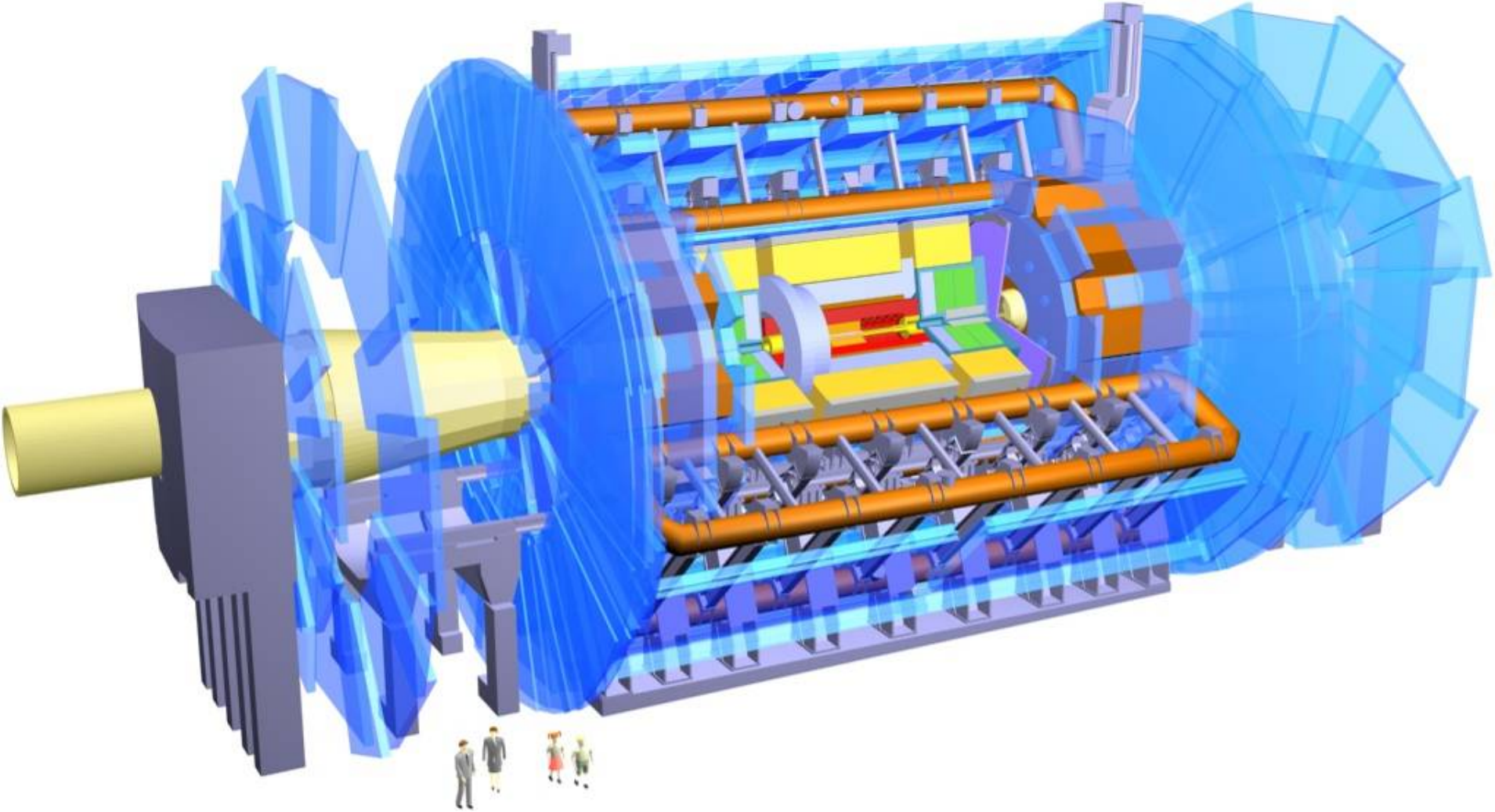
Top mass measurement in ATLAS: perspectives and challenges

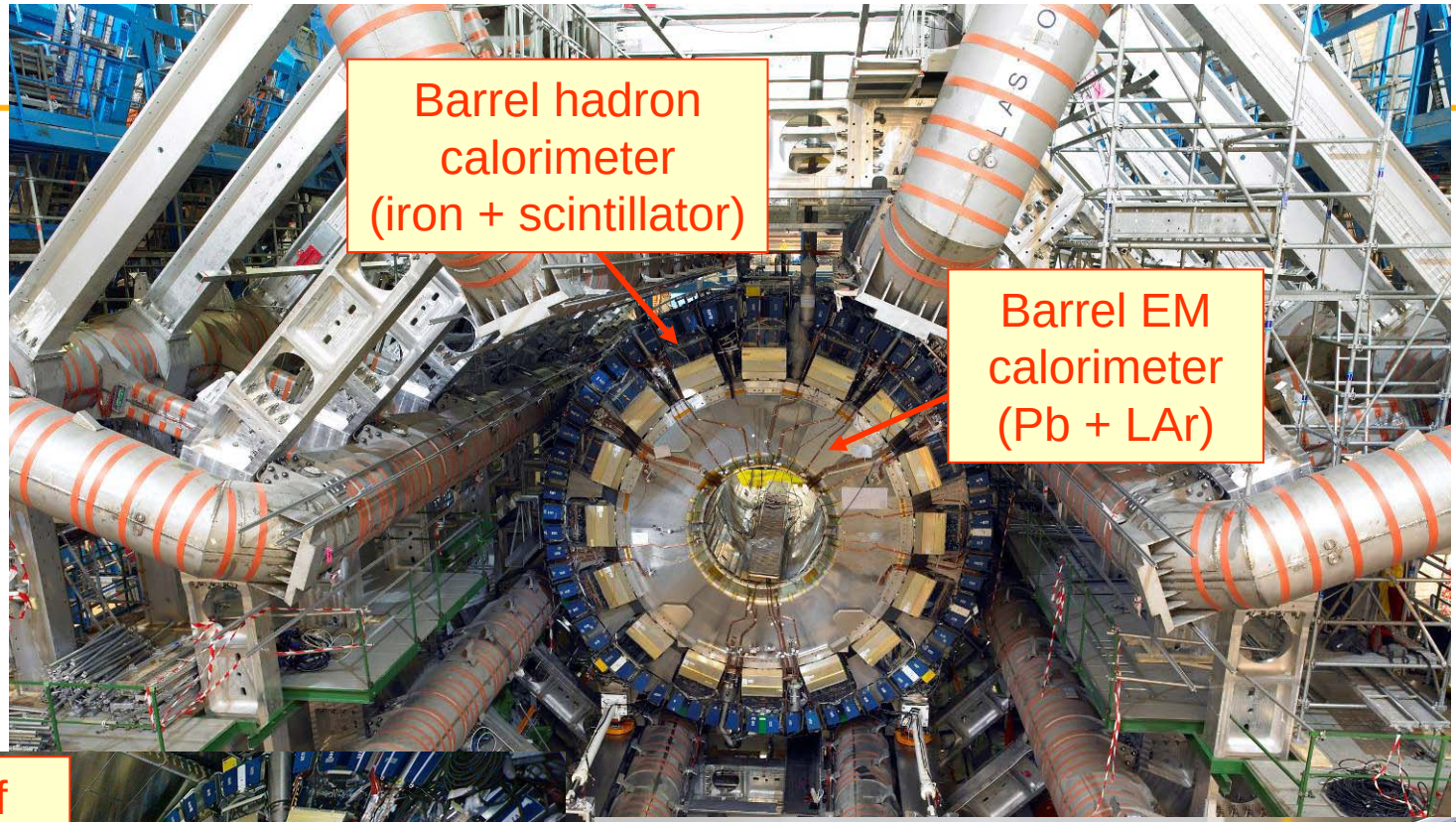
- Status of ATLAS and LHC
- Top mass measurement:
  - challenges in the $l\nu b$ jjb channel
- Other channels, ideas for commissioning

The ATLAS detector

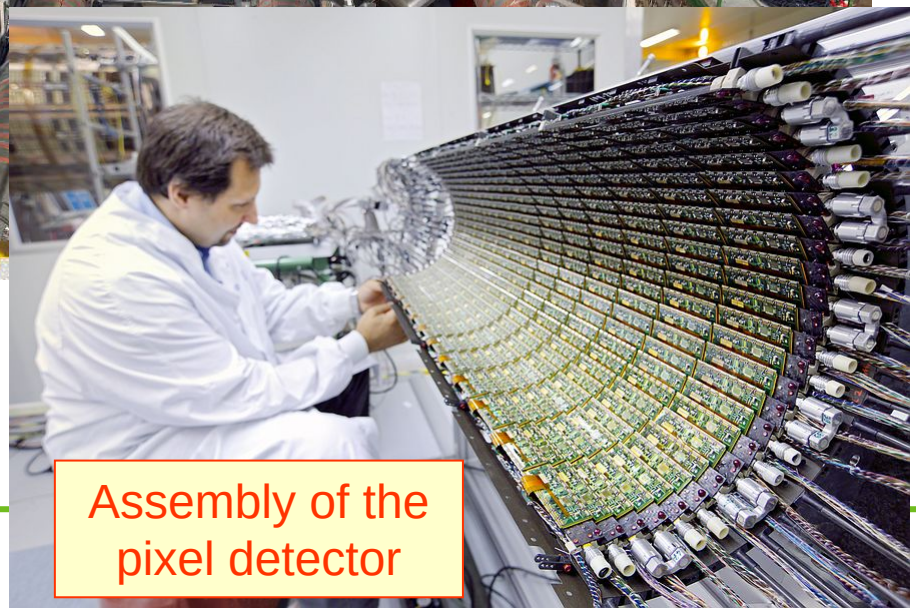
- We are going from this…



- … to that

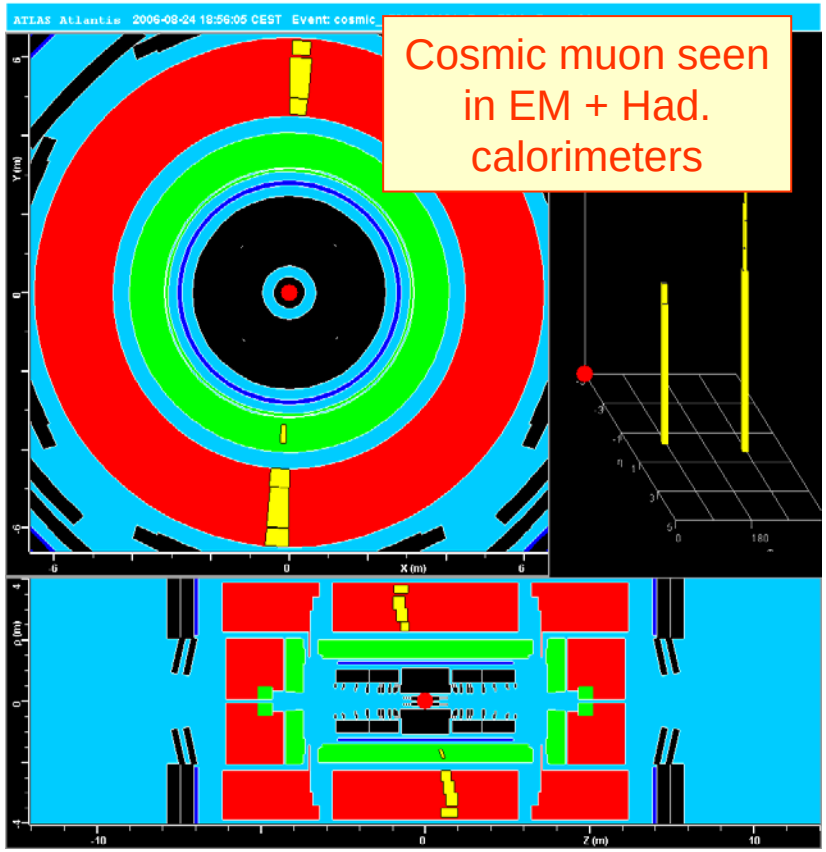

Barrel hadron calorimeter (iron + scintillator)
Barrel EM calorimeter (Pb + LAr)

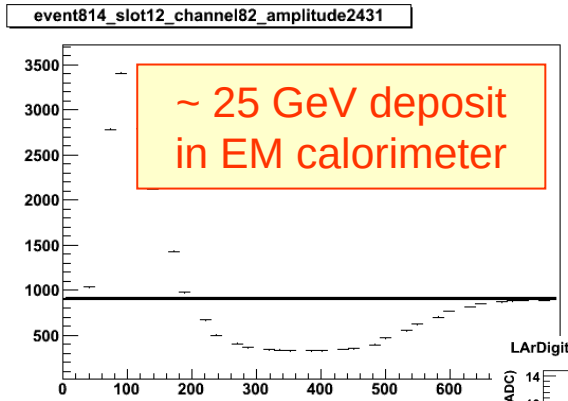
Installation of central tracker (end August 06)

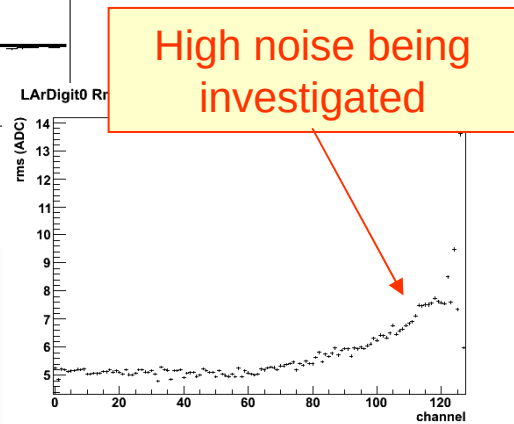

Assembly of the pixel detector

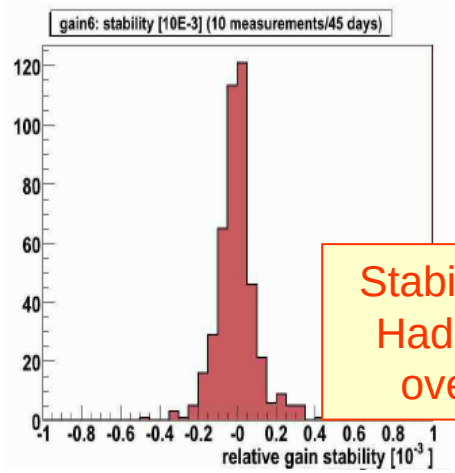
Commissioning

- Commissioning of the detectors + electronics + DAQ has started
  - Allows to check HV, dead channels, pulse shapes, stability, noise, …







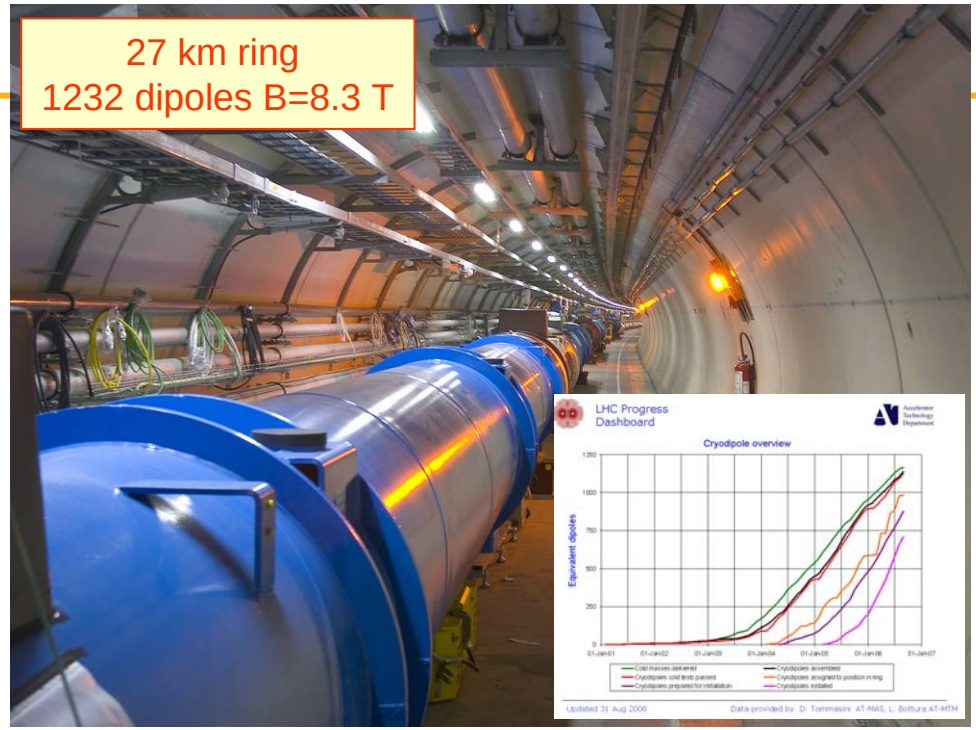


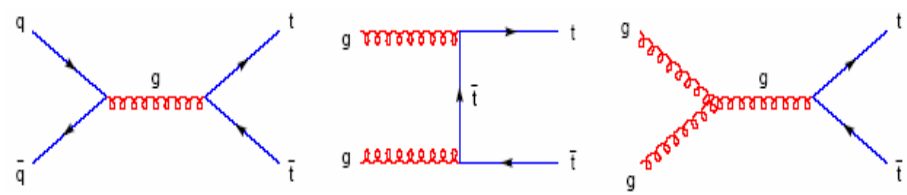
LHC

- LHC:
  - Being installed, 60% of the dipoles in the tunnel
  - Run at 900 GeV in November 2007
  - 14 TeV in 2008, hope to integrate a few fb^{-1} in 2008

- Top at LHC:
  - ttbar pairs produced mainly by gluon fusion
  - σ ~ 830 pb → 80000 ttbar pairs / day @ 10^{33} cm^{-2} s^{-1} (nominal lumi: 10^{34})
  - Also single top, see F.Chevallier

- σ^{tot} ~ 100 mb, bunch crossings every 25 ns → pileup ~ 2.5 events at 10^{33} ($\sigma(z)$ = 5.6 cm)





$q\bar{q} \rightarrow t\bar{t}$

~10%

$gg \rightarrow t\bar{t}$

~90%

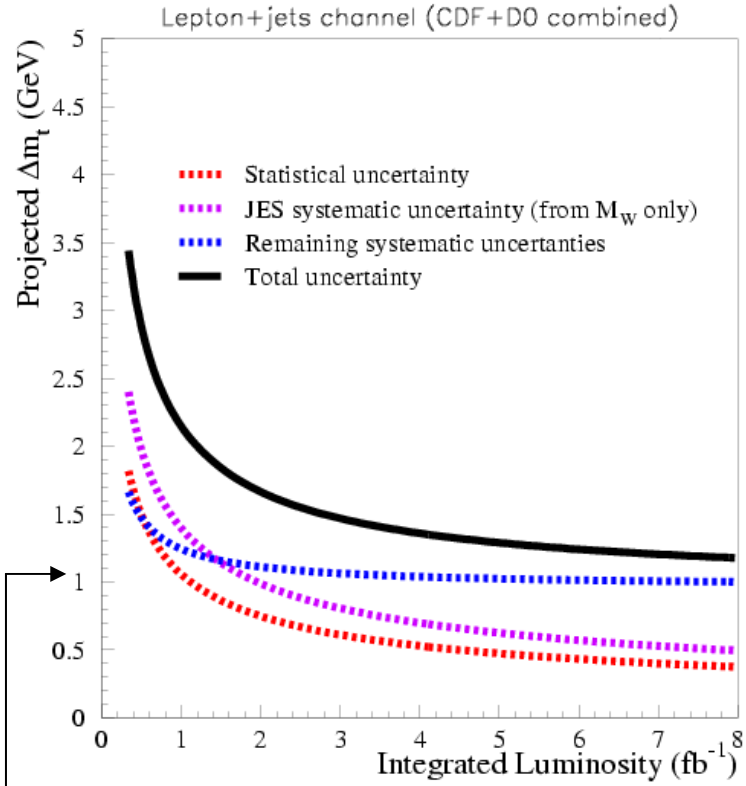
Top mass measurement: the challenge

- σ(14 TeV) = σ(2 TeV) x 100
- At one tenth of design luminosity (10^{33} cm^{-2} s^{-1}), will integrate 10 fb^{-1} / year

→ LHC will be a top factory

- However:
  - In ATLAS Physics TDR (1999): « *a total error below 2 GeV should be obtainable* »
  - In hep-ex/0403021: « *a total error on the top mass at the level of 1 GeV should be achievable* »

→ What are the limitations at LHC ?



The challenge for LHC !

Sources

- Published information (fast or full simulation):
  - Physics Technical Design Report (P-TDR, 1999)
  - Scientific note : hep-ex/0403021
  - ATLAS-Notes : 2001-016, 2002-007, 2003-011, 2003-012, 2005-002

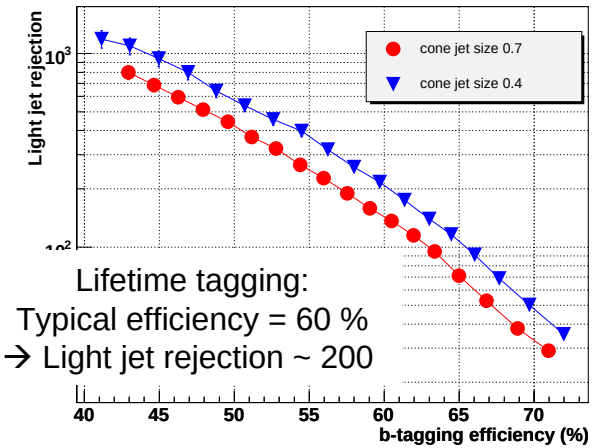
- Recent work in top and jet/$E_T$miss groups (mostly full simulation)

- A lot of work is starting right now:
  - With a realistic detector simulation (misalignments, …)
  - With larger samples
  - Aiming at notes by next spring

Numbers quoted here should be taken with care …

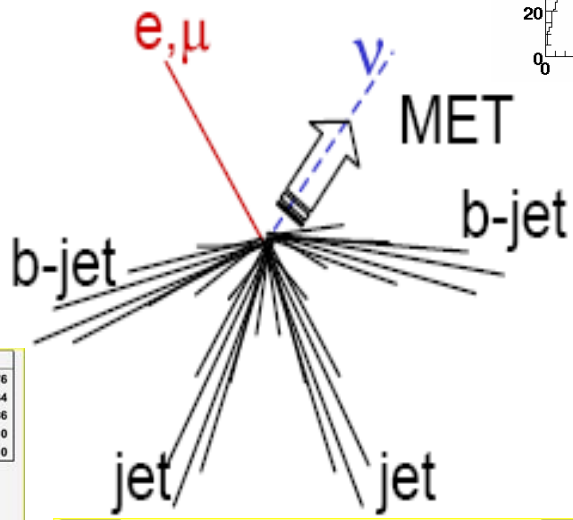
- obtained with limited MC statistics, no recent simulation with pileup
- uncertainties in the methods
- uncertainties in the cross-sections
- uncertainties in the efficiencies

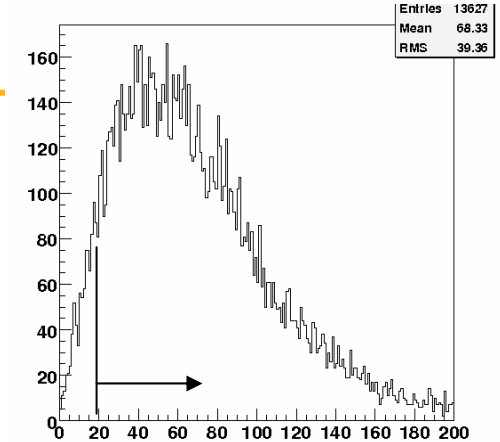
The ttbar → lνb jjb topology



Lifetime tagging:
Typical efficiency = 60 %
→ Light jet rejection ~ 200

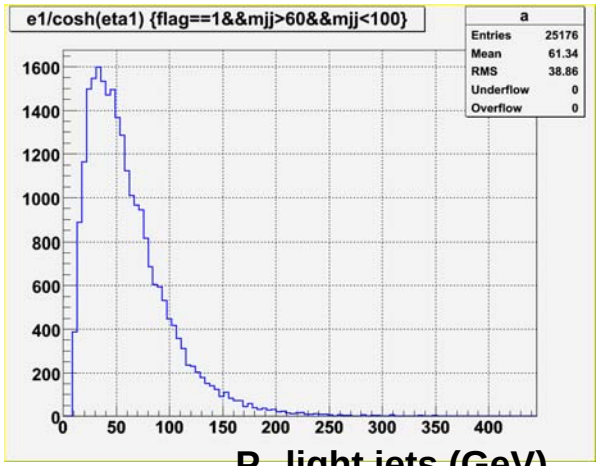
P_T > 20 GeV
isolated



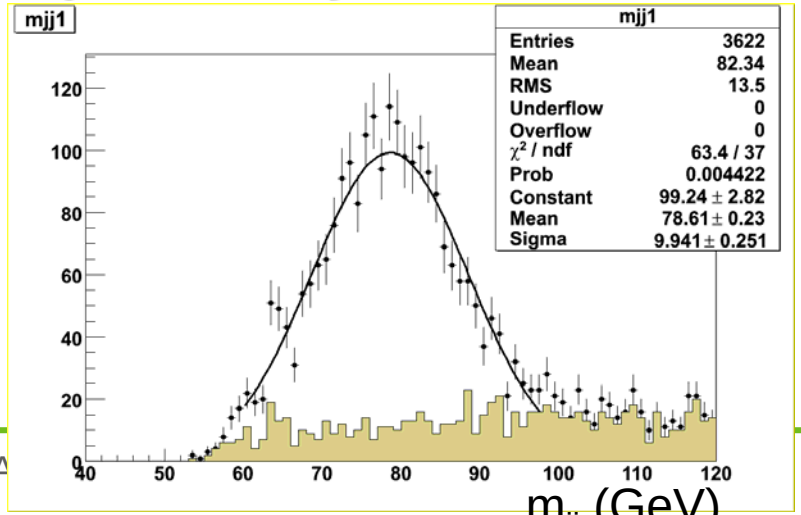


Missing E_T (GeV)

Can reconstruct:
- hadronic side only
- or both sides



P_T light jets (GeV)



m_{jj} (GeV)

ttbar → lνb jjb: event selection and reconstruction

- Event selection:
  - One and only one isolated e or μ with P_T > 20 GeV
  - Missing E_T > 20 GeV
  - At least 4 jets with P_T > $P_T$cut
    - Jets reconstructed with cone algorithm, size ΔR = 0.4
    - Possibility to use K_T algorithm also being studied
  - Among them 2 b-tagged jets

Usually use $P_T$cut = 40 GeV:
- good S/B
- lower combinatorics
- easier jet calibration

However also trying to go lower

- Hadronic W reconstruction:
  - For each jj pair, compute

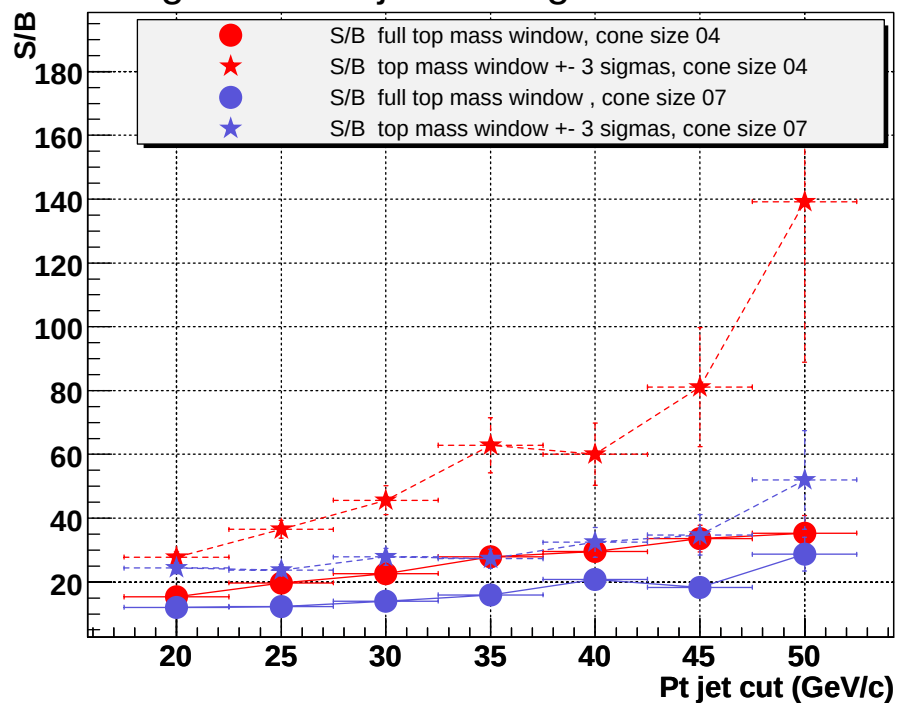
$$\chi^2 = \frac{\left(M_{jj}(\alpha_1,\alpha 2) - M_W\right)^2}{\Gamma_W^2} + \left(\frac{E_{j1}(1-\alpha_1)}{\sigma_{j1}}\right)^2 + \left(\frac{E_{j2}(1-\alpha_2)}{\sigma_{j2}}\right)^2$$

    - Choose the pair with minimum χ^2
    - Improves mass resolution
    - Reduces effect of light jets mis-calibration

« In-situ rescaling »

- b-jet choice:
  - The one maximizing P_T(jjb)

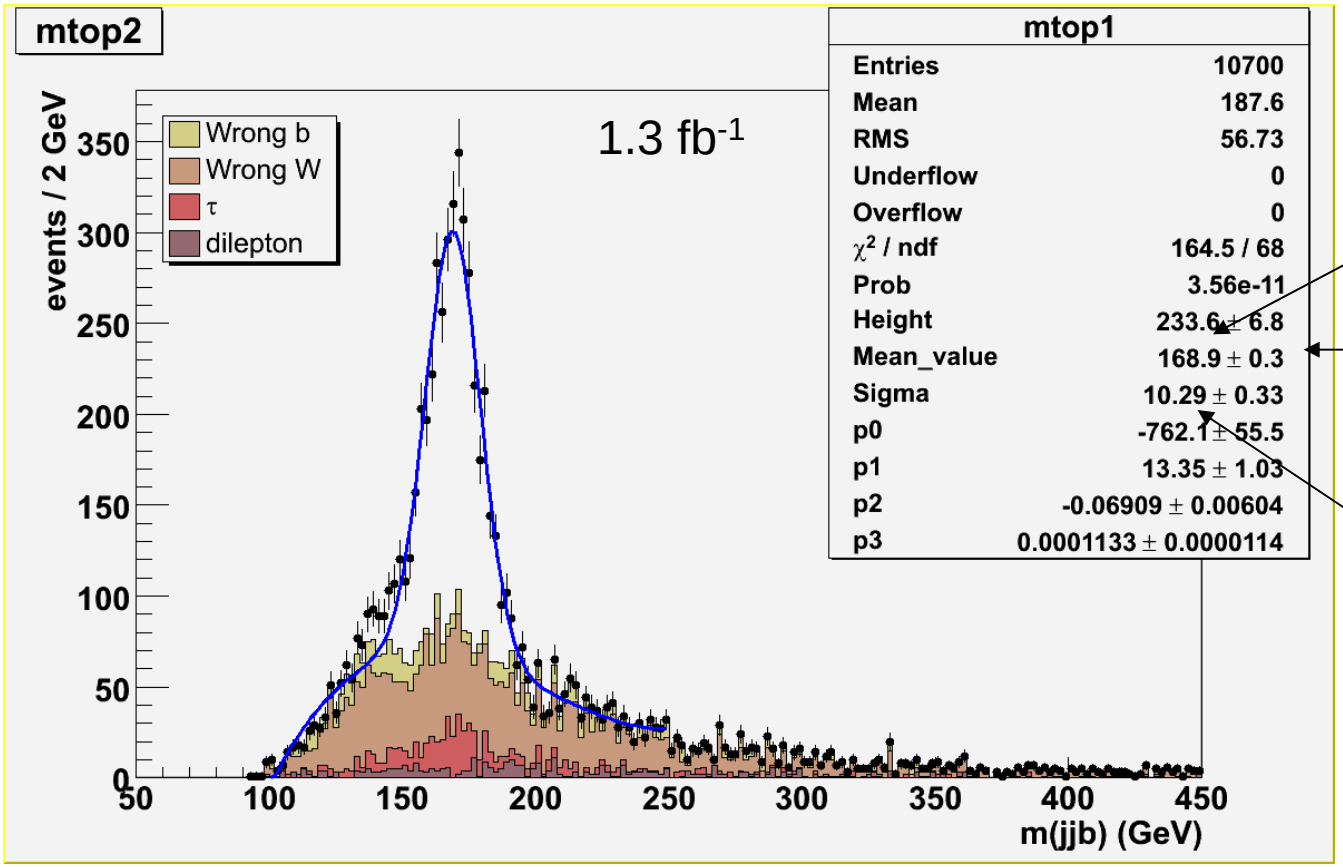
Signal / W+4 jets background



ttbar → lνb jjb: performances

~ 6500 events / 1 fb^{-1}

	Efficiency (%) (wrt semil. events)	W purity (%)	b purity (%)	top purity (%)
Full window	2.70 ± 0.05	56.0 ± 0.9	63.2 ± 0.9	40.5 ± 0.9
± 3 $\sigma(M_{top})$	1.82 ± 0.04	69.1 ± 0.8	75.8 ± 0.8	58.6 ± 0.8



Jets not calibrated

Statistical error small

Resolution ~ 11 GeV

ttbar → lνb jjb: systematic errors

Largely dominated by:

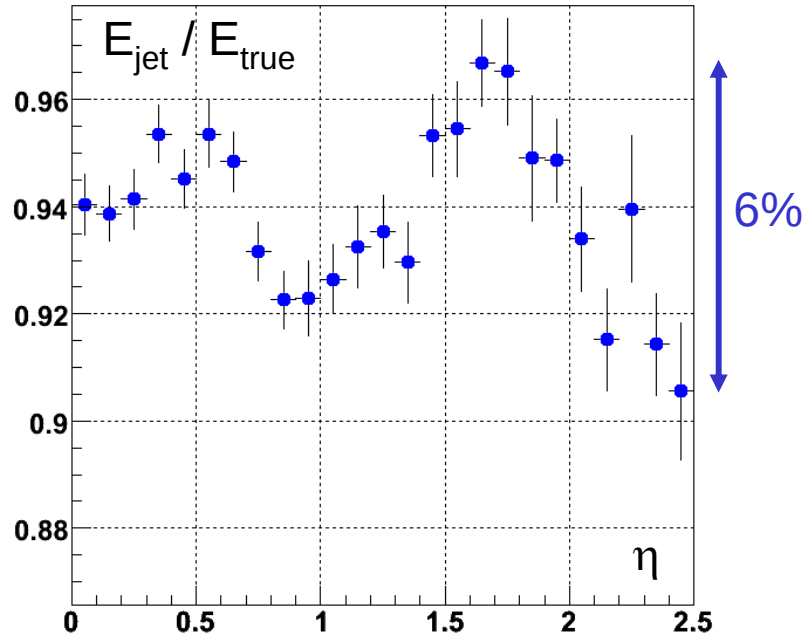
- JES:
  - Light jets: 0.2 GeV / % (would be 1 GeV without in-situ rescaling)
  - b-jets: 0.7 GeV / %, partly correlated with light jets + additional correction for b-jets (leptonic decays, fragmentation)

- Gluon ISR/FSR → determines the shape of the signal peak

Systematic	Δm (GeV)
b quark fragmentation	0.1
Combinatorial background	0.1
Background from other processes	0.1
Others: MC statistics, PDFs,…	??
Jet Energy Scale • b-jet • light jets	0.9 / % 0.7 / % 0.2 / %
ISR / FSR	~ 1

Jet Energy Scale: external inputs

- Di-jet events (already at 900 GeV) will be used to check detector uniformity



- Z + jet:
  - 160000 events (ee ou μμ) per day @ 10^{33} with $P_T(Z) > 20$ GeV
  - Requires veto on additional jet activity / cut on Δφ (Z-jet)
  - Difference between gluon (28%) and quark jets ?
  - Also Z + b jet (~ 6%): ~ 2000 events with 1 fb^{-1} after selection

More work in coming months
Comparison with in-situ W → jj

- γ + jet:
  - S/jj background ~ 30% (π^0)

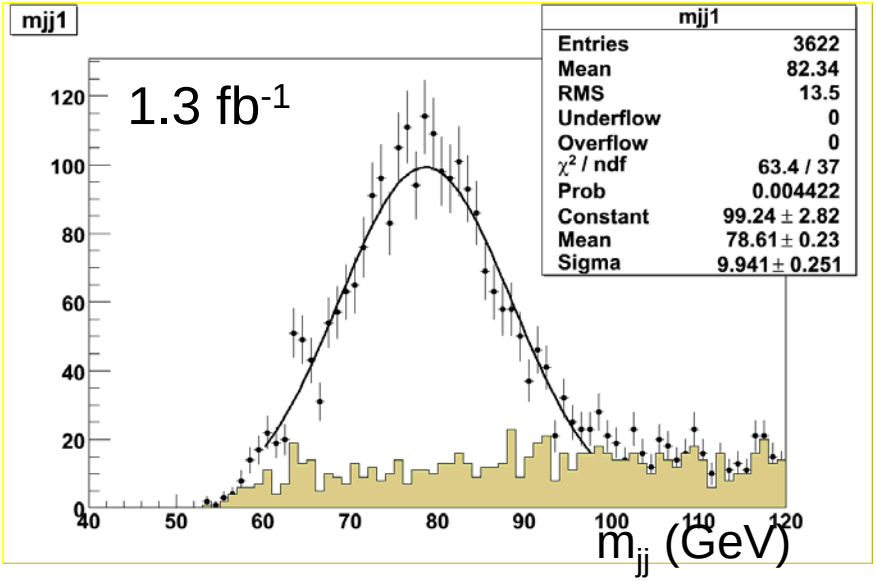
JES from ttbar → W → jj

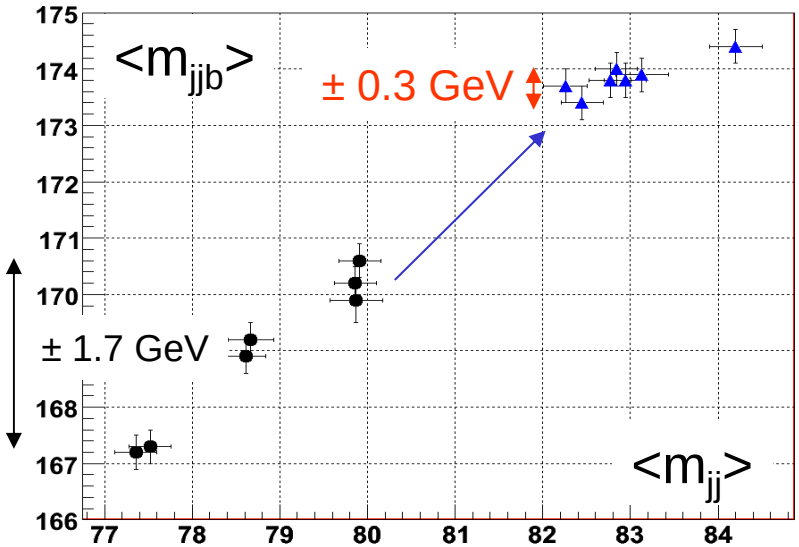
- 2000 - 3000 jj pairs selected / 1 fb^{-1}, purity ~ 80%

- Average JES can be measured with a 0.5% precision with 1fb^{-1}. Two methods exist:
  - An iterative method measuring $<m_{jj}>$ as a function of E_j
  - A template method

- Under resonable assumptions on initial calibration, calibrates top mass to ± 0.3 GeV

- With ~ 1fb^{-1}, can be used to retrieve JES as a function of E to ~ 2%

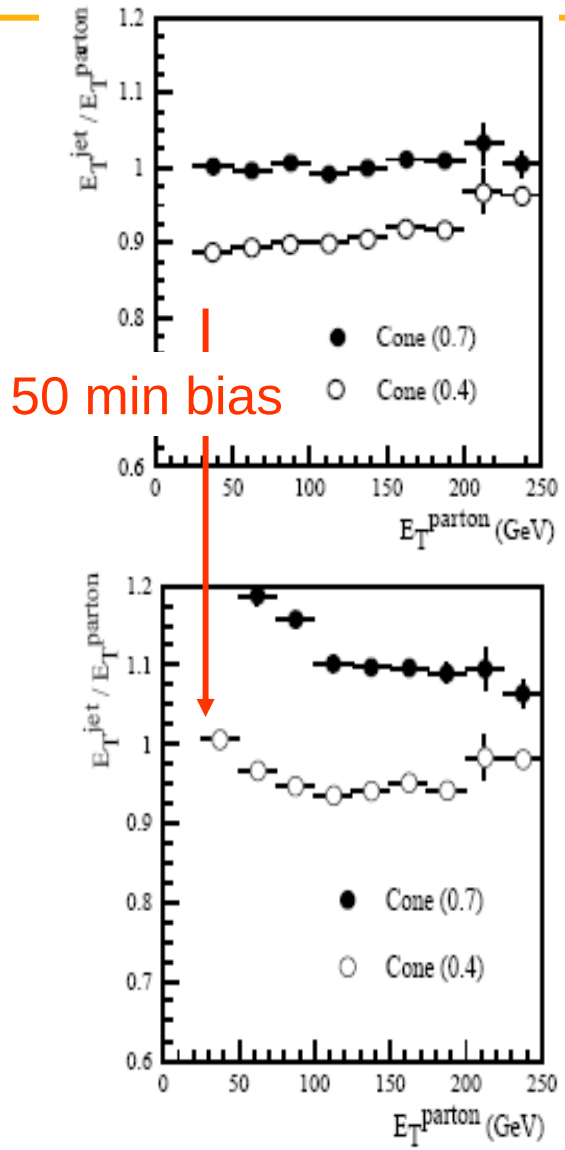




Underlying Event and Pileup

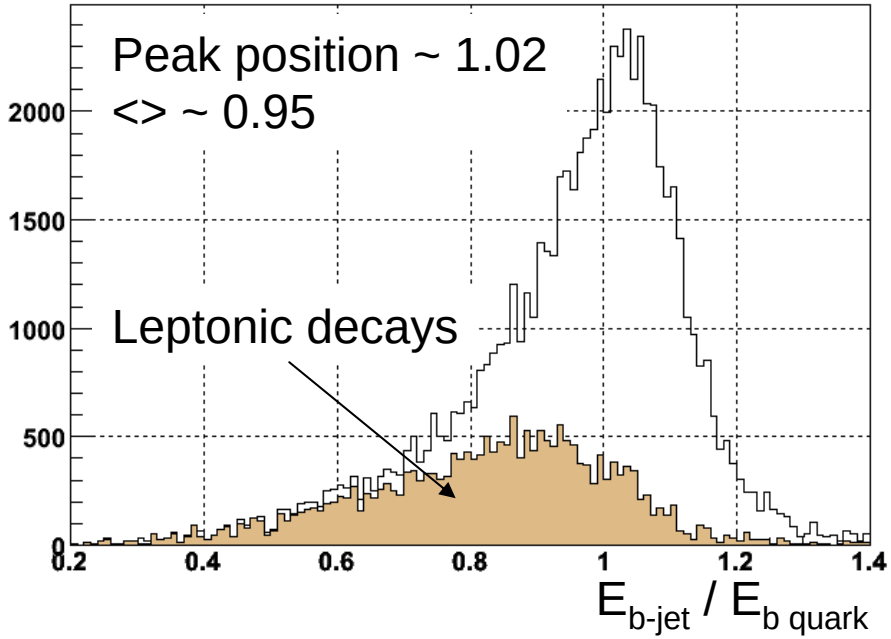
- UE is about 40 MeV / 0.1x0.1 tower ~ 2% jet energy
  - can probably be checked at low luminosity
  - Negligible effect on top mass if JES from in situ W → jj ?

- Contribution of pileup to jet energy was assessed at time of Physics TDR: ~ 0.1 – 0.2 % / min bias event
  - This number will be checked with current jet algorithms / cuts
  - Must figure out how to correct as a function of luminosity
  - May be automatically corrected by in situ W → jj on same set of events

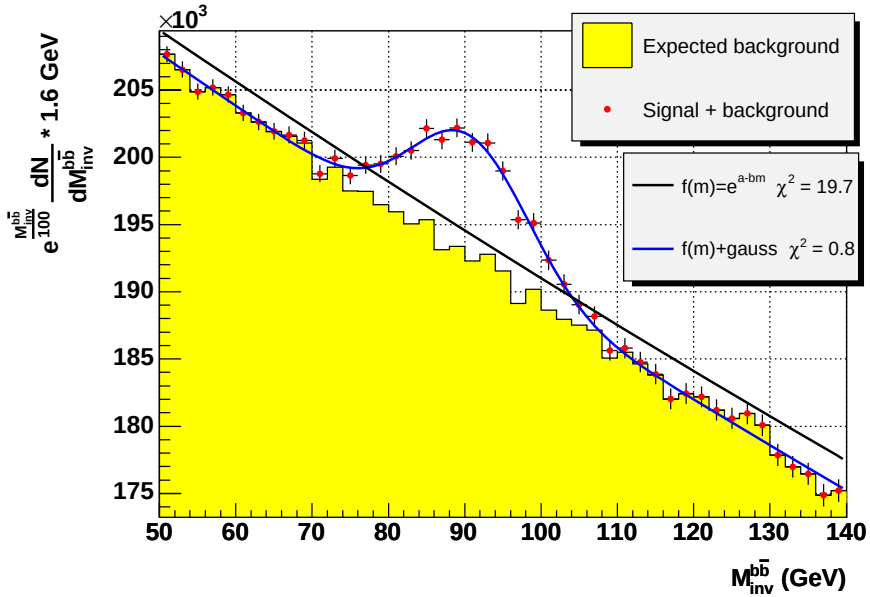


Some thoughts on b jet energy scale

- b jet energy scale ~ 0.95 light jet energy scale
  - Seems to be largely dominated by ν from leptonic decays
  - What's the uncertainty on this number ?
    - leptonic BR
    - E_ν
    - b-jet E spectrum vs light jet E spectrum
  - How well can we control it in the data ?



- Z + b-jets ?
- Z + jet → bb + jet ? (trigger ?)



1% on b-jet scale seems challenging

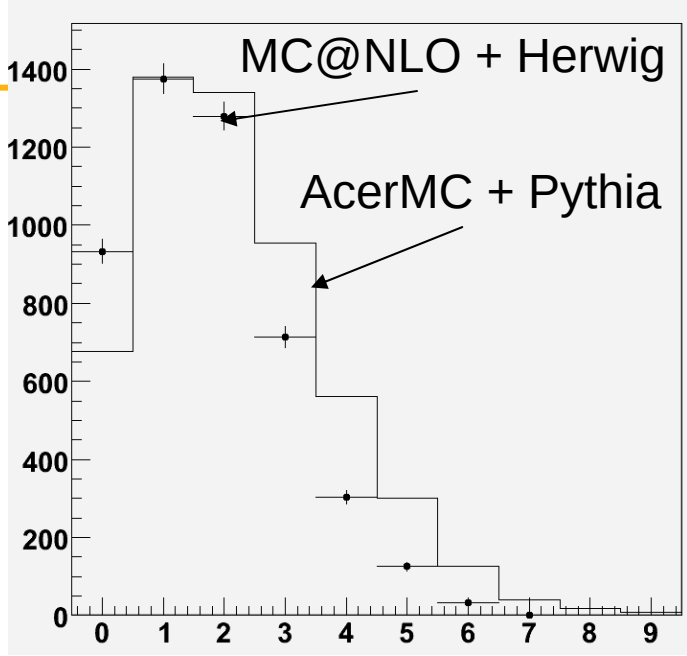
ISR/FSR

- Up to now, systematic error due to gluon ISR/FSR is estimated as 20% of the ISR/FSR on/off difference (PYTHIA)
  - The calibration has not been redone, so may be pessimistic
  - However doesn't estimate the effect of higher ISR/FSR

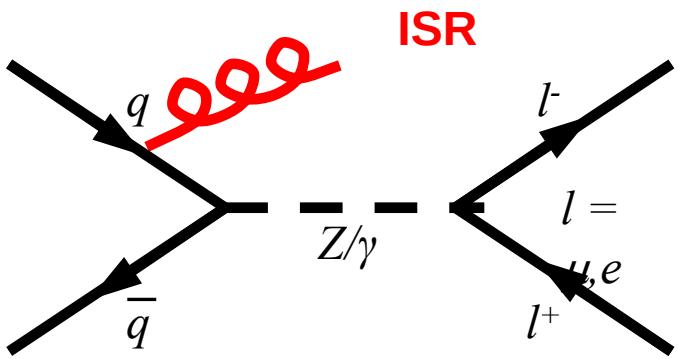
- Currently some work going on:
  - To estimate again the ISR/FSR error after recalibration
  - To find ways to measure it / tune the Monte-Carlo from the data

→ see B.Kersevan's talk

- ISR/FSR uncertainty may be reduced by cuts on event topology / quality of reconstruction, reconstruction in larger cone



Number of additional jets with P_T > 10 GeV



Measuring ISR using Drell-Yan events ?
But ttbar mainly by gg fusion

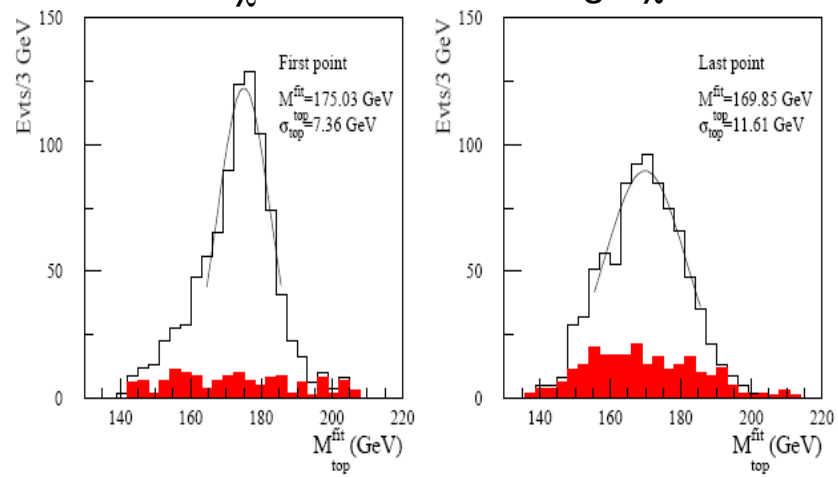
lνb jjb kinematic fit: method

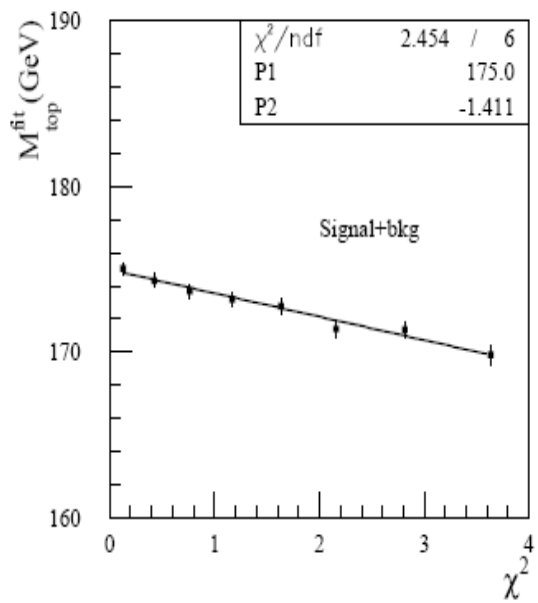
- Use information from both top decays
  - Hadronic side as before
  - Leptonic side: $p_z(\nu)$ from $m_{l\nu} = m_W$

- 2 χ^2 per event with energies and angles varying within their resolutions and constraints $m_{jj} = m_W$, $m_{jjb} = m_{l\nu b} = m_{top}^{fit}$
  - Choose smallest χ^2

- Events badly reconstructed (gluon radiation or leptonic b decay) → high χ^2 → take $m_{top} = m_{top}^{fit}(\chi^2 = 0)$

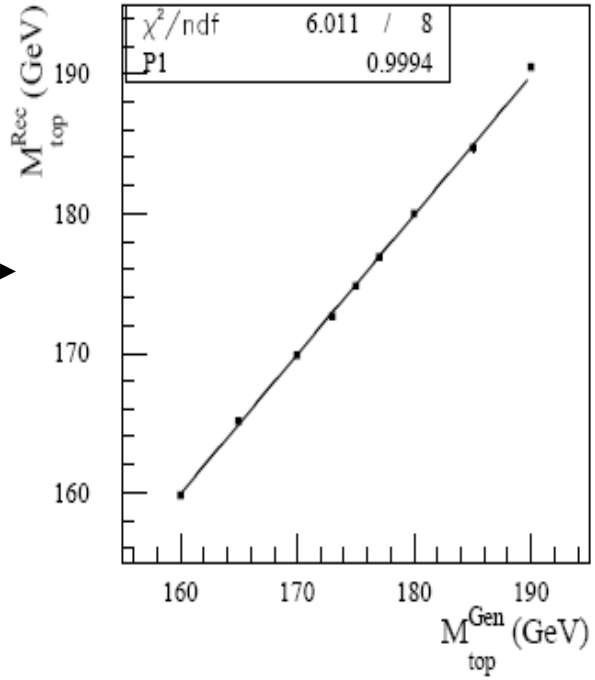
small χ^2 large χ^2





lνb jjb kinematic fit: results

- 2600 events @ 1 fb^{-1}
  → Δm(stat) = 0.4 GeV
- Good linearity of the method
- Reduced systematic errors:



Systematic	Δm (GeV)
JES	0.9 / %
b quark fragmentation	0.1
Combinatorial background	0.1
ISR / FSR	0.6

Reduced dependance on ISR/FSR

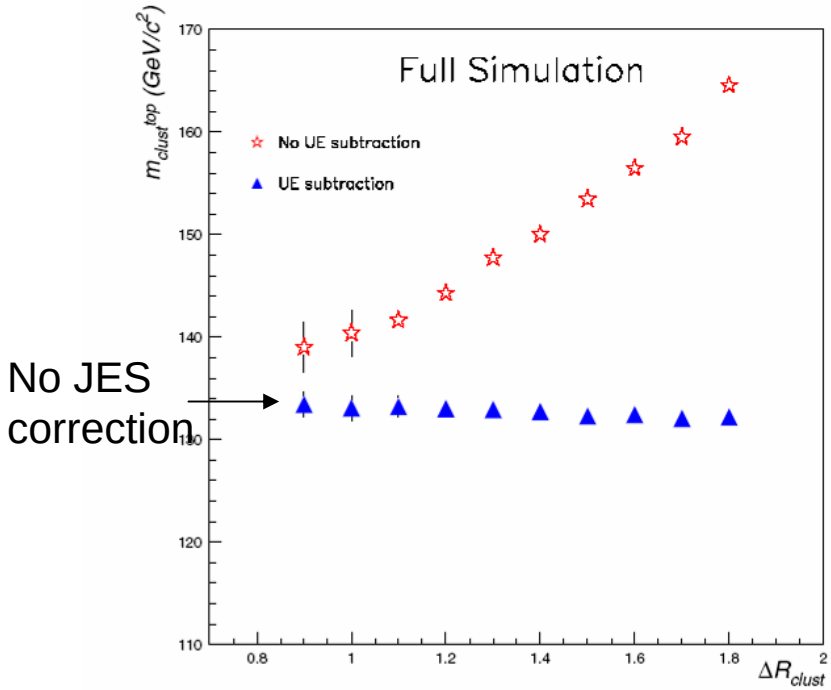
Using events with large P_T(top)

- P_T(top) > 200 GeV

- The 3 jets are in one hemisphere and tend to overlap → reconstruct hadronic top in a large calorimeter cluster ($0.9 < \Delta R < 1.8$)

- Requires subtraction of UE and pileup

- Performance:
  - ~ 360 events / 1 fb^{-1}
  - Systematic errors:
    - ISR/FSR ~ 0.2 GeV
    - UE ± 10% → 1.3 GeV
    - Pileup ?



No JES correction

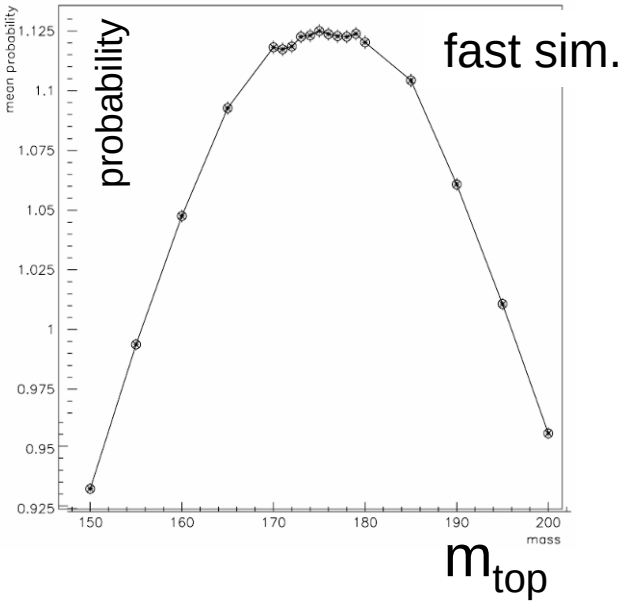
May be useful to control our knowledge of UE / pileup

Complementary channels

- Fully hadronic ttbar → jjb jjb
  - Huge QCD background → need tight cuts (P_T(tops)) → small efficiency
  - Trigger ?

- Di-leptonic channel ttbar → lνb lνb
  - Small background but small BR
  - No top invariant mass reconstruction → compute a likelihood as a function of m_{top}
  - Less systematics due to ISR/FSR (< 1 GeV ?)
  - Larger systematics due to PDFs (> 1 GeV ?)

New effort in the coming months to assess performances / systematics

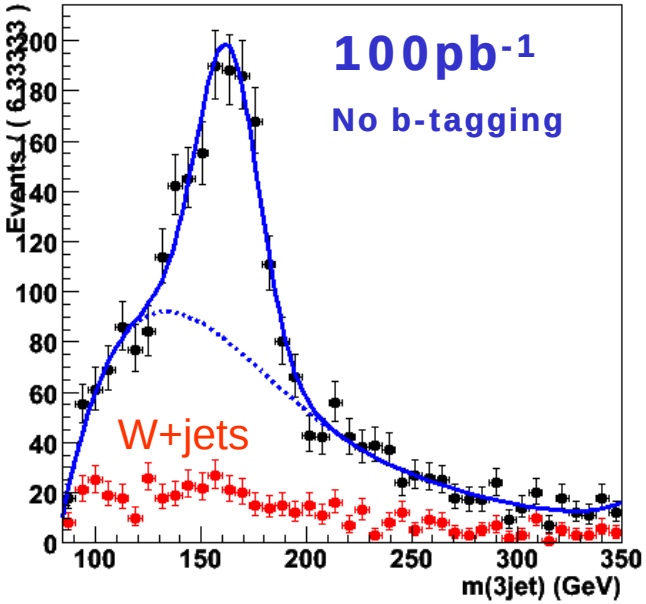


Top observation with early data

- Goal:
  - Assume lifetime b-tagging not fully efficient (mis-alignment)
  - Mass peak with 100 pb^{-1} (10 days @ 10^{32}) ?

- Several methods:
  - No b-tagging at all
  - Only 1 b-tagged jet

  More W+jets bck
  QCD multijet to be checked
  - b-tagging using soft muons
    - Low BR



- Top with early data may be useful:
  - Observation of a large σ SM signal
  - First check of JES
  - Measurement of b-tagging efficiency

Conclusions

- The LHC will produce 80000 ttbar pairs per day @ 10^{33} cm^{-2} s^{-1}
- Several methods have been investigated to measure m_{top}

- Main systematic errors are
  - Light JES: very well controlled with in situ W → jj
  - b JES / light JES: requires further work
    - What's the uncertainty on this ratio ?
    - How to measure it in the data ?
    - Can we use Z + b jets ?
  - Knowledge of the signal shape (gluon ISR / FSR)
    - ~ 1 GeV
    - Large statistics will allow for methods with reduced sensitivity (cut on χ^2, …)
    - How to best measure it in the data ?

- In most cases, a lot of work will be redone in the coming months:
  - Non perfect detector
  - Trigger issues
  - Review the methods and the systematics