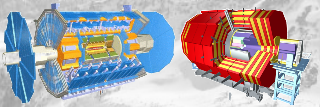
Commissioning of ATLAS and early SM measurements with leptons in ATLAS and CMS

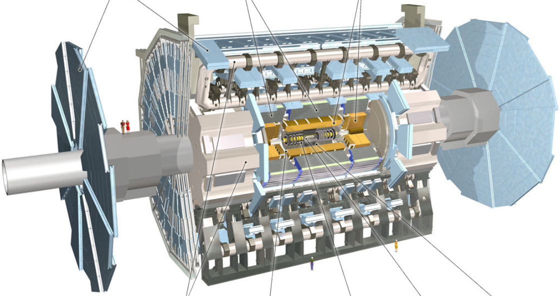
Mathieu Plamondon[1]
on behalf of
ATLAS and CMS collaborations

[1] LAL, Univ Paris-Sud, CNRS/IN2P3, Orsay, France

IVIIIrd Moriond Conference - EW Session



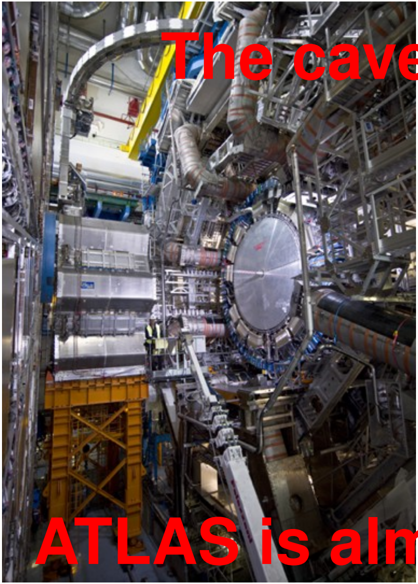
ATLAS commissioning before the collisions...

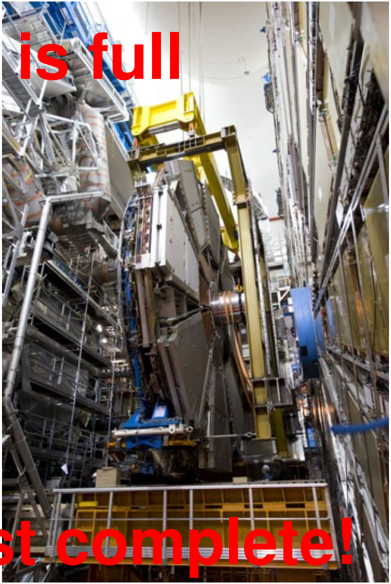


- How ready are the components a few months before start-up?
- What have we learned from the commissioning?

Detector Status

The cavern is full

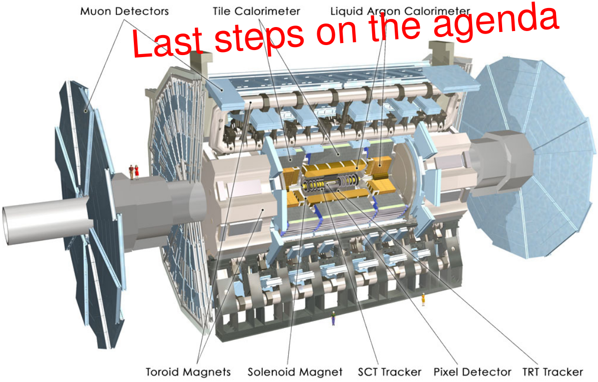


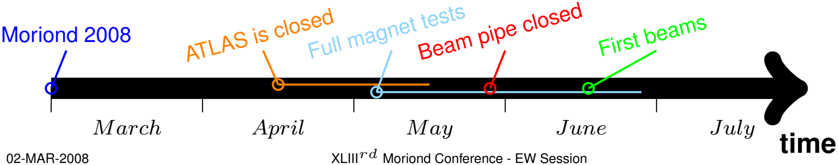


ATLAS is almost complete!

Detector Status

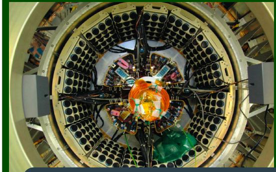
Last steps on the agenda



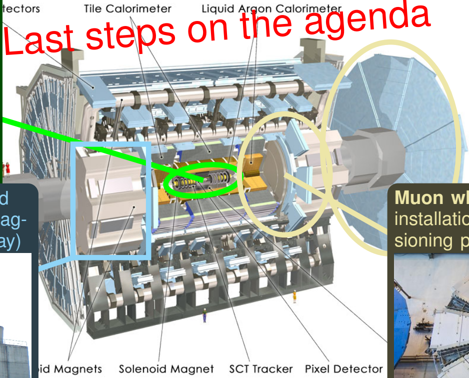


Detector Status

Pixels: connection on a tight schedule, to be completed by the end of March

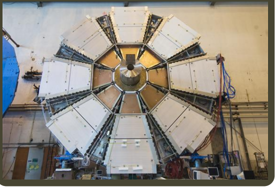


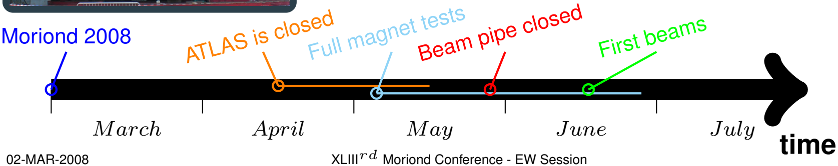
Last steps on the agenda



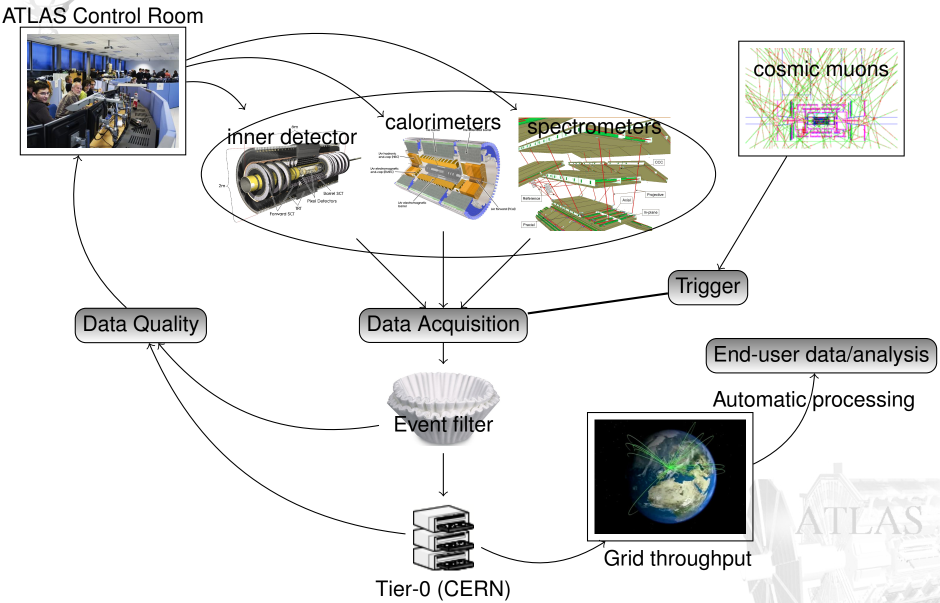
EndCap Toroids: were tested at 50-75% nominal (overall magnet tests with full power in May)

Muon wheels: 15 days for installation, minimal commissioning possible



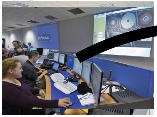


Integration



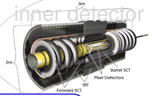
Integration

ATLAS Control Room

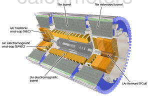


Detector Control System (DCS) operational

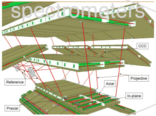
inner detector



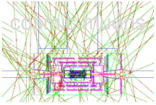
calorimeters



spectrometers



cosmic muons



Monitoring tools developed

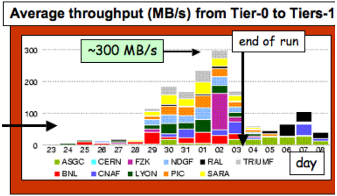
Trigger

Data Quality

Data Acquisition

End-user data analysis

Load tests with cosmics
(200MB/s vs 1GB/s at LHC)



Event filter

Full Dress Rehearsal (FDR): *stress test* of the full data processing and analysis chain

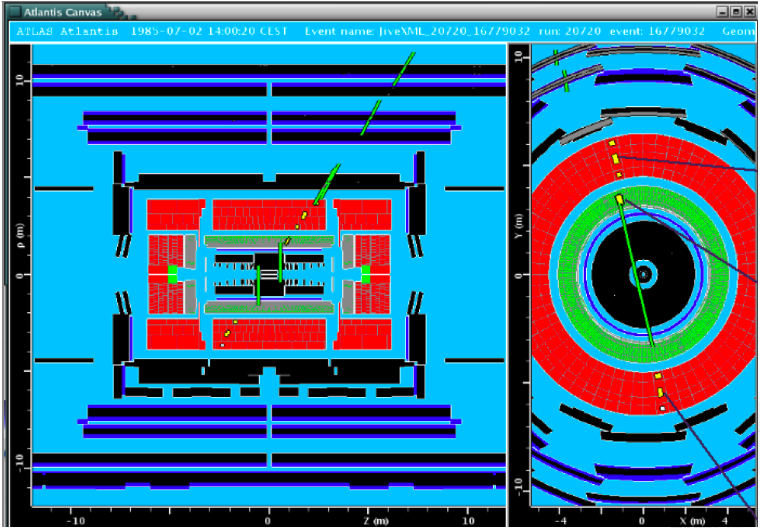
processing

Grid throughput

Tier-0 (CERN)

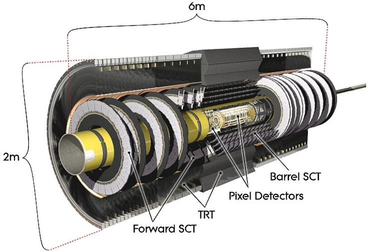
Results from cosmics

ATLAS recording data(from cosmics)

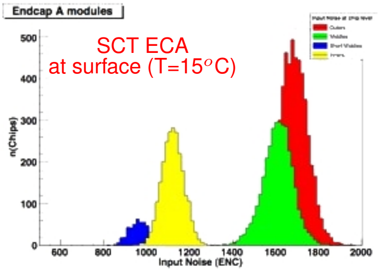


Inner detectors

- do debugging, identify non-working channels
- noise levels are not degraded once in the pit (compared to conditions at the surface)
- non-pointing cosmics are useful in alignment studies



Sub-detector	# channels (non-working)
Pixels	80×10^6 (0.3%)
Silicon Strips (SCT)	6×10^6 (0.3%)
Transition Radiation (TRT)	3.5×10^5 (1.0%)



Global SCT-TRT barrel misalignments

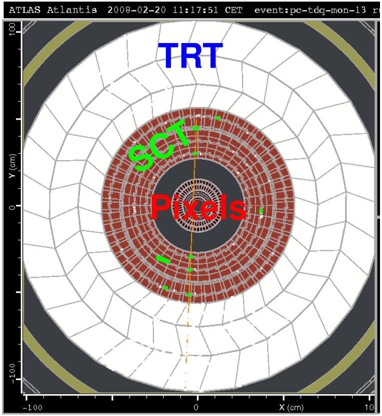
Displacement	Survey	Cosmics
Δx(mm)	$-0.300 \pm .008$	$-0.290 \pm .007$
Δrot-y(mrad)	$+0.221 \pm .006$	$+0.285 \pm .021$

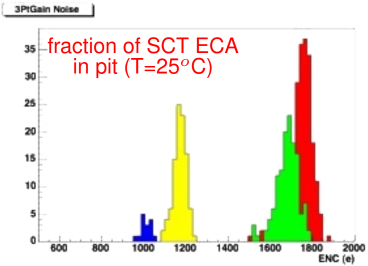
comparison between survey measurements and results from reconstructed *cosmics* tracks (after alignment)

Inner detectors

- do debugging, identify non-working channels
- noise levels are not degraded once in the pit (compared to conditions at the surface)
- non-pointing cosmics are useful in alignment studies

Sub-detector	# channels (non-working)
Pixels	80×10^6 (0.3%)
Silicon Strips (SCT)	6×10^6 (0.3%)
Transition Radiation (TRT)	3.5×10^5 (1.0%)





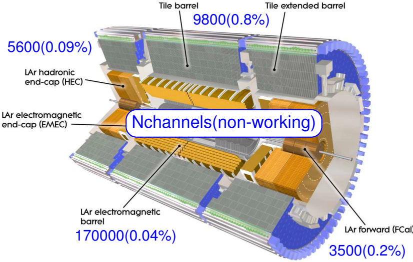
Global SCT-TRT barrel misalignments

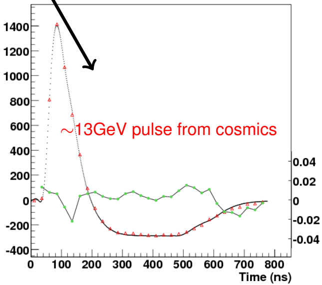
Displacement	Survey	Cosmics
Δx(mm)	$-0.300 \pm .008$	$-0.290 \pm .007$
Δrot-y(mrad)	$+0.221 \pm .006$	$+0.285 \pm .021$

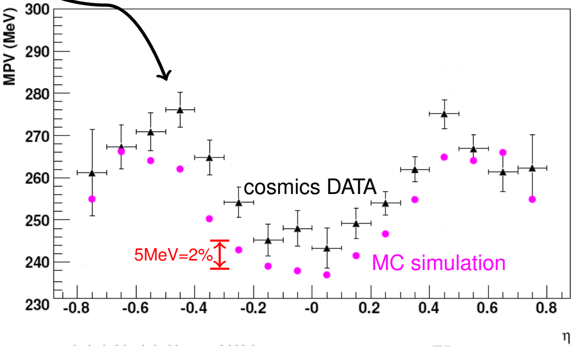
comparison between survey measurements and results from reconstructed *cosmics* tracks (after alignment)

Calorimeters

- have operated under *stable* conditions (high voltage,temperature) for more than one year
  - e.g. liquid argon kept at 88K with an rms(T)$\lesssim$10mK
- the good understanding of the detectors illustrated by cosmics, e.g.
  - signals in the LAr calorimeter are well described/predicted
  - EM energy scale and uniformity along η verified with cosmics at the 2% level

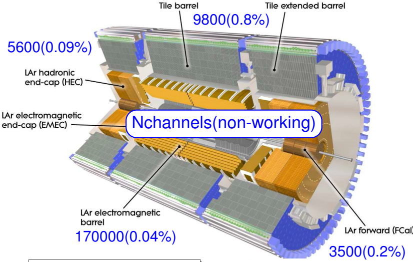


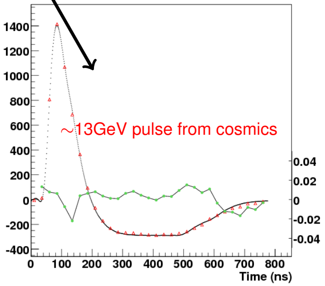


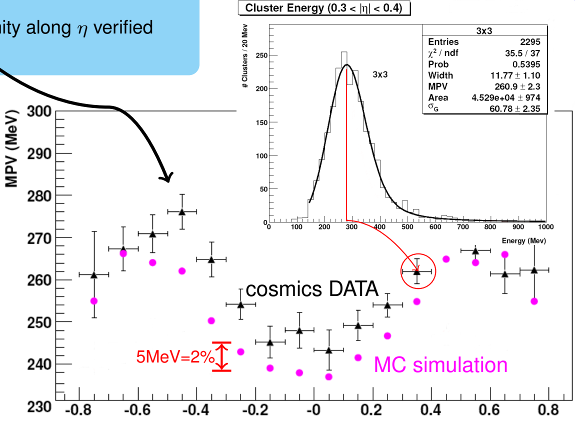


Calorimeters

- have operated under *stable* conditions (high voltage,temperature) for more than one year
  - e.g. liquid argon kept at 88K with an rms(T)$\lesssim$10mK
- the good understanding of the detectors illustrated by cosmics, e.g.
  - signals in the LAr calorimeter are well described/predicted
  - EM energy scale and uniformity along η verified with cosmics at the 2% level

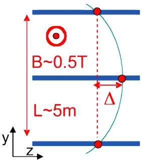


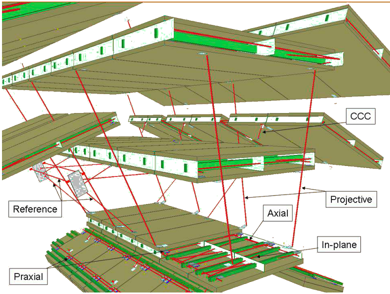


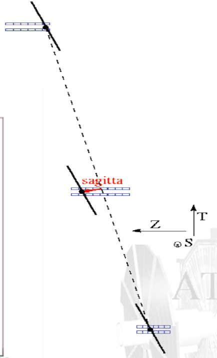


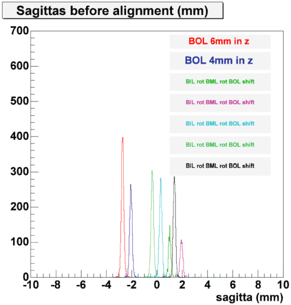
Muon spectrometer

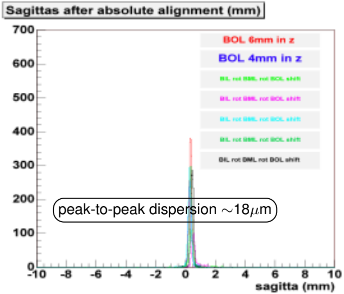
- $\Delta \sim 500 \mu m$ @1TeV$\Rightarrow$ alignment precision very crucial
- $\sigma_p/p \approx 10\% \Rightarrow \delta\Delta \sim 50\mu m$ (ultimate accuracy $\sim 30\mu m$)
- alignment by optical sensors tested by moving barrel MDT modules (rotations,displacements)
- a small fraction (0.03%) out of $\sim$110000 channels is non-working



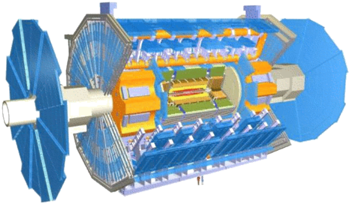


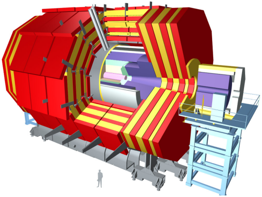






And the first collisions...





What ATLAS and CMS plan to do with 2008 data ($\approx$100pb^{-1})?

At start-up

	Performance @ Start-up	Ultimate goal	Physics goals	Physics signals tools
EM energy uniformity	$<$2%(ATLAS) $<$4%(CMS)	0.7%(ATLAS) 0.5%(CMS)	H$\rightarrow\gamma\gamma$	isolated e, Z$\rightarrow$ee, ϕ-symmetry
Electron energy scale	$\sim 2\%$	0.02%	W mass	Z$\rightarrow$ee
Inner detector alignment	50-100μm(ATLAS)	$<$10μm	b-tagging	isolated μ,Z$\rightarrow\mu\mu$,generic tracks
Muon system alignment	$<$200μm(ATLAS)	30μm	Z'$\rightarrow\mu\mu$	Z$\rightarrow\mu\mu$
Muon momentum scale	$\sim$1%	0.02%	W mass	Z$\rightarrow\mu\mu$

- Commission and calibrate the detector in situ using well-known physics samples ("standard candles")
- Rediscover and measure SM physics at $\sqrt{s} = 14\ TeV$
- Validate and Tune MC. Prepare the road to new physics.
- Early discoveries?

At start-up

	Performance @ Start-up	Ultimate goal	Physics goals	Physics signals tools
EM energy uniformity	<2%(ATLAS) <4%(CMS)	0.7%(ATLAS) 0.5%(CMS)	$H\rightarrow\gamma\gamma$	isolated e, Z$\rightarrow$ee, ϕ-symmetry
Electron energy scale	$\sim 2\%$	0.02%	W mass	Z$\rightarrow$ee
Inner detector alignment	50-100μm(ATLAS)	<10μm	b-tagging	isolated μ,Z$\rightarrow\mu\mu$,generic tracks
Muon system alignment	<200μm(ATLAS)	30μm	Z'$\rightarrow\mu\mu$	Z$\rightarrow\mu\mu$
Muon momentum scale	~1%	0.02%	W mass	Z$\rightarrow\mu\mu$

- Commission and calibrate the detector in situ using well-known physics samples ("standard candles")
- Rediscover and measure SM physics at $\sqrt{s} = 14\ TeV$
- Validate and Tune MC. Prepare the road to new physics.
- Early discoveries?

channels (examples)	events to tape for 100pb^{-1} @ LHC	total stat. @ Tevatron
W$\rightarrow\mu\nu$	$\sim 10^6$	$\sim10^6$-10^7
Z$\rightarrow\mu\mu$	$\sim 10^5$	$\sim10^5$-10^6
$t\bar{t}\rightarrow\mu\nu$+X	$\sim10^5$	$\sim10^3$-10^4

Illustrative trigger menu at $\mathcal{L} = 10^{31}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ (ATLAS):

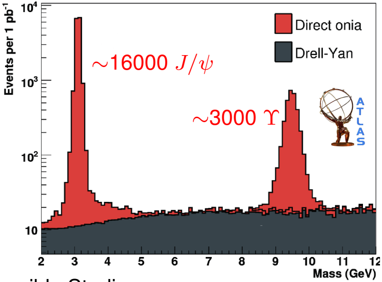
Signature	Examples of physics coverage		Rates(Hz)
minimum bias	Prescaled trigger item		10
e10,2e5	b,c$\rightarrow$e,W,Z,Drell-Yan,tt,J/ψ,Υ	electrons	~27
γ20,2γ15	Direct photon, photon pairs, γ-jet balance	photons	~7
μ10,2μ4	b,W,Z,Drell-Yan,tt,J/ψ,Υ	muons	~22
j120,4j23	QCD,high p$_T$ and multi-jet final states	jets	~13
τ20i+$^{e10}_{\mu6}$	Z$\rightarrow\tau\tau$	taus	4
τ20i+xE30	W,tt	tau+$\not{E}_T$	~10
	Prescaled,calibration,monitoring triggers		~17
Total HLT rate			~100

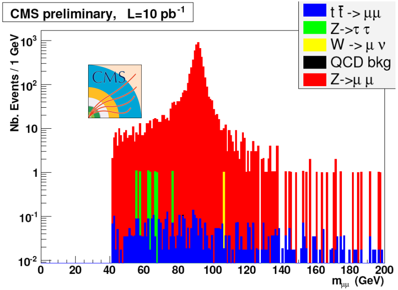
Leptons play an important role for early physics

First peaks: $(J/\psi, \Upsilon, Z) \to \mu\mu$

Statistics for 1pb^{-1}(3.85days) @ 10^{31}
assuming a 30% detector+machine efficiency

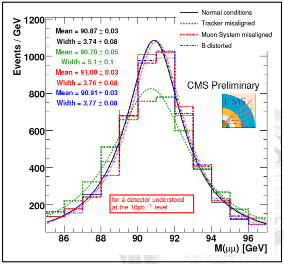
After all cuts:
$\sim$600 Z$\to\mu\mu$ events per pb^{-1}





Possible Studies:

- with J/ψ: sanity checks, tracker alignment and momentum scale
- with Z: detector efficiencies, trigger performance, detector momentum scale, alignment



- use the Z boson mass candle to assess:
  - misalignments of tracker and spectrometer
  - uncertainties on the magnetic field (distorded B field)

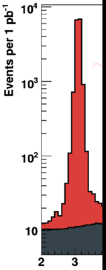
First peaks: $(J/\psi, \Upsilon, Z) \to \mu\mu$

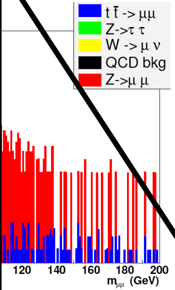
Statistics for 1pb^{-1}(3.85days) @ 10^{31}

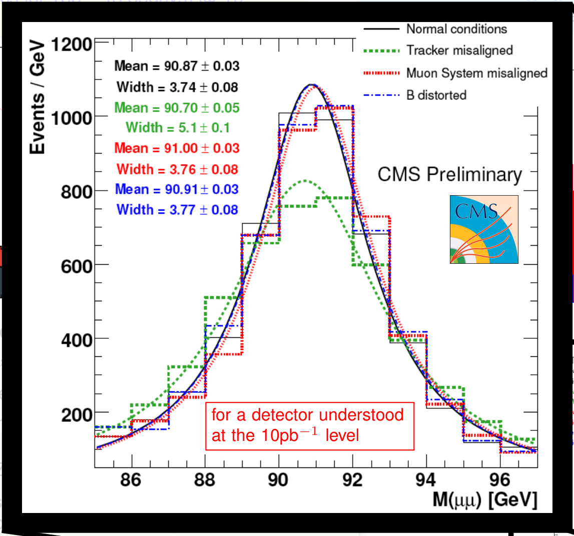
assuming

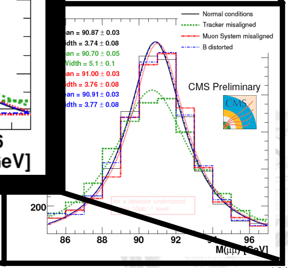
After all cuts:

nts per pb^{-1}







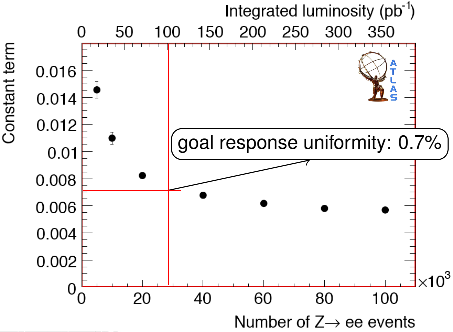


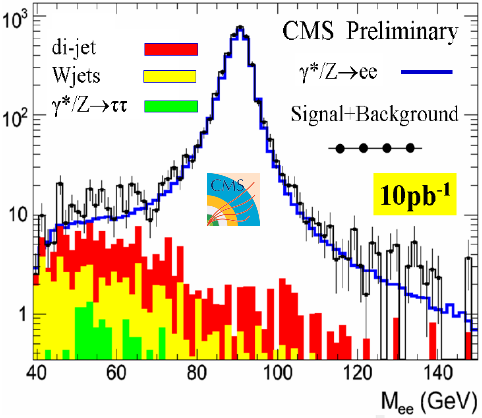
Possible Stu

- with J/ψ
- with Z: de momentu
- use the Z
  - mis
  - unc (distorded B field)

Z→ee calibration and energy scale

- Z will be seen very early, even with simple cuts
- robust analysis are considered at the beginning (e.g. no tracker needed, in the barrel region only)
- Z→ee is a key tool for the commissioning of electron reconstruction and ID





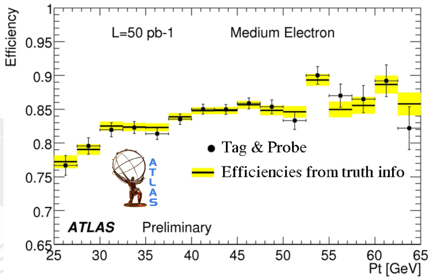
- use Z-mass constraint to correct residual long-range non-uniformities
- in ATLAS, intercalibrate relatively large regions which are locally uniform
  $\Rightarrow$ ∼30000 Z→ee events enough to achieve the goal response uniformity of $\sim 0.7\%$
- in CMS, the local cristal-to-cristal response is also non-uniform
  $\Rightarrow$ statistics of $10fb^{-1}$ required to perform a similar intercalibration

Z and W cross-sections

for 100pb^{-1}

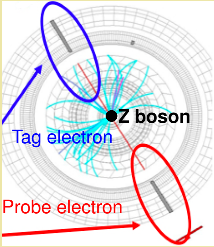
	$\frac{\Delta\sigma}{\sigma}(pp \to Z/\gamma^* + X \to \mu\mu)$
ATLAS	$0.004(stat) \pm 0.008(sys) \pm 0.02(th) \pm 0.1(lumi)$
CMS	$0.004(stat) \pm 0.011(sys) \pm 0.02(th) \pm 0.1(lumi)$

- not statistically limited
- systematics at the 1% level (efficiencies,background,. . .)
- Tag&Probe method used to determine efficiencies
  - single lepton trigger to allow unbiased probes
  - agrees well with truth matching (<1% in average)
- theoretical error at 2%, rel. acceptance determination and PDFs
- **limited by luminosity uncertainty: 10%**



Tag&Probe method

- well identified electron on one side: **tag** electron
- simple object on the other side (track or EM cluster): **probe** electron
- determine the efficiency with the number of events in the mass window: $M_{inv}=M_Z \pm 20$GeV

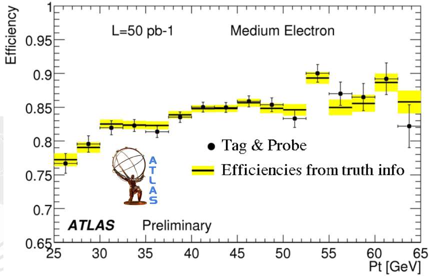


Z and W cross-sections

for 100pb^{-1}

	$\frac{\Delta\sigma}{\sigma}(pp \to Z/\gamma^* + X \to \mu\mu)$
ATLAS	$0.004(stat) \pm 0.008(sys) \pm 0.02(th) \pm 0.1(lumi)$
CMS	$0.004(stat) \pm 0.011(sys) \pm 0.02(th) \pm 0.1(lumi)$

- not statistically limited
- systematics at the 1% level (efficiencies,background,. . .)
- Tag&Probe method used to determine efficiencies
  - single lepton trigger to allow unbiased probes
  - agrees well with truth matching (<1% in average)
- theoretical error at 2%, rel. acceptance determination and
- **limited by luminosity uncertainty: 10%**

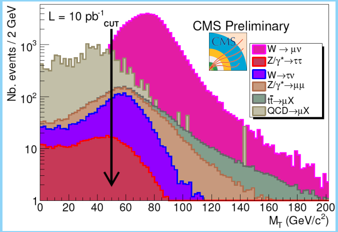


Tag&Probe method

- well identified electron on one side: **tag** electron
- simple object on the other side (track or EM cluster): **probe** electron
- determine the efficiency with the number of events

$W \to \ell\nu$

- use the knowledge acquired with the Z
- more background than the Z



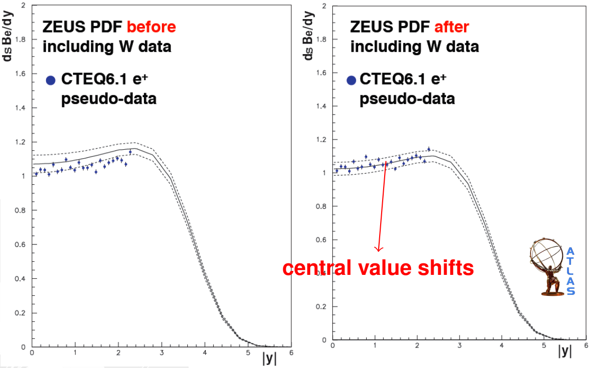
$\Rightarrow$ evaluate bkg by data-driven techniques

- higher systematic errors, e.g. $\frac{\Delta\sigma}{\sigma}(W \to e\nu)$ with 50pb^{-1} (ATLAS) = $\pm 0.002(\text{stat}) \pm 0.05(\text{sys}) \pm 0.1(\text{lumi})$

Constrain PDFs with W$\rightarrow\ell\nu$

- W production at LHC over $|y|<2.5 \Rightarrow 10^{-4}<x_{1,2}<0.1$
- low-x region dominated by g$\rightarrow q\bar{q}$: sea-sea parton interactions
- low-x uncertainties on present PDF are large (4-8%)
- possibility to constrain PDFs by adding LHC data in global fits
- early measurements of $e^{\pm}$ angular distributions at LHC can provide discrimination between different PDF **if experimental precision is $\lesssim 5\%$**

$$x_{1,2} = \frac{M}{\sqrt{s}} e^{\pm y}$$

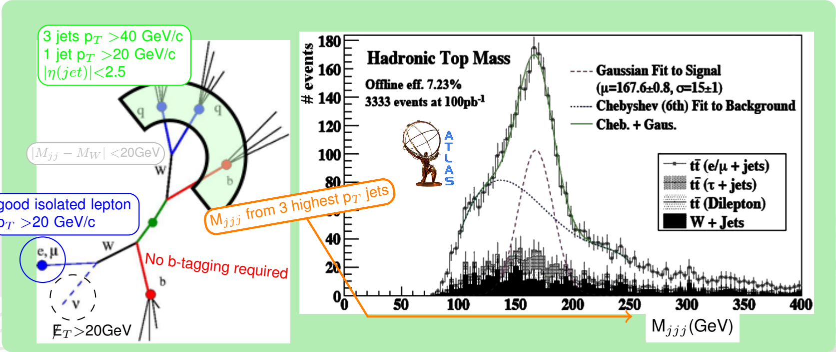


Example:

- simulate 10^6 W$\rightarrow$ eν events (an equivalent of 150pb^{-1} of data) generated with CTEQ6.1 PDF and detector simulation
- introduce 4% systematic errors by hand (statistical error negligible)
- these pseudo-data are included in the global ZEUS PDF fit
- error on low-x gluon shape parameter λ [xg(x)$\sim$x$^{-\lambda}$] reduced by 41%
- systematics (e.g. $e^{\pm}$ acceptance vs η) are already controlled to a few percents with Z$\rightarrow$ee

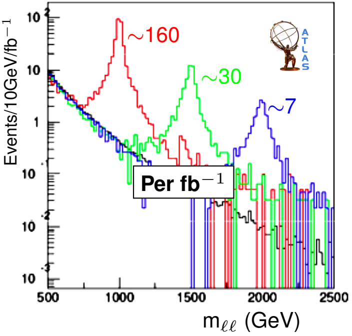
Leptons for early top

- easiest channel will be lepton + jets (tt→b$\ell\nu$ bjj)
- main backgrounds: W+jets, tt combinatorics and QCD
- assume b-tagging will not be available yet
- also, $\not{E}_T$ might be problematic at the start ⇒ **early top analyses are lepton-triggered**
- signal can be quickly seen (with ∼10pb^{-1}), even with limited detector performance and simple analysis
- with 100pb^{-1}, measure σ_{tt} to ∼20% and m$_{top}$ to <10GeV
- excellent sample for: light jet calibration, b-jet efficiency determination, general detector performance (see Tim Christiansen's talk)

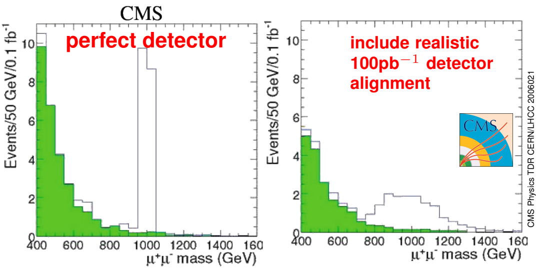


Early discoveries with leptons?

Mass (TeV)	$\int \mathcal{L}dt$ for discovery
1	**$\sim$70 pb^{-1}**
1.5	$\sim$300 pb^{-1}
2	$\sim$1.5 fb^{-1}



- early search of a narrow resonance decaying to e^+e^-
- with 100pb^{-1}, signal large enough for discovery for up to M$\sim$1TeV
- ultimate calorimeter performance not needed
- would require much more data to distinguish a Z' from a graviton for instance
- dimuons? Significantly worse resolution than for electrons but generally lower instrumental background may make dimuons a discovery channel along with dielectrons



Conclusions

ATLAS is getting ready to collect data by recording already cosmic ray particles and is eagerly awaiting the first LHC collisions next summer...