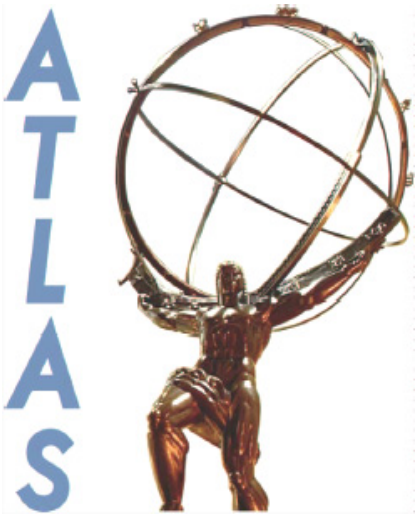
Physics reach of ATLAS during the first LHC run

Jörn Grosse-Knetter, University of Bonn
for the ATLAS Collaboration

- Understanding the first data: detector calibration
- Physics potential of the first year (few examples)
- Physics consequences of the staged detector



ATLAS Detector Layout

Inner Detector (ID) tracker:
- Si pixel and strip + transition rad. tracker
- $\sigma(d_0) = 15\mu m@20GeV$
- $\sigma/p_T \approx 0.05\% p_T \oplus 1\%$

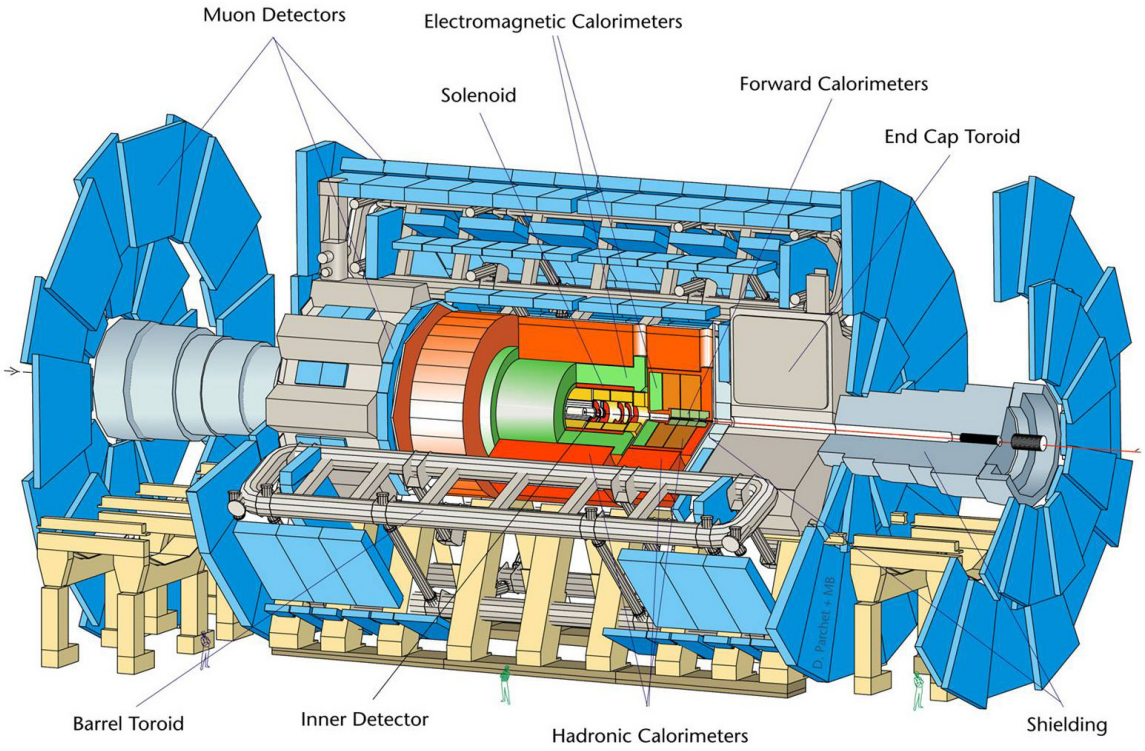
Calorimeter
- Liquid Ar EM Cal, Tile Had.Cal
- EM: $\sigma_E/E = 10\%/\sqrt{E} \oplus 0.7\%$
- Had: $\sigma_E/E = 50\%/\sqrt{E} \oplus 3\%$

Muon spectrometer
- Drift tubes, cathode strips: precision tracking +
- RPC, TGC: triggering
- $\sigma/p_T \approx 2\text{-}7\%$

Magnets
- Solenoid (ID) $\rightarrow$ 2T
- Air toroids (muon) $\rightarrow$ 4T

Full coverage for $|\eta|<2.5$

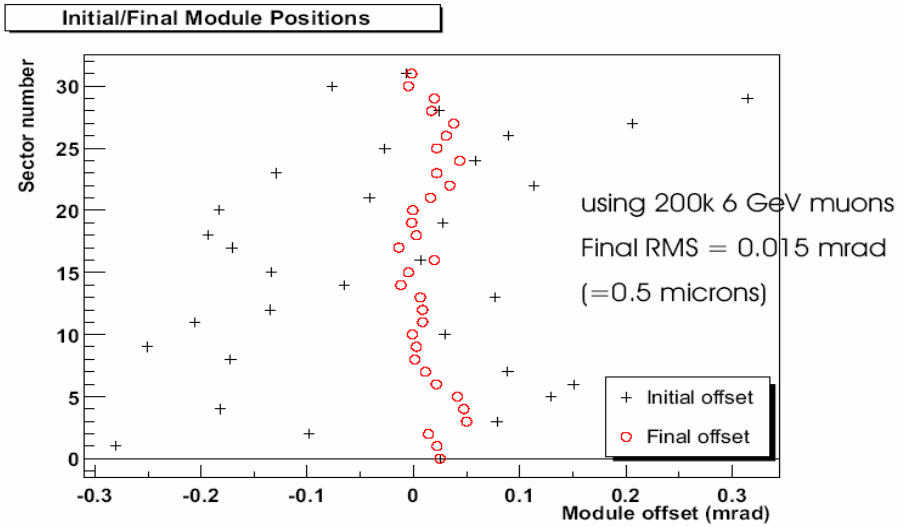
- LHC: pp-collisions as $\sqrt{s}=14TeV$
- First LHC beam: spring 2007
- First collisions: summer 2007
- Initial peak lumi. ~10^{33} $cm^{-2}s^{-1}$
  integrated: $10fb^{-1}$ per year

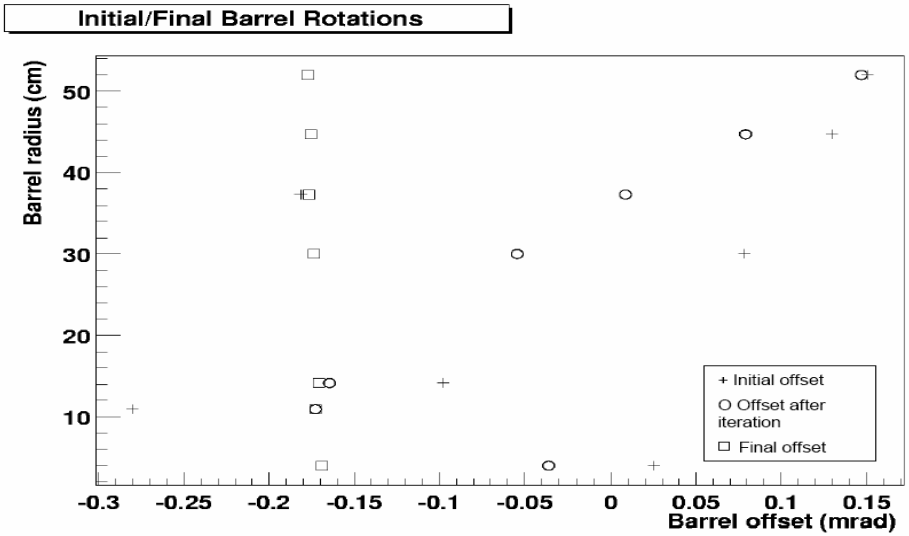


First data – ID calibration

Inner Detector alignment and calibration

- Initial metrology & survey as starting point
- Use single μ and low-p_T tracks for offline alignment (+complem. laser monitoring system)
- Can get stat. error of indiv. module position to *O*(1μm) in one day!
- e± in EMCal → *E/p*, used to remove sagitta distortions
- Z,J/ψ → μμ for mass calibration → measure B-field to ~0.1% locally



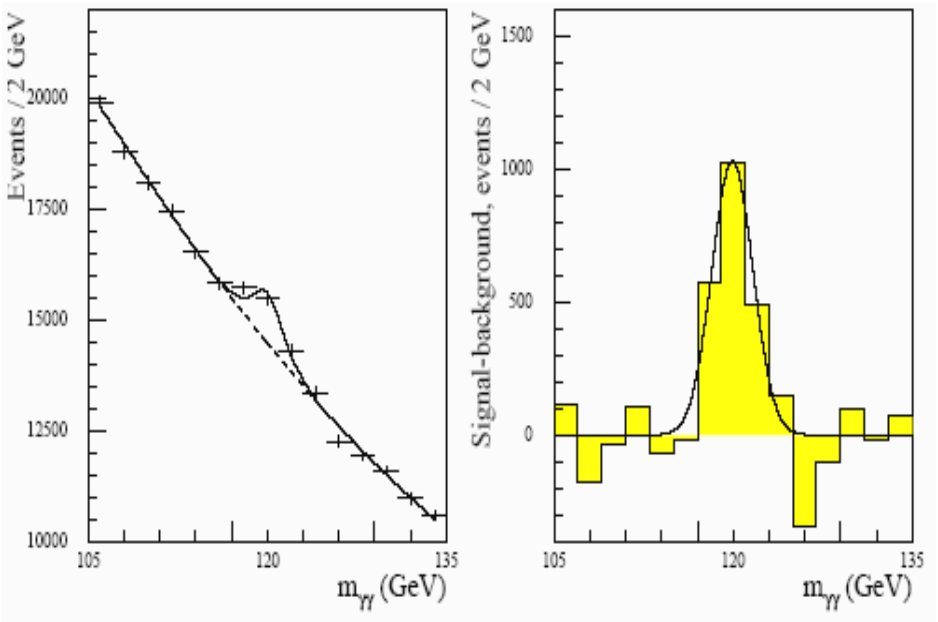


First data – EM Cal calibration

Good resolution needed for e.g. $H \rightarrow \gamma\gamma$:

$\sigma_E/E = 10\%/\sqrt{E} \oplus$ const.

need const. = 0.7% for $\Delta m_H \sim 1\%$



Calibrate of EM CAL

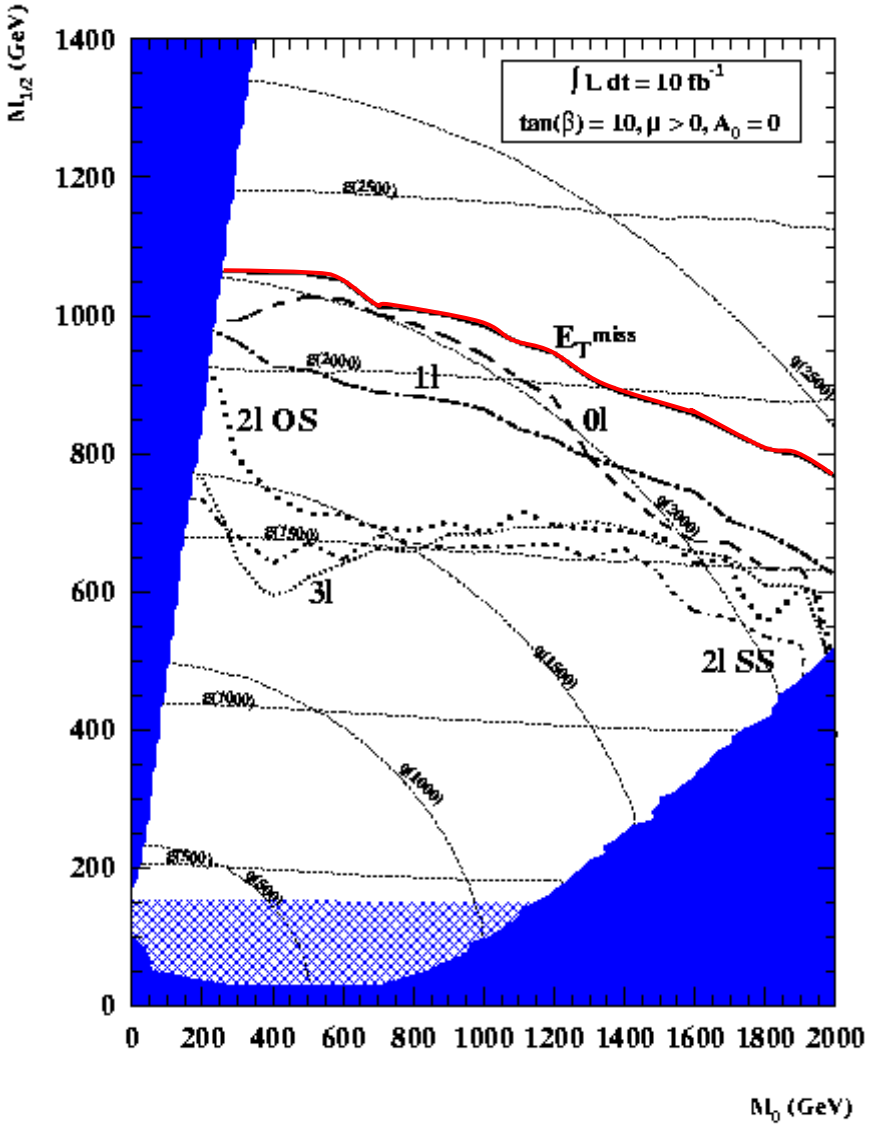
- By construction: individual cells uniform to ~0.5% testbeam → over $\Delta\eta \times \Delta\varphi = 0.2 \times 0.4$ region: const<0.5%
- Check local non-uniformity with cosmics
- $Z \rightarrow e^+e^-$ (at 1Hz, no backgrd): mass-constraint → even out long-range non-uniformities → const<0.4% in few days
- $0.5\% \oplus 0.4\% \leq 0.7\%$ → goal achieved

First physics: SUSY

Good candidate for early discovery @ LHC:

- ~100 events per day (for squark/gluino masses of ~1TeV)
- discovery possible with only 1 fb^{-1}

- Multiple signatures on most of parameter space
- E_T^{miss} - dominant signature $\rightarrow$ need full calorimeter coverage



First physics: light SM Higgs

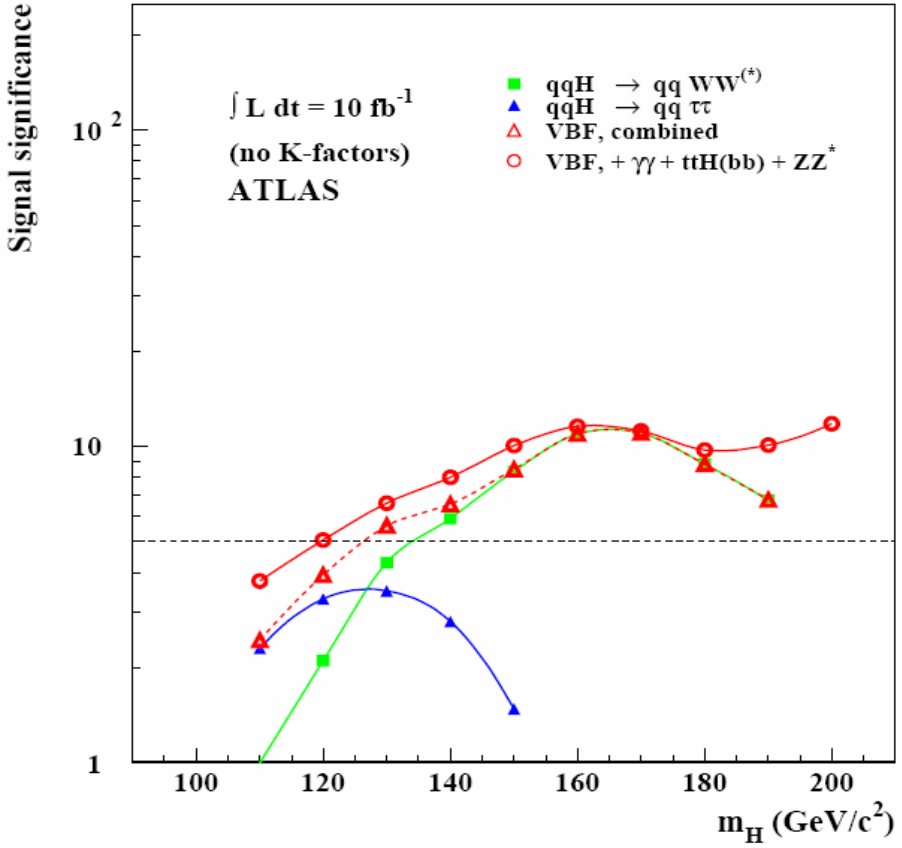
ATLAS with 10fb^{-1}:

5σ significance for 120GeV ≤ m_H ≤ 200GeV

Important channels:

- $H \rightarrow \gamma\gamma$
- ttH, $H \rightarrow bb$
- qqH, $H \rightarrow \tau\tau$
- qqH, $H \rightarrow WW^{(*)}$
- $H \rightarrow ZZ^{(*)}$, $Z \rightarrow 4\ell$

Relies on very good detector & background understanding



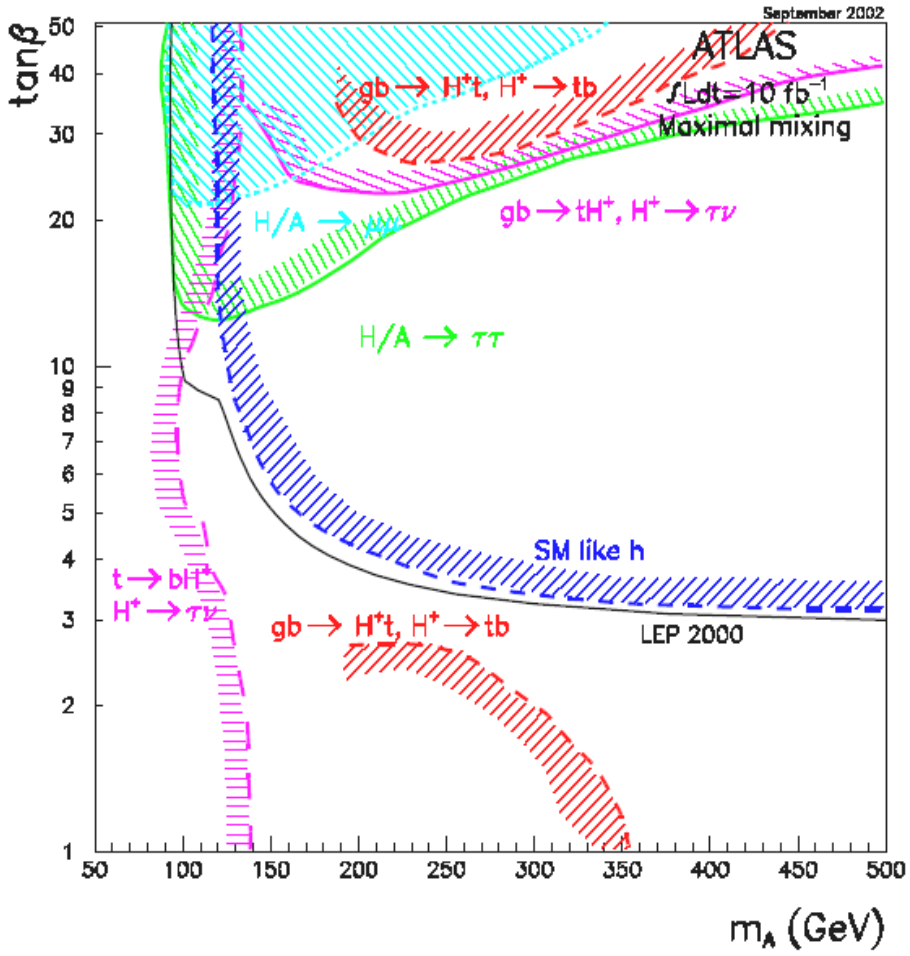
First physics: MSSM Higgs

Search for h, H, A, $H^{\pm}$

- $h \rightarrow \gamma\gamma$, $tth \rightarrow ttbb$ as in Standard Model
- $A/H \rightarrow \tau\tau, \mu\mu$
- $H^{\pm} \rightarrow \tau\nu, tb$

Can explore large part of parameter space with 10 fb^{-1}

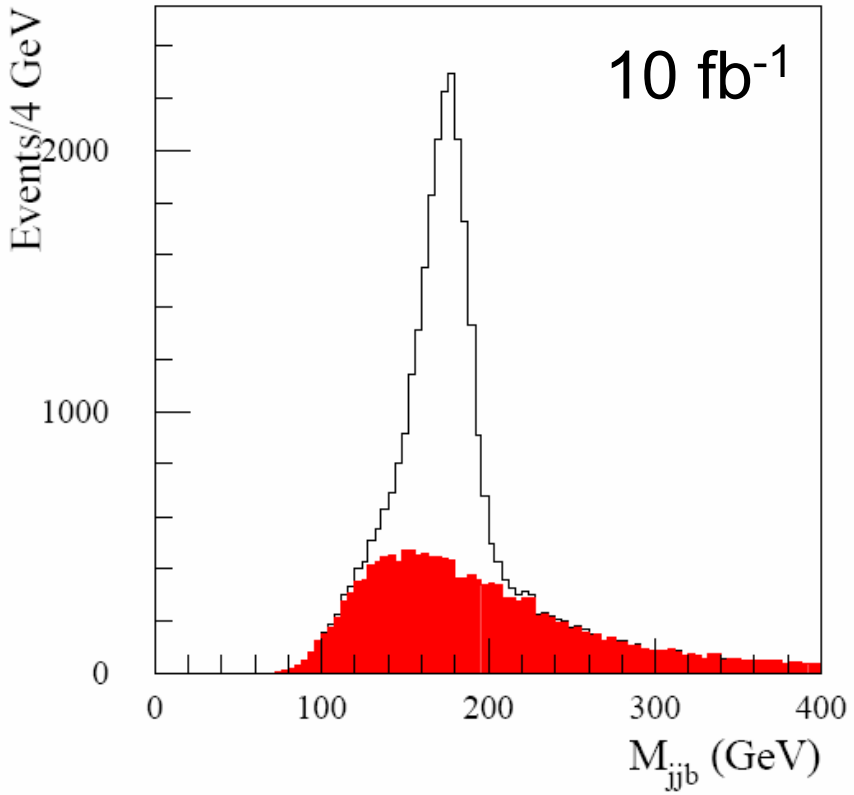
10 fb^{-1}, maximal mixing



First physics: electroweak

- Benefit from reduced pile-up effects during low-lumi phase
- W mass:
  - Reconstruct transverse mass
  - 60M *identified* W's per year
  - Error dominated by systematics → needs excellent lepton E,p scale calibration
  - Can achieve $\Delta m_W < 20$MeV (15MeV from lepton scale)
- Top mass:
  - 8M tt per year
  - Limited by jet energy calib. ⊕ FSR
  - Can achieve $\Delta m_t \approx 1$GeV
- …+ many more

Reconstruct top-mass from decay $tt \rightarrow bWbW \rightarrow b\ell\nu bqq$



Staged installation

Staged components:

- One Pixel layer
- Transition rad. tracker outer end-caps
- Cryostat gap scintillator
- Part of Muon drift tubes and half cathode strip layers
- Part of forward shielding
- Part of LAr read-out
- Large part of trigger/DAQ CPUs

Guiding physics principles:

- All sub-detectors needed already in 1st year
- Physics potential decreases fast with decreasing η coverage (e.g. $H \rightarrow \gamma\gamma$ significance decreases linearly)
- Sacrifice part of radial redundancy: less crucial at initial lumi. & technical and schedule constraints

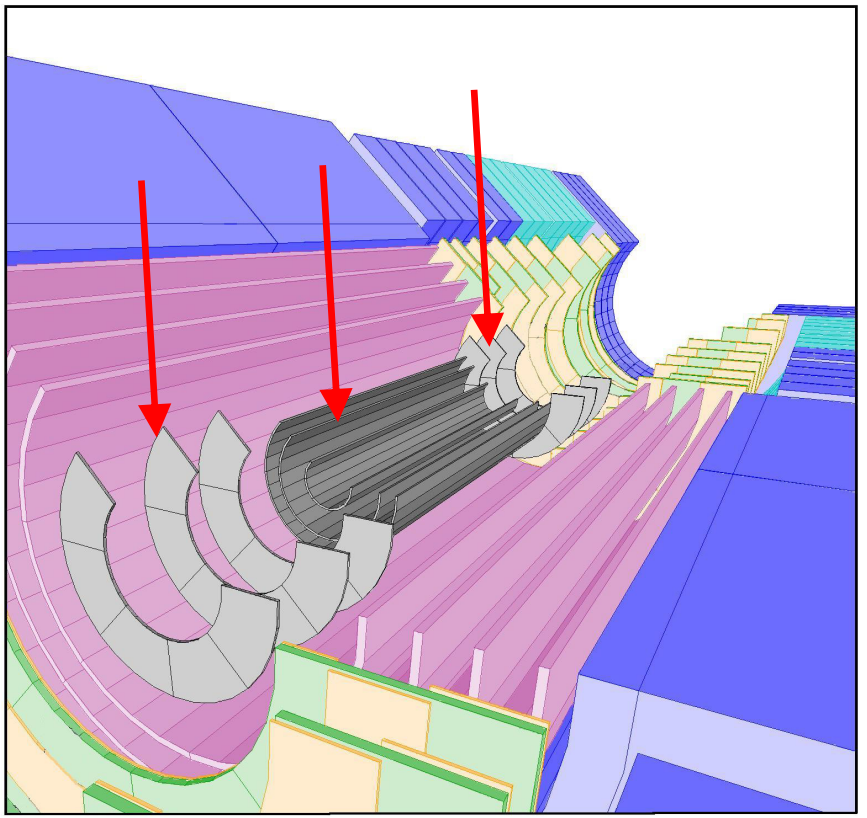
Initial layout: pixel

1 barrel layer and 1 disk on either side missing

Degrades b-tagging

Affects e.g. ttH→ℓνb jjb bb

- analysis requires 4 identified b-jets
- main background: tt+jets (½ true ttbb + ½ mistagged ttjj)
- mistagged ttjj increases by ~20%
- ⇒ decrease in $S/\sqrt{B} \approx 8\%$
- ⇒ need 15% more lumi



Initial layout: muon

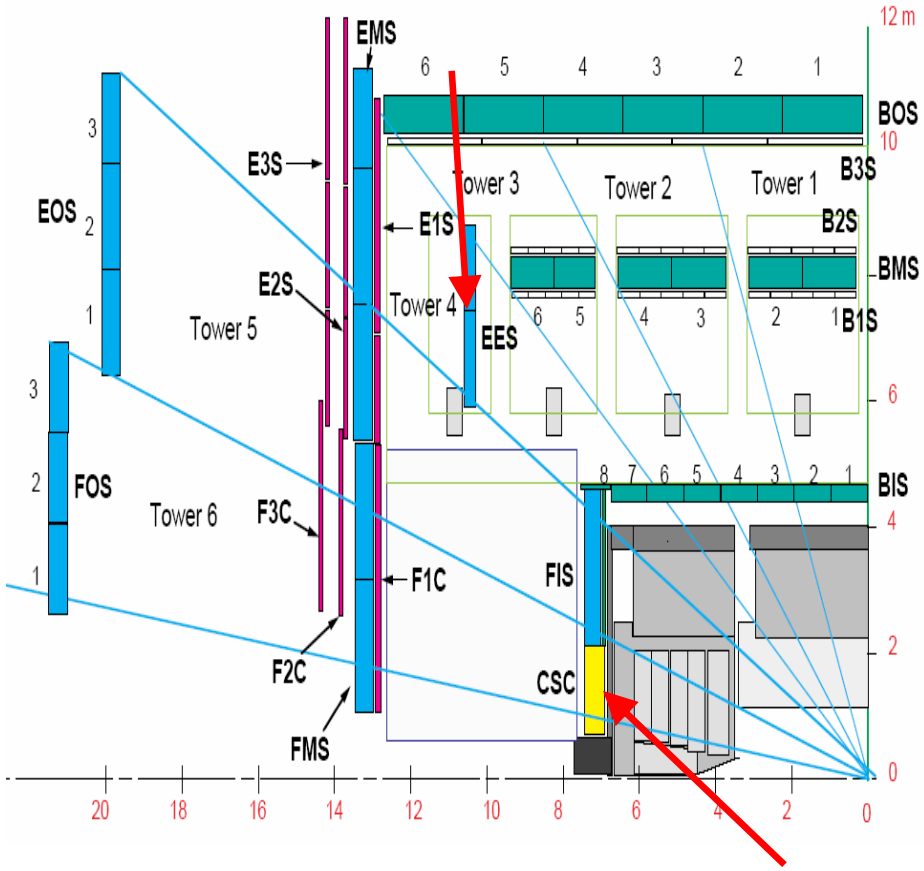
Forward drift tubes partial, ½ cathode strips missing

affects high momentum μ e.g.:
A/H→μμ with $m_{A,H}$ >200GeV
mass resolution driven by Muon Spectrometer:

- $\sigma_{m\mu\mu}$ =10.8 GeV with μ-Spectr.+Inner Tracker
- $\sigma_{m\mu\mu}$ =12 GeV with μ - Spectr. only

(for m_H =300 GeV)

- ⇒ decrease in S/√B 5%
- ⇒ need 10% more lumi



Initial layout: trigger,DAQ

Deferrals to high-level trigger/DAQ processor $\Rightarrow$ need to limit Level1 output rate:

- Level1 design output rate: 75kHz $\rightarrow$ reduced to 25kHz
- increased trigger thresholds on multijets, E_T^{miss}, p_T(e, μ), etc – affects e.g.:
  - ttH$\rightarrow \ell\nu$b jjb bb – higher cut on ℓ energy
  - H/A$\rightarrow\tau\tau$ – higher cut on τ
  - Jet triggers: reduce overlap with Tevatron

- No room left for safety-factor
- Under current backgrd. assumptions: effect on physics notable, but for most channels modest and acceptable
- but: B-physics strongly reduced, recover parts by introducing a di-muon trigger and by exploiting the low-lumi. part of a LHC-fill

Summary

- First pre-collision and collision data needed to calibrate and align detector
  - Large statistics from tracks/ known SM-processes $\rightarrow$ fast calibration
- Discovery of SUSY and SM Higgs possible in first year
- Performance degradation due to staged detector:
  - Most analyses $<O(10\%)$ loss in $S/\sqrt{B}$
  - Most serious loss: B-physics largely reduced