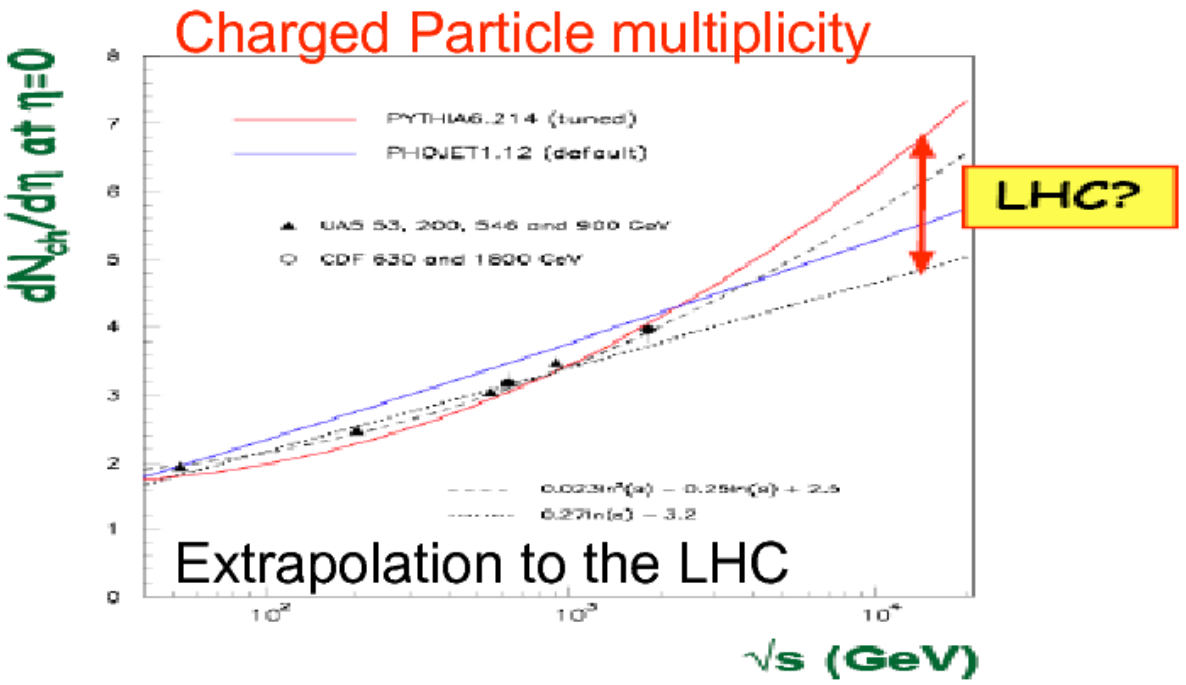
Cal … of freedom – real dat…

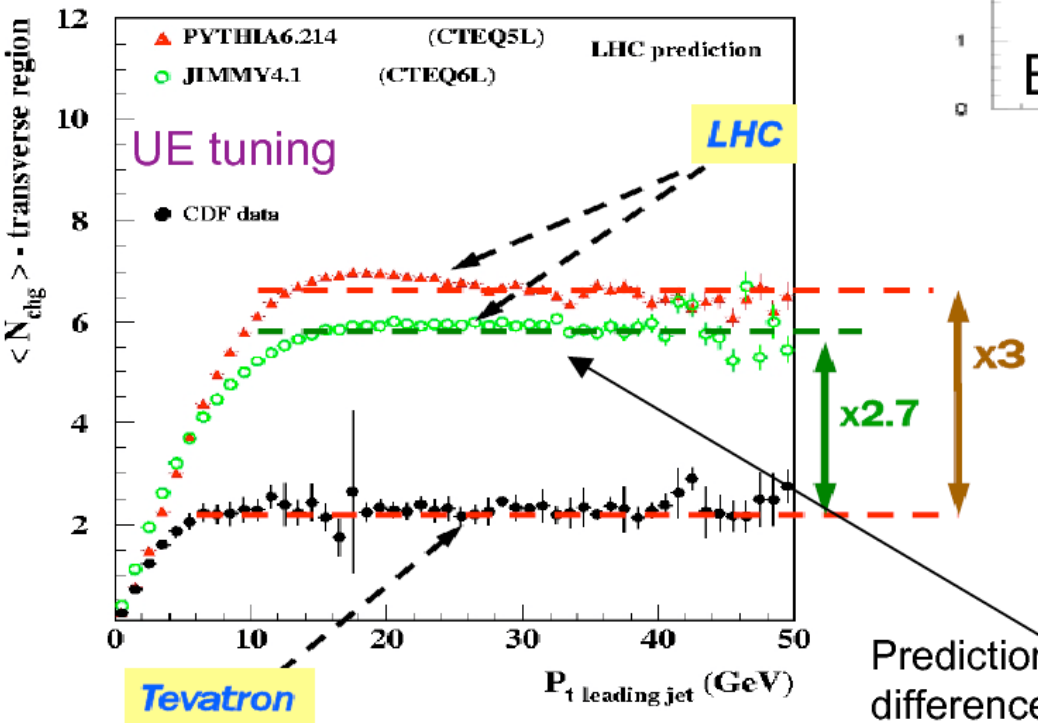
Needs substantial samples of high-p_t tracks (ID alignment stream)

Minimum Bias

Enabled when we have reasonable tracking...

Do need to understand tracking efficiency, material





Predictions similar:
difference used to be a factor 2

Will this be our second ATLAS paper?

Jets

High cross-sections – rapidly probe QCD at a scale above Tevatron

Need data to help conclude on:

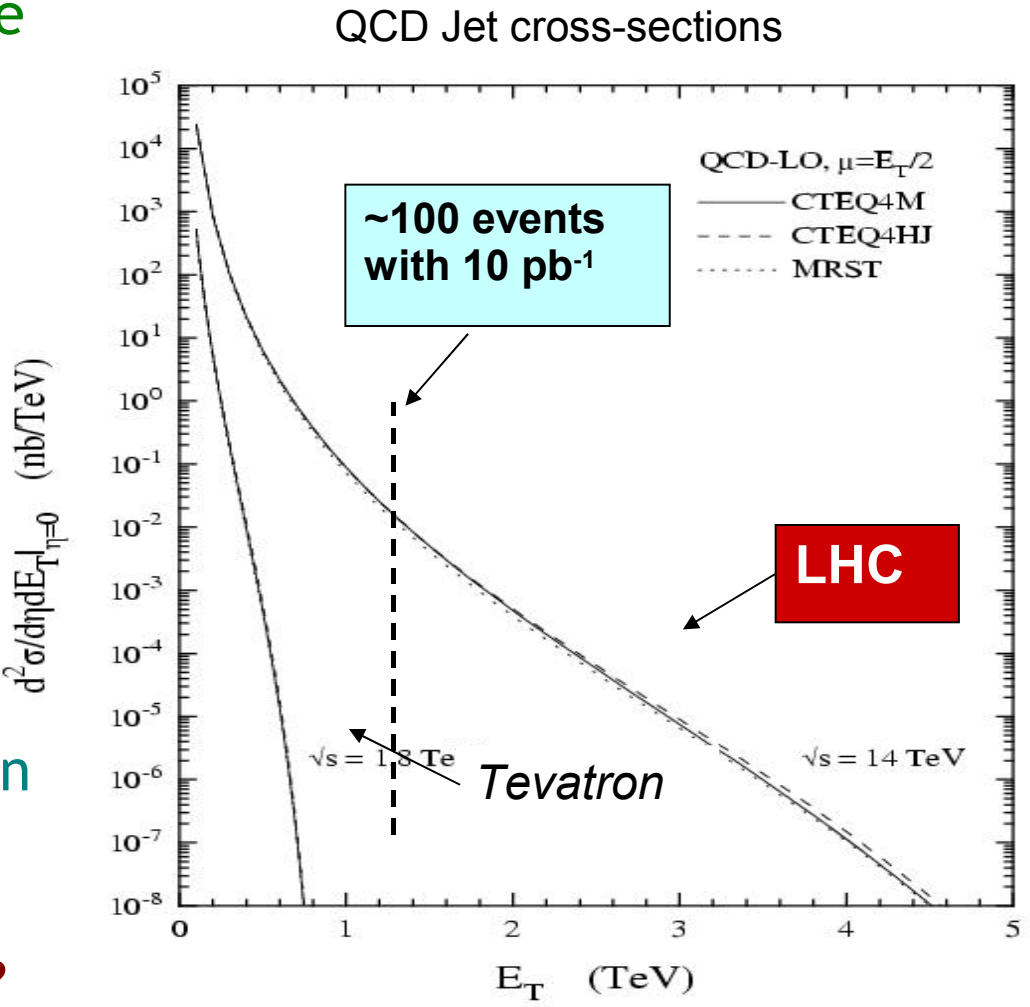
- topoclusters vs. calocells
- calibration methods
- algorithm robustness

More gradually:

- Jet energy scale and resolution (γ-jet, Z-jet, tt)

New physics sensitivity at high-E_t?

Must understand resolution well...

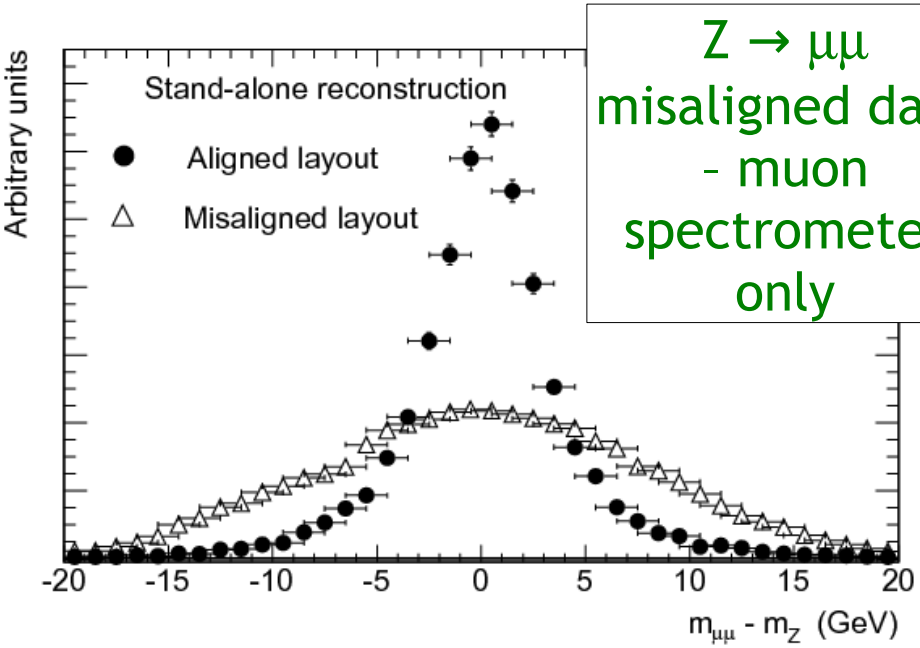


Muon ID

Detailed studies of alignment of muon system ongoing – needs a high rate of muons for final alignment (~30 μm)

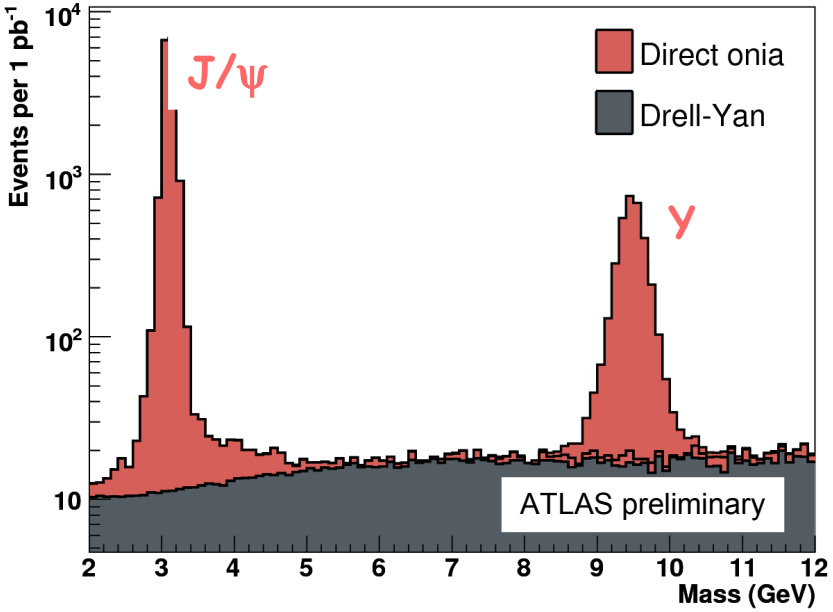
Align ID vs. muon spectrometer with high-p_t tracks

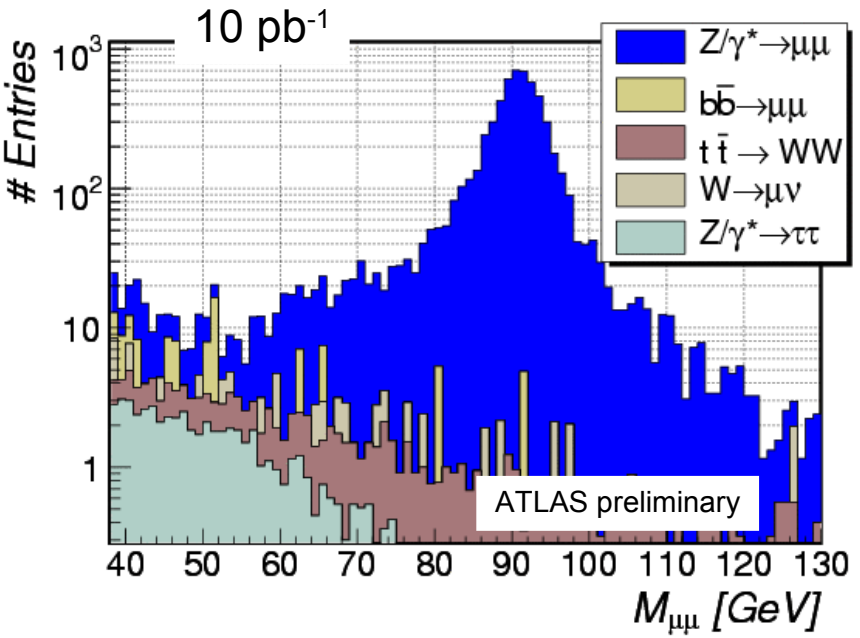
Converge on optimal muon ID



Z → μμ misaligned data – muon spectrometer only

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

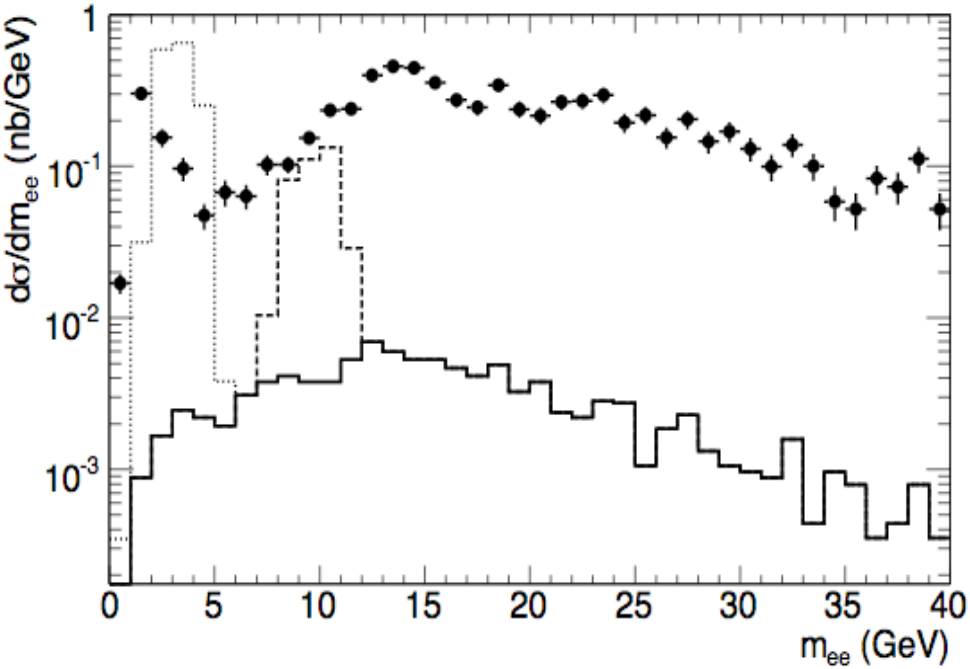




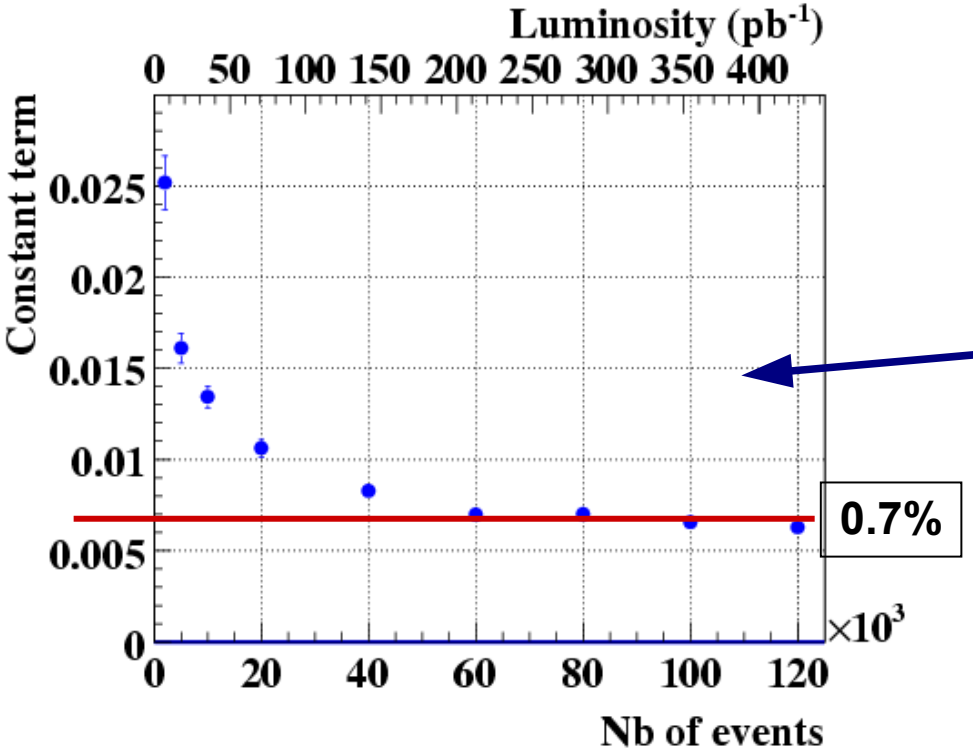
e/γ and LAr

Signal to noise is very tough – e/jet and γ/jet are 10-100 times worse than at Tevatron

Low-p_t dielectrons...



Build on test-beam data



Intercalibration with Z to ee

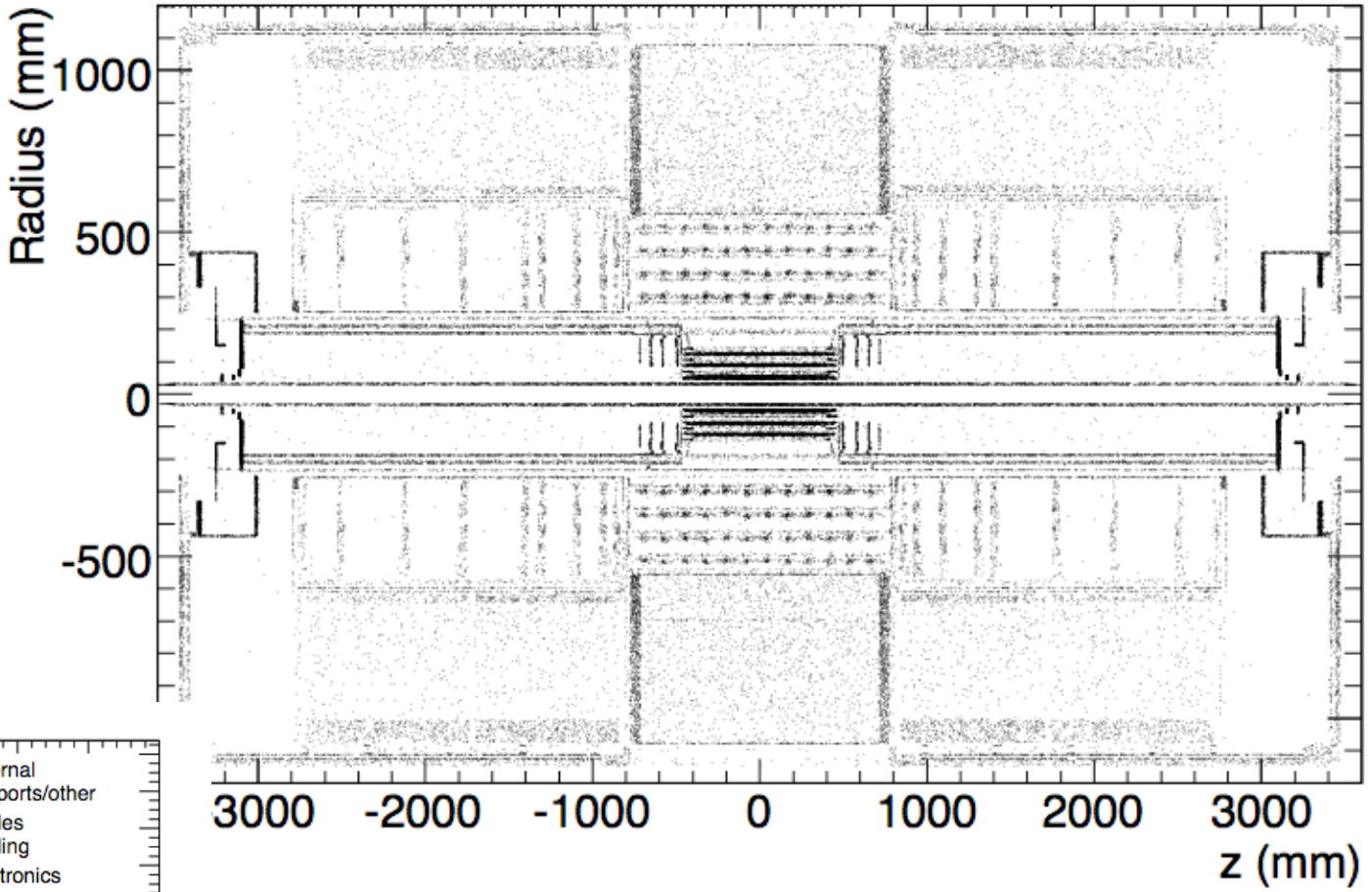
Long-range non-uniformity in EM response

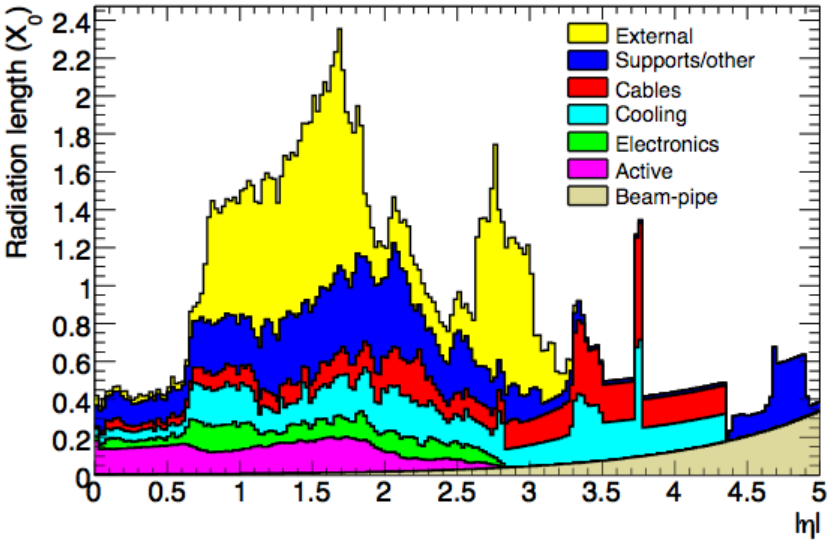
Constrain with high stats Z→ ee

Material Budget

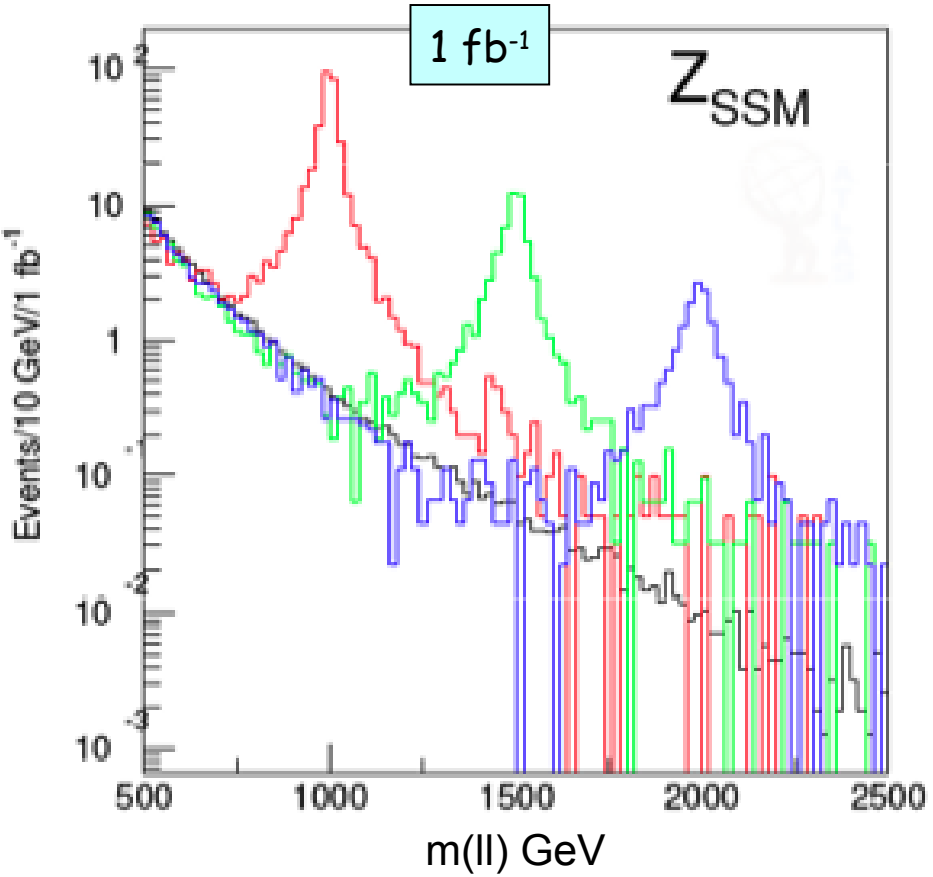
Photon conversions in min. bias. events

Great care taken in material assay – still surprises in store?





And just perhaps...



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

Mass (TeV)	Events/fb^{-1} (after cuts)	discovery I.L. (10 obs. evts)
1	~160	~70 pb^{-1}
1.5	~30	~300 pb^{-1}
2	~7	~1.5 fb^{-1}

Discovery window above Tevatron limits
M ~ 1 TeV, perhaps even in 2008...

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

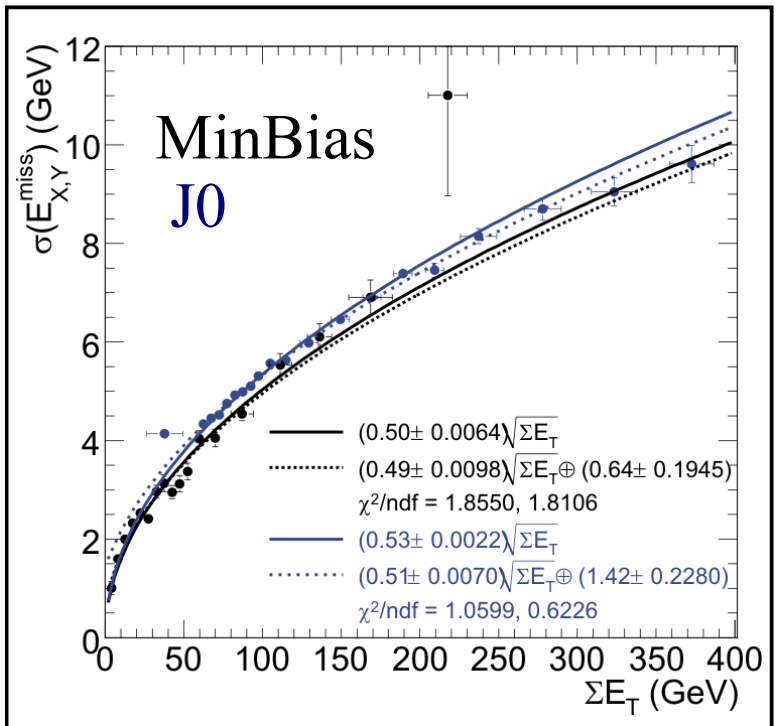
Missing-E_t

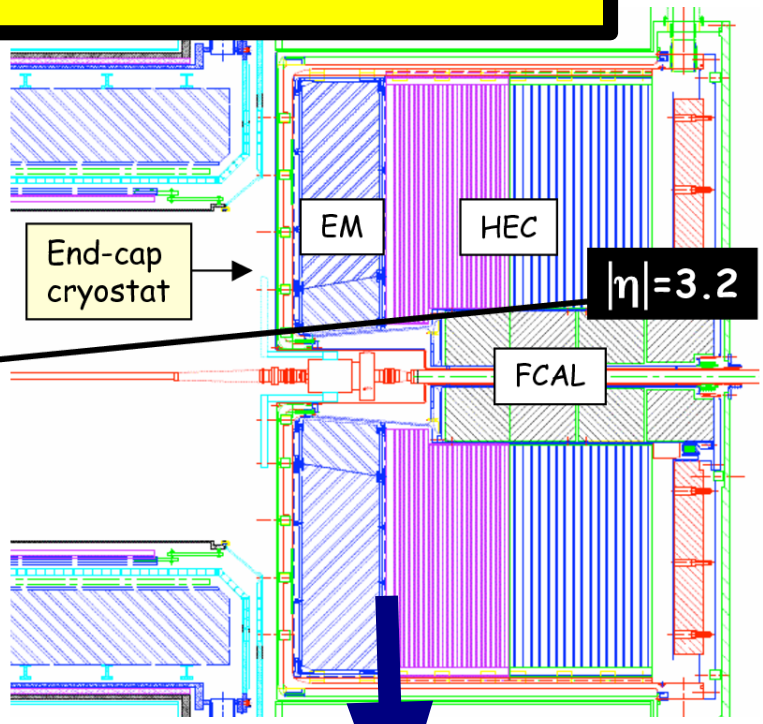
Challenging to commission:

- dependence on all calos including FCAL
- modelling of crack regions, eg
- machine backgrounds, etc

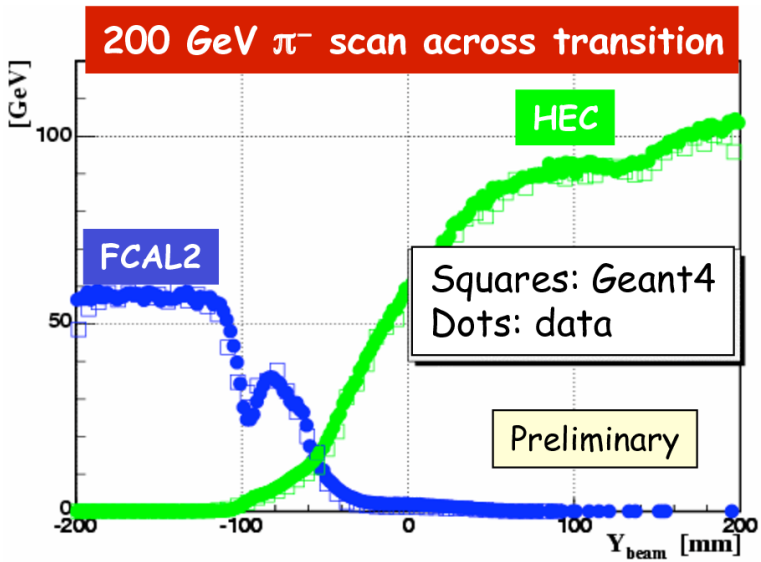
MET trigger hard too - not much can be done at level-2

Detailed studies ready for control samples of data...





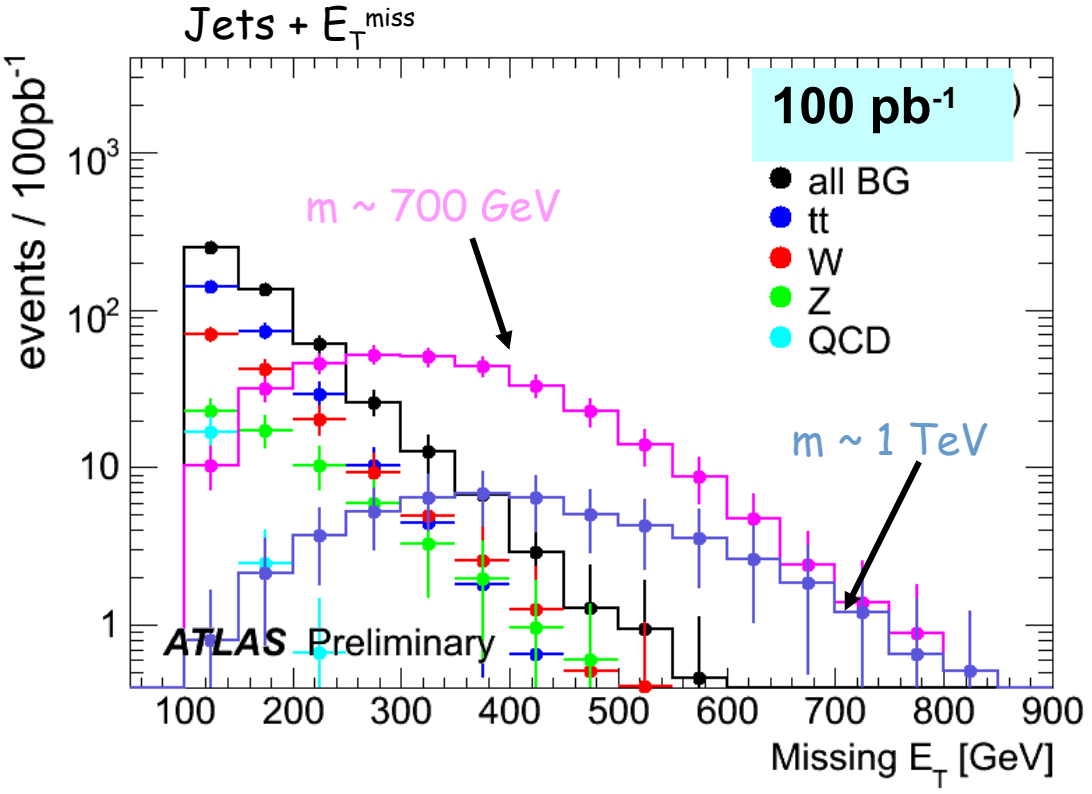
test-beam



An early SUSY observation?

With 100 pb^{-1} hints of SUSY can show up, for the right mass

→ the problem is to know if it is real



gluinos and squarks M ~ 1TeV

Need to

- understand E_t^{miss} performance
- control backgrounds with data – requires higher lumi, ~ 1fb^{-1}

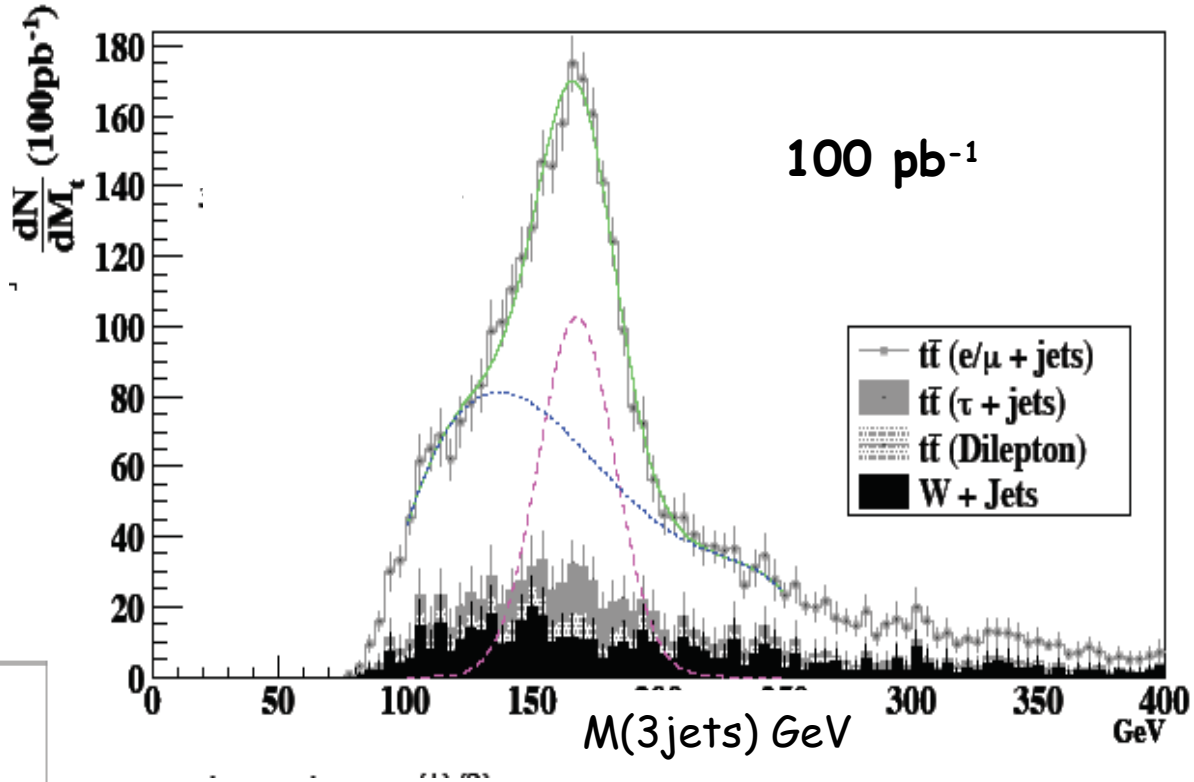
Observations based mainly on E_t^{miss} will be tough – and quite exciting!

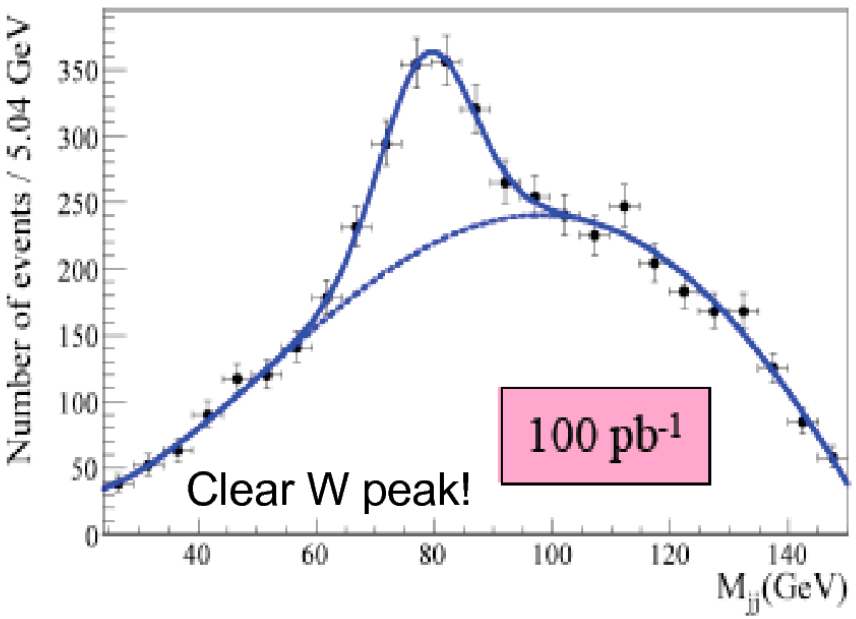
and maybe even new physics in trileptons...

Top Samples

Invaluable channel for data-driven calibration

- can select without b-tags
- commission b tagging
- general performance
- calibrate the light jet energy scale with W→jj

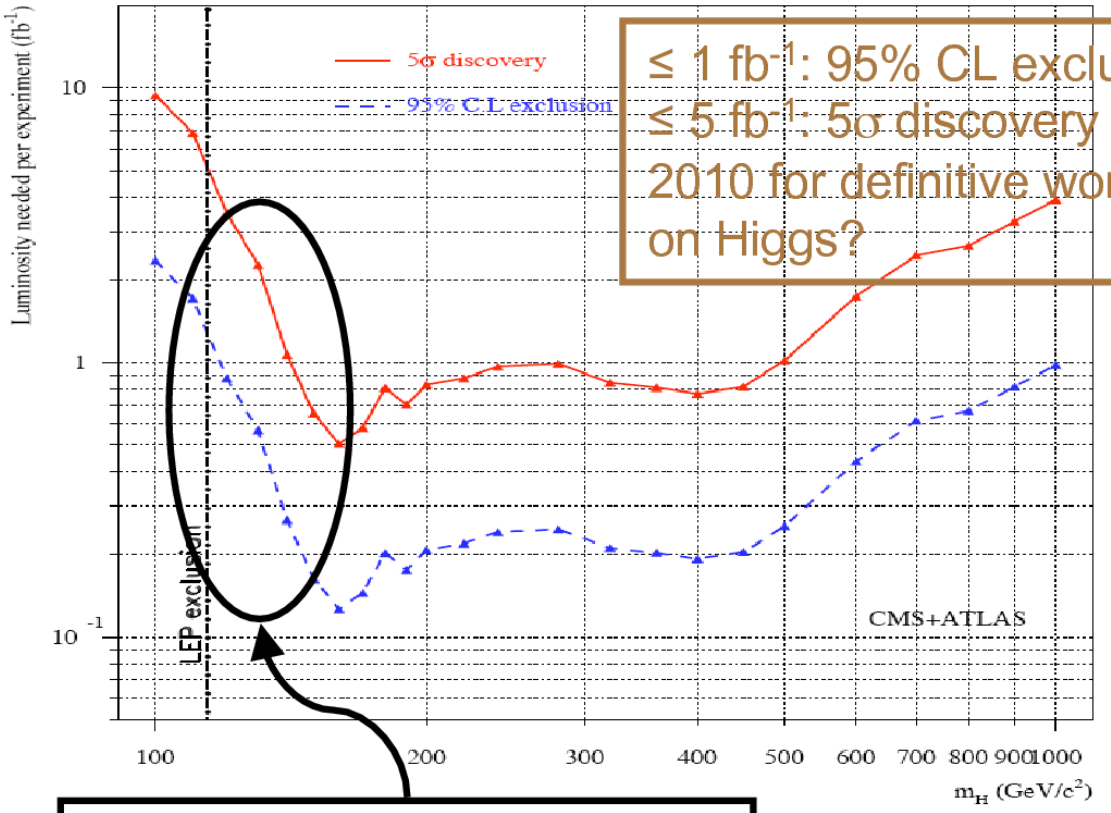




Top "re-discovery" with ~ 1pb^{-1}?
~1k events @ 30pb^{-1}

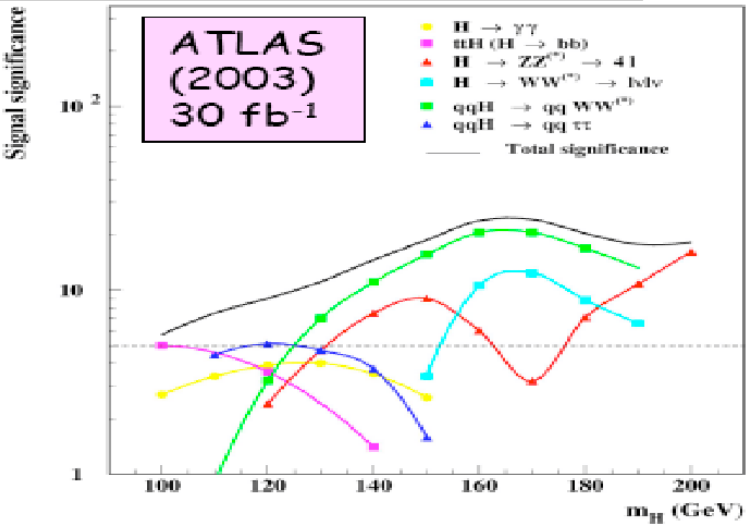
Higgs?

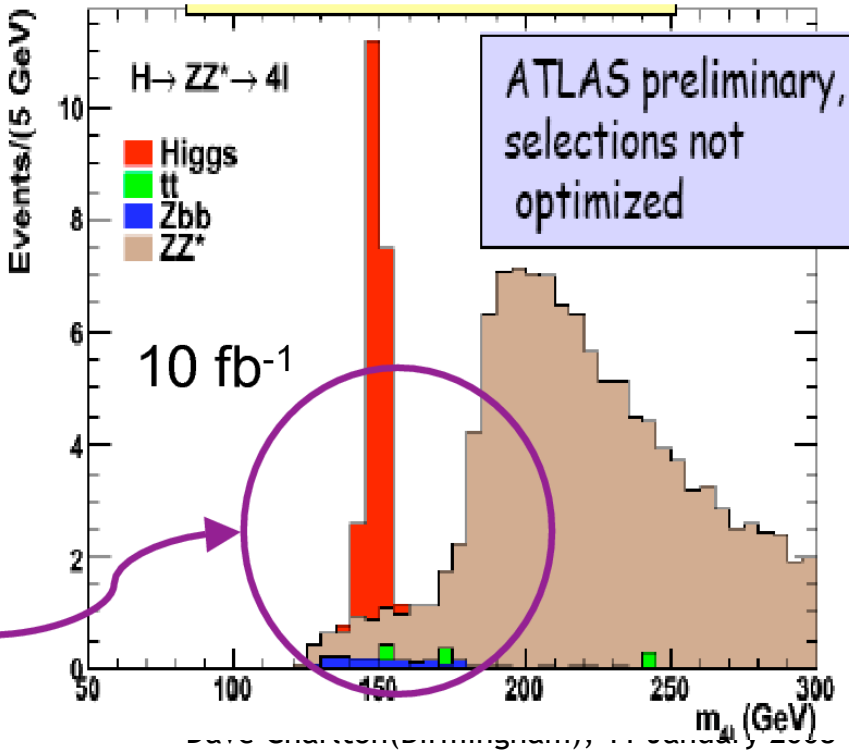
Need ~ fb^{-1} of well-understood data per experiment



≤ 1 fb^{-1}: 95% CL exclusion
≤ 5 fb^{-1}: 5σ discovery
2010 for definitive word on Higgs?

Most difficult region: combine many channels with small S/B





m_H > 140 GeV, easier discovery with H→ZZ*→4l
H→WW→lνlν dominates at 160 but no mass peak (counting experiment)

Slide from K Assamagan, NewPhys'08

Don't forget...

There is still a huge amount to do in the central offline software – in many cases continuing/increasing when data arrive:

- software frameworks
- release management
- reconstruction
- software validation
- simulation – new GEANT, fast simulations
- detector description (material, ...)
- production & data management systems
- etc etc (15 dense pages of deliverables for release 14...)

We are really short of effort in several of these areas: an opportunity!

And of course the *sine qua non* that Jamie covered – the detector, trigger and online systems and associated software

Closing words

This year we will start to commission with beam:
a completely new – and unprecedentedly complex - experiment
at a completely new hadron-hadron collider in
a completely new energy regime
(for the first time in 20 years)

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This will not be easy: we all have a huge amount to do in the next couple of years to make this succeed

Remember that the work needed is in very large part to commission, operate, understand, align, calibrate and tune the detector – this is experimental physics!

We DO start in a much better place than the last time this was done – good simulations and extensive test beam

It's going to be an interesting couple of years