Freiburg Physics

ATLAS First Year Operations Experience: Muons

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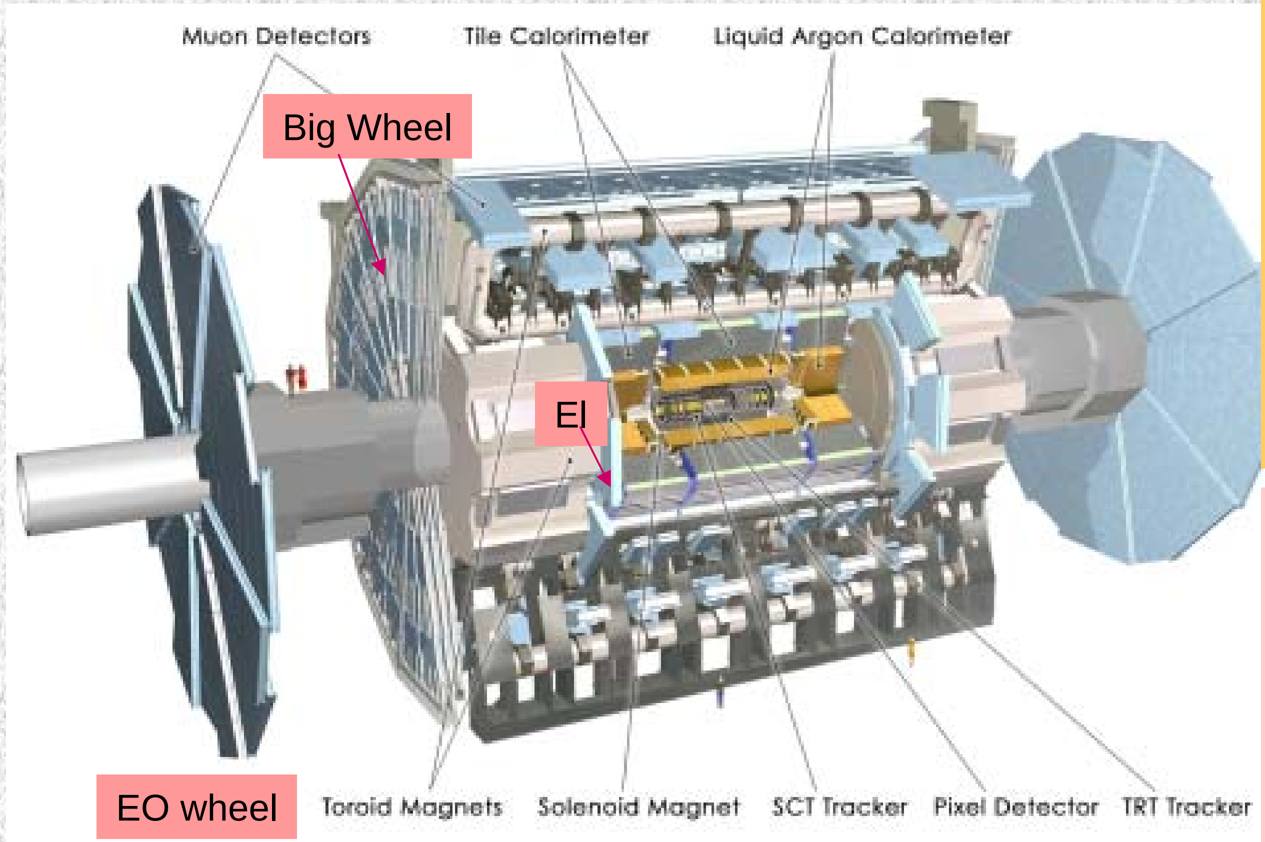
- Short System Overview.
- Detector Status – Failures. Lessons learned.
- Detector Efficiency with respect to data taking. Shift/Human Operations.
- Background studies.
- Muon Upgrade plans.

The ATLAS Muon System

Standalone muon spectrometer (η < 2.7), 3 layers gas based muon chambers, muon trigger and muon momentum determination $\Delta p/p < 10\%$ up to 1 TeV



detector technologies:

Precision tracking

- Monitored Drift Tubes (MDTs)
- Cathode Strip Chambers (CSCs)

Muon trigger and 2nd coordinate measurement

- Resistive Plate Chambers (RPCs)
- Thin Gap Chambers (TGCs)

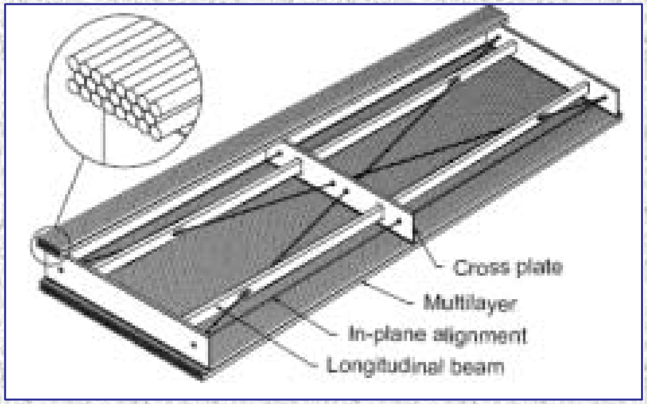
Geometry:

- Muon chambers form 3 layers: Inner, Middle, Outer
- Barrel layers are cylinder shells: BI (MDT), BM (MDT+RPC), BO (MDT+RPC)
- Endcap layers have the form of wheels:
- EI (MDT/CSC +TGC), Big Wheel (MDT, TGC), EO (MDT)

3 Air Core Toroid Magnets, 8 coils each:

22 kA, peak field strength up to 4T

Muon Precision Chambers

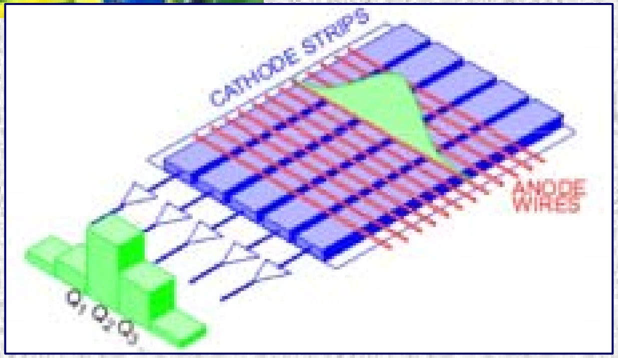


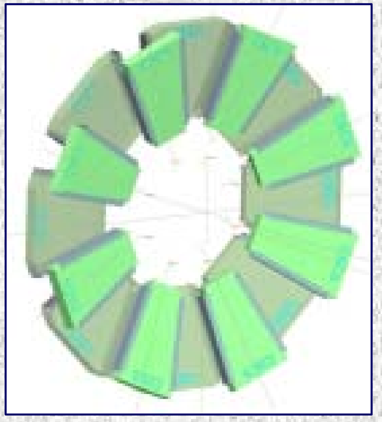
MDTs:

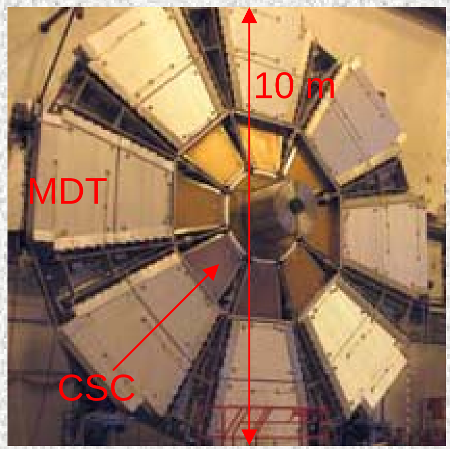
- 380k 3cm Ø aluminum drift tubes, assembled into 1150 chambers
- Ar:CO_2 = 93:7 gas mixture @ 3 bar, $2\cdot10^4$ gas gain
- Tube resolution < 80 μm, track resolution per stations <= 50μm
- Optical alignment system: in situ monitoring of chamber deformation/ movements

CSCs: 32 Multi-wire proportional chambers

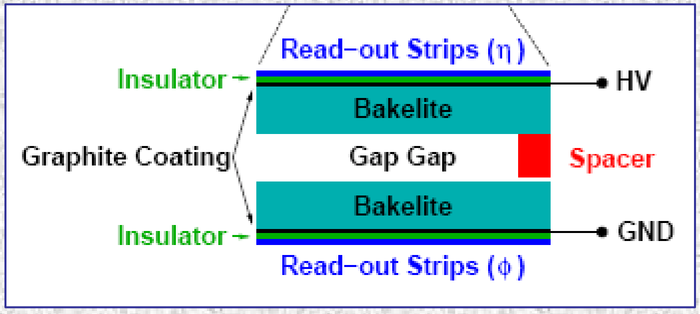
- wires in radial direction, segmented cathode, perpendicular strips
- Ar:CO_2 = 80:20 gas mixture @ 1 bar
- Position reconstruction from cathode charge distribution, resolution/ plane: 60 μm

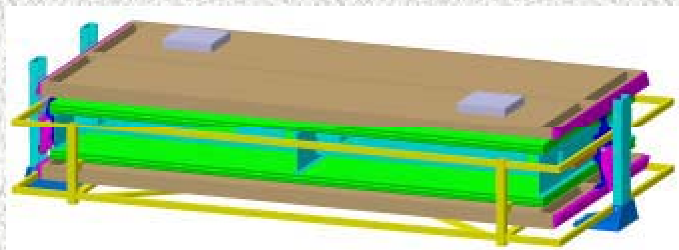






Muon Trigger Chambers



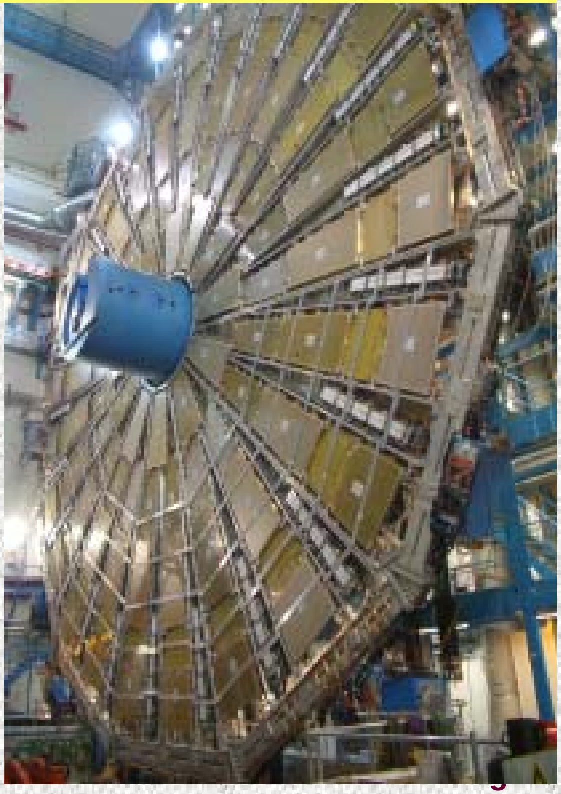


RPCs:

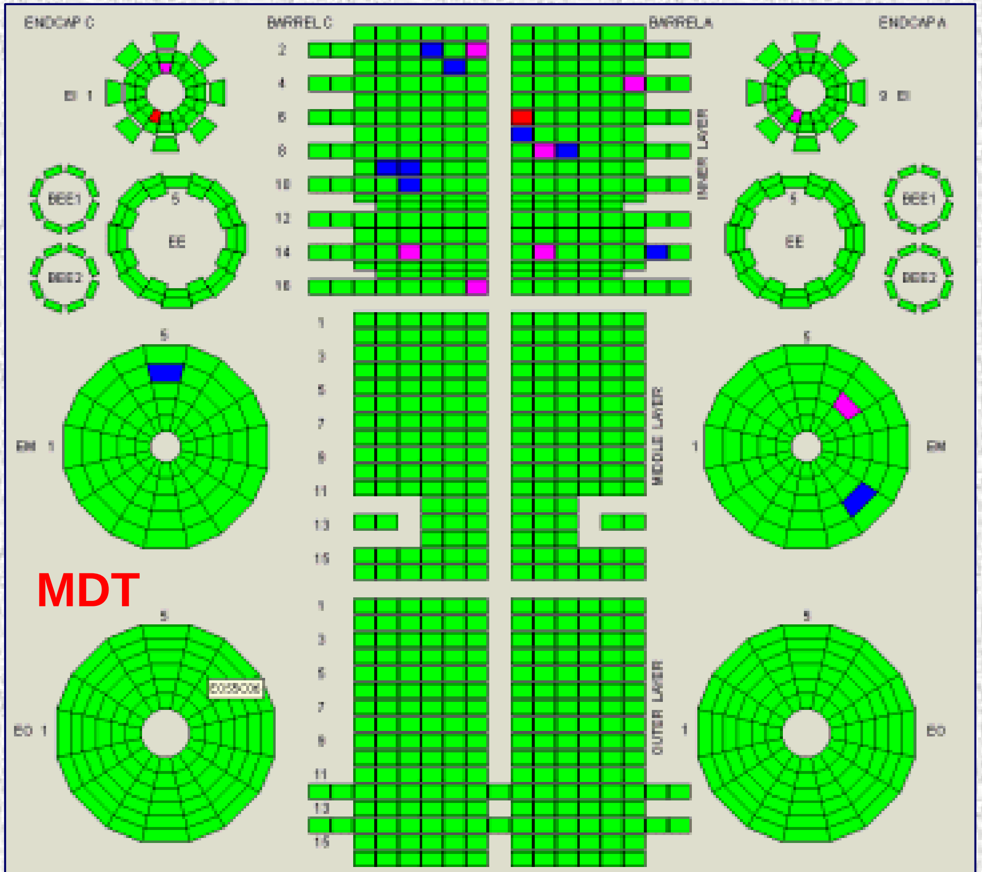
- Double layers of gas gaps, built from Bakelite plates separated by 2 mm spacer
- Proportional mode operations, gas Freon:i-butane:SF_6 = 94.7:5:0.3
- Perpendicular readout strips on both sides of gas gaps
- Fast readout, intrinsic jitter < 1.5 ns, efficiency > 98.5%/layer
- RPC planes form a mechanical unit with MDT chambers

TGCs:

- Multiwire proportional chambers with wire-to-wire distance < wire – cathode distance
- Operated with n-pentane : CO_2 mixture in quasi-saturated mode
- Gain $3 \cdot 10^5$
- Readout both of wires and cathode strips
- TGC doublets and triplets assembled into sectors, sectors into wheels



Detector Status: CSC + MDT



- Chamber readout problem
- HV problem (single tube layer disconn.)
- Single frontend card readout problem

+ 349 single dead tubes
+ ~250 tubes with excessive noise

- Non-recoverable channels are concentrated on Barrel Inner Layer due to <u>no access in most cases</u> to on-chamber electronics and HV Faraday cage
- **Lesson learned: Careful planning of maintenance access needed !**
- HV and single FE card problems do not degrade reconstruction efficiency since only single multilayers affected !
- So far no breakdown due to radiation effects …

MDT - Current dead channel (drift tube) fraction:

- 0.19% non-recoverable (broken wire, tube damage during installation, …)
- 0.30% recovery expected during end of year shutdown

Missing 52 MDT EE chambers to be installed in 2012 shutdown

CSC – Current dead layers: 2/192 (1% due to broken wires)

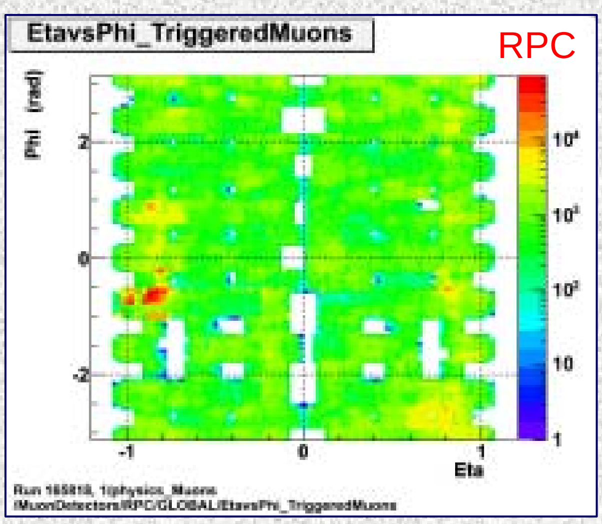
Detector Status: RPC + TGC

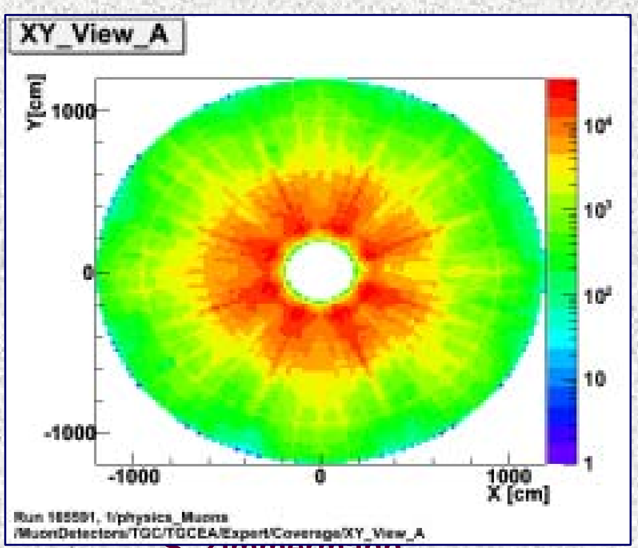
RPC Gas gaps – dead fraction:

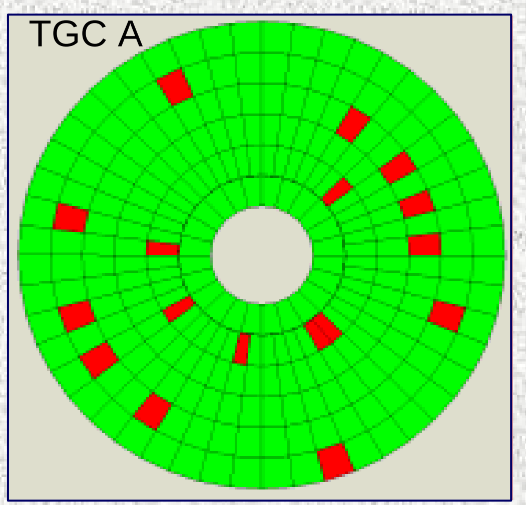
- 36 gaps (out of 3592) disconnected from HV due to broken gas inlets – **mechanical design weakness, not robust enough for Atlas cavern environment** -- Mostly on BOL chambers, not accessible
- 23 gaps disconnected from HV due to excessive gap current
- No degradation in trigger coverage

TGC problematic chambers:

- ~45 out of 3588 chambers with HV problems – dominantly one production batch which has not undergone irradiation tests … -- currently considering rebuilding these chambers …
- LV and thresholds 100% operational







all layers (M1,2,3)

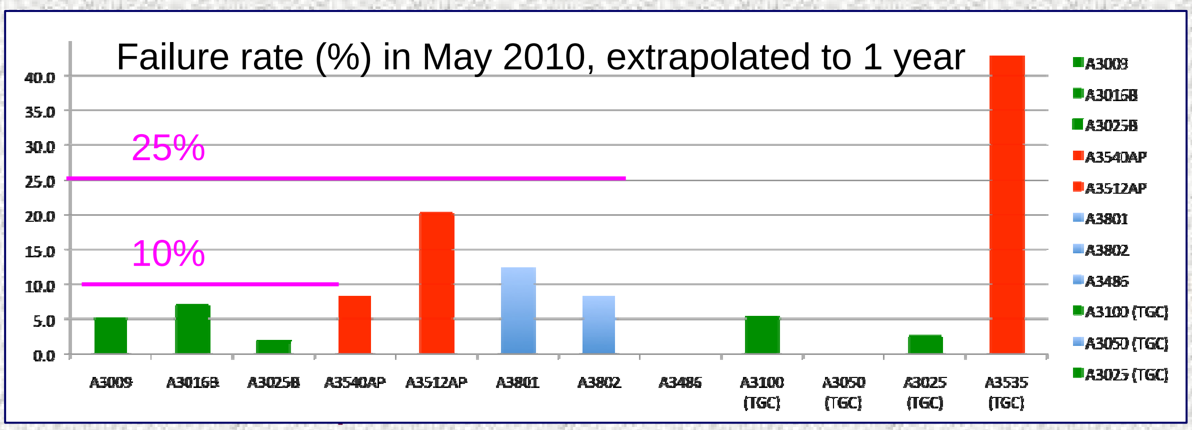
First year's problems …

Bad production of RPC HV connectors:

- Systematic electrical break down (discharges) of rack side connectors, frequency increasing with time …
- Each connector supplies HV to 16 RPC gas gaps
- Affected connectors all from same production batch, unknown change of mould injection procedure by manufacturer after validation and 'good' first series …
- Replacement of all (~3700) connectors scheduled for this Xmas shutdown !

Break down and instabilities of LV and HV power supply boards:

- High failure rate for Muon HV and LV modules during first months of data taking
- TGC HV board type in particular affected: Traced to under-dimensioned voltage regulator and overheating → monitoring of detector infrastructure crucial !
- Rate has considerably gone down, but still need to replace a boards every ~ 2 weeks: Ease of access, consider from the start work in magnetic field etc.

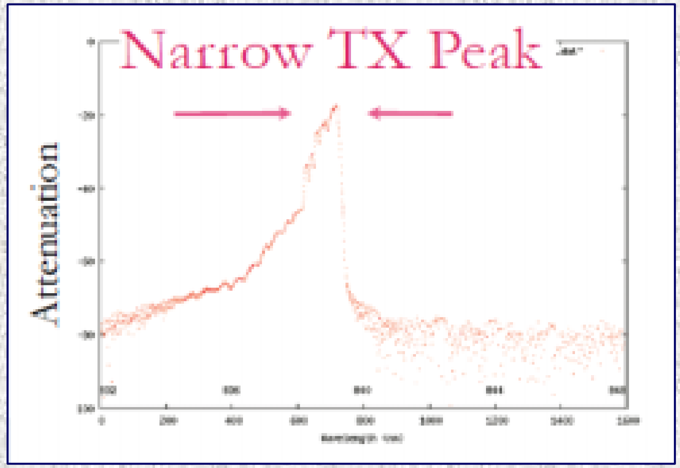


- MDT HV channels with sudden instable Vout > Vset: still not understood, effect not reproducible in small lab setup !

First year's problems …

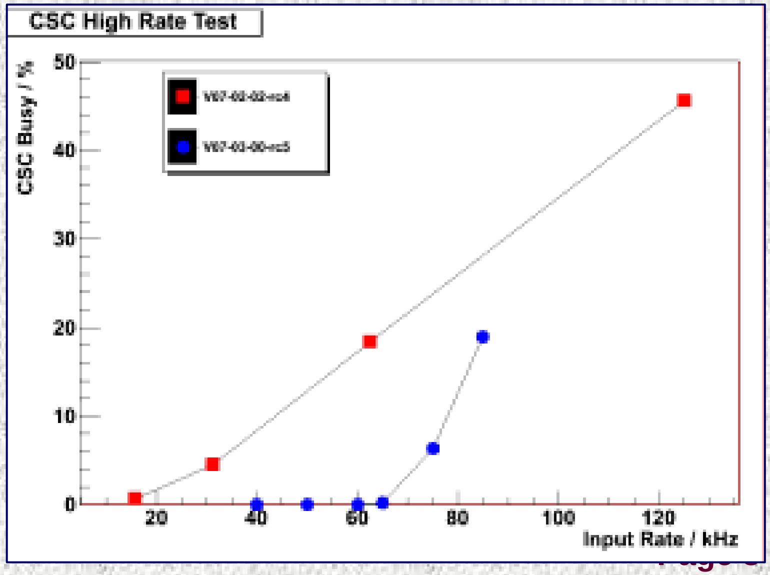
Failure of optical readout links for RPC Level-1 trigger boxes:

- On average 1 trigger tower out of the run due to a broken optical (TX) link
- So far no speed up of break downs with time observed, however from SCT, PIX experience one worries ….
- Optical measurement show correlation between broken links and too sharp spectra …
- 60 (out of 400) trigger boxes scheduled for link re-placement …



CSC sustainable LV1 trigger rate limitations:

- Original ReadOut Driver (ROD) design found not working in 2008
- ROD firmware redesigned ~ from scratch in 2009
- Limited rate capability during first half of this year's run, no problem with initial luminosity
- Great effort on firmware revisions → now able to sustain up to 65 kHz without introducing any BUSY
- In time for bunch train runs ☺ ☺
- Max. output rate validated 73 kHz



Data Quality, data taking efficiency

'Good' detector fraction in terms of luminosity – 2010 pp data

Inner Tracking Detectors			Calorimeters				Muon Detectors			
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	CSC	TGC
99.0	99.9	100	90.5	96.6	97.8	94.3	99.9	99.8	96.2	99.8

Luminosity weighted relative detector uptime and good quality data delivery during 2010 stable beams in pp collisions at $\sqrt{s}$=7 TeV between March 30th and October 31st (in %). The inefficiencies in the calorimeters will largely be recovered in a future data reprocessing.

Close to 100%

Lower number For CSC due to LV module failure During 48 h

Overall data quality and detector uptime for muon detectors is very good ☺

Key ingredients for achieving close to 100% uptime/good detector fraction:

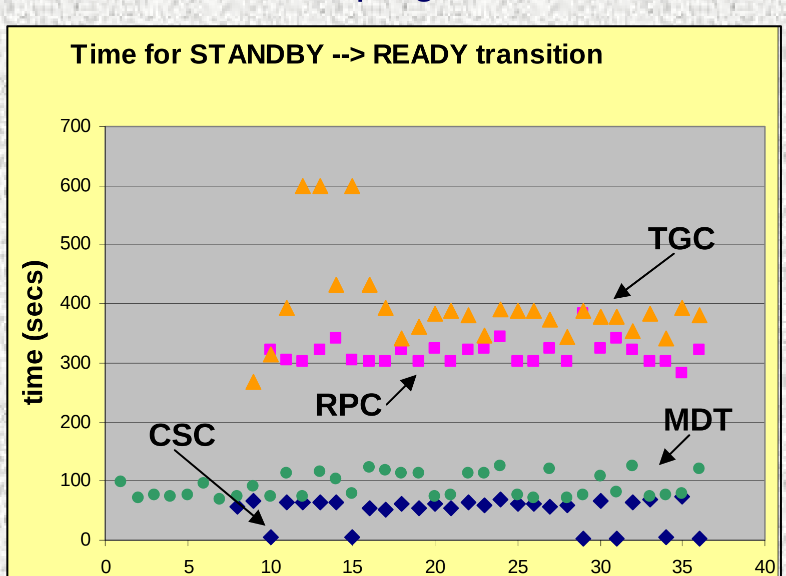
- "Stopless Removal" and "Stopless Recovery" features of Atlas DAQ
  - on-the-fly disabling of modules/channels for which data flow is "stuck" during data taking – prevents a BUSY (triggers held) due to waiting for an event to complete for ever …
  - Removal implemented for all muon systems, recovery implemented for TGC, MDT, brought significant improvements when activated in spring/summer
- Handling of HV transitions between STANDBY (no stable beams) and READY (stable beams) has been automatized (→ next slide)

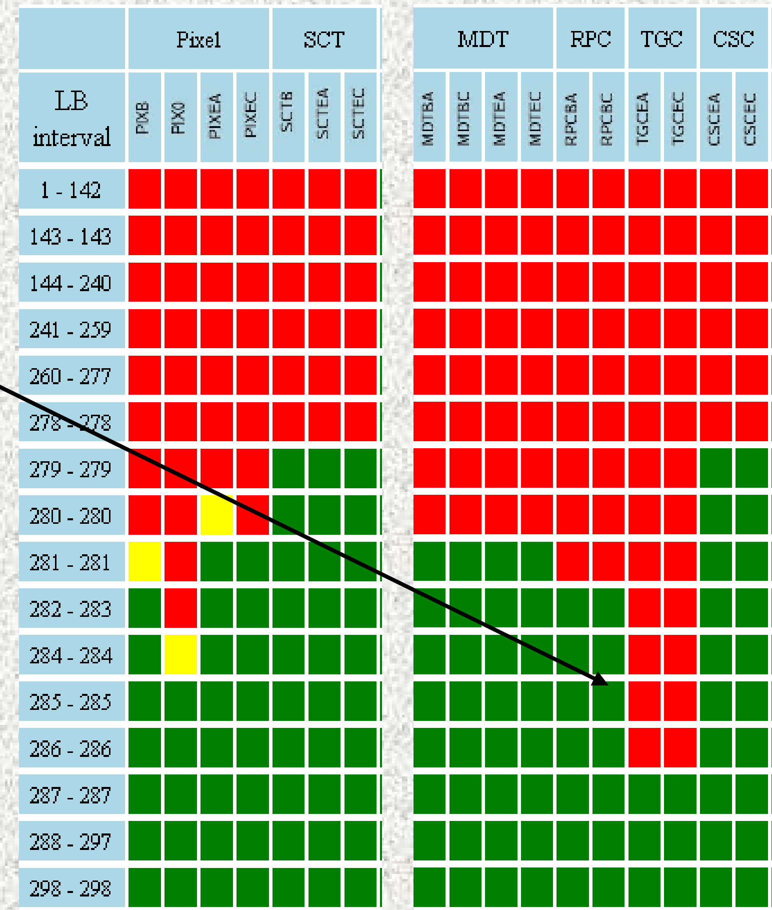
Ongoing work and improvements:

- Current "good" DQ flags are based on > 90% working fraction of the detector → refine taking into account acceptance, geometry etc.
- Start to use detector conditions with high granularity (e.g. RPC strip panel) within reconstruction

HV Standby versus Ready

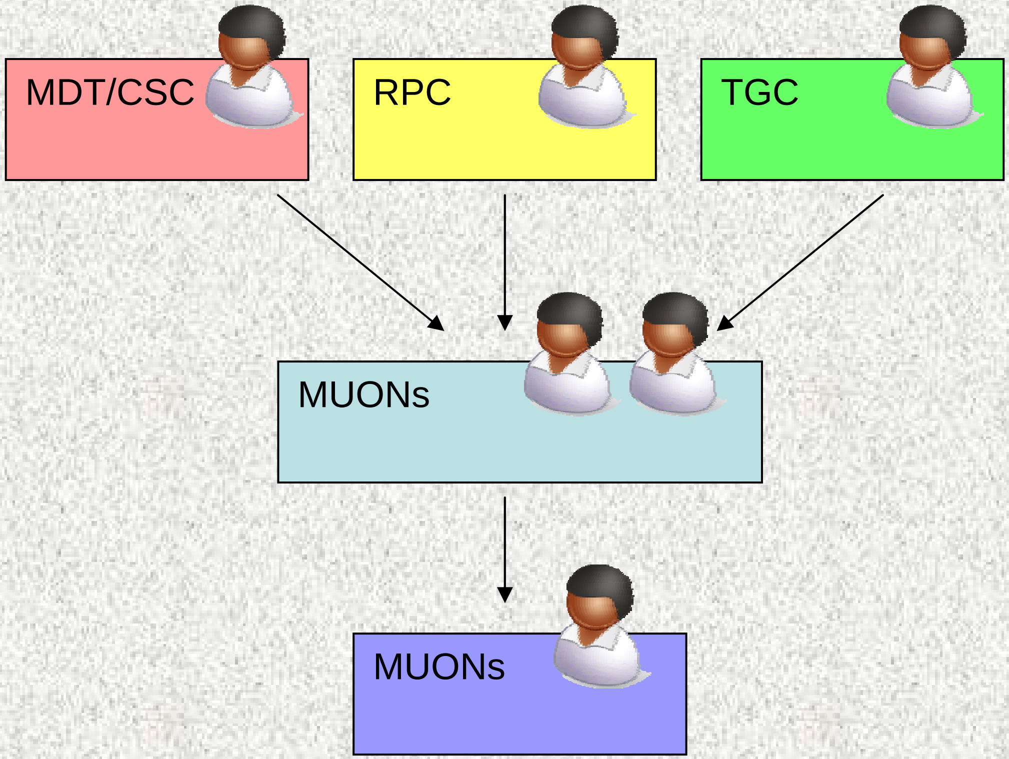
- All muon sub-detectors put to lower Standby HV outside stable beams (injection, ramp, adjust) for protection
- Efficient transition STANDBY → READY when reaching stable beams is important factor for recorded physics data. Automatic actions:
  - ~ 70 secs for CSC, ~80-120secs for MDT
  - ~ 5 mins for RPC, ~ 7 mins for TGC
- Some room for improvements, especially for TGC where transition time is dominated by waiting for readback of values from power supplies, not actial HV ramping !





1 LB = 1 min

2010 "Human" (Shift) Operations



- Jan – June:
  - Separate shifters for different muon sub-detectors, with specific training
- July: Merged muon operations into a common scheme
  - 2 people handling the full muon system,
  - All shifters trained for all 4 muon technologies
  - Good experience
- 2011: Further reduction to have a single person covering muons

• Adequate training proved crucial for efficient operations, plans for improvements to include practical excersises, systematic trouble shooting guides, instructions, more and more relevant !

• Move from the detector being the experts' baby constantly watched to a system essentially run by shifters !

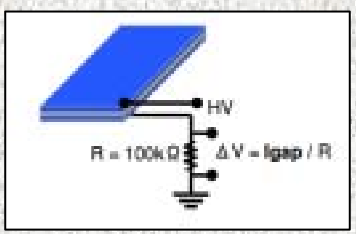
• Efficient data taking depends on shifters being experienced, to deal speedily with problems; requires some willingness from people to spend longer times at CERN, etc. !

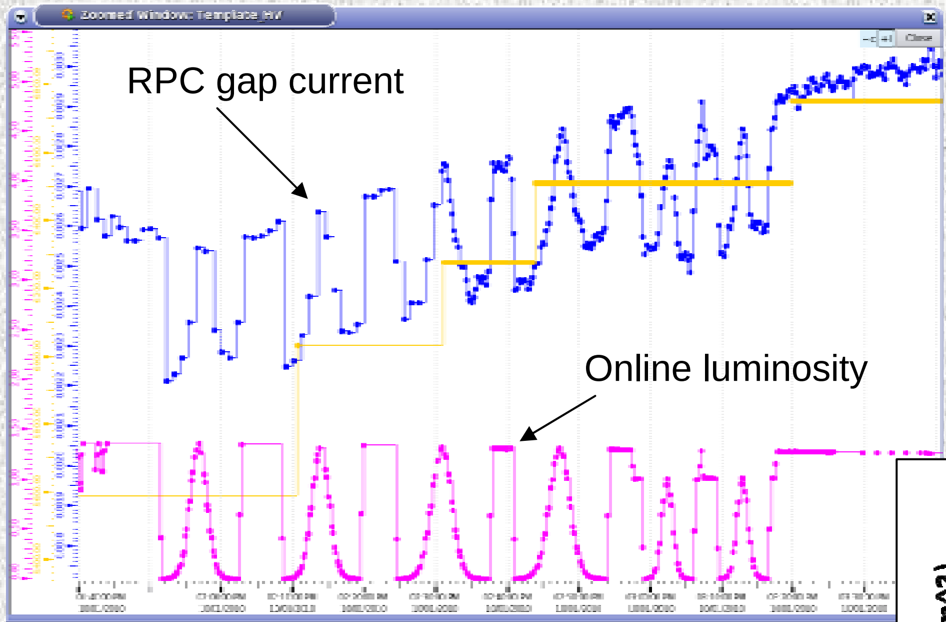
Background studies: RPC

Pre-data-taking background calculations for muon system has large uncertainties and safety factors (up to factor 5) → very important to validate/refine from data for upgrade planning !

RPC - Main information from

- HV current monitoring on individual gas volume basis, RPC LV1 rates

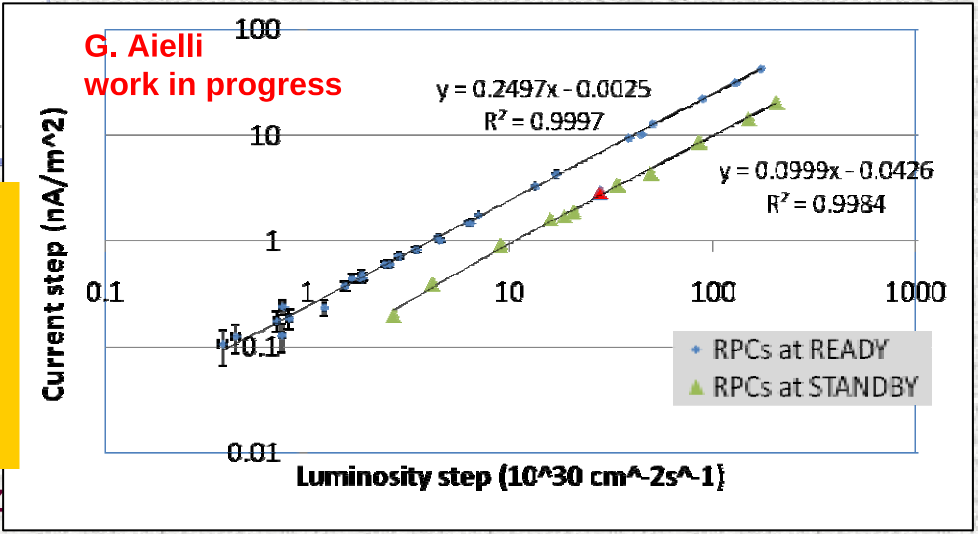




- Currents mirrors closely changes luminosity
- need to correct for slow drifts due to atmospheric pressure changes
- First analysis show gap current is linear w.r.t. to luminosity over 3 orders of magnitude

Comparing data from alignment run with toroid field OFF with runs with magnetic field:

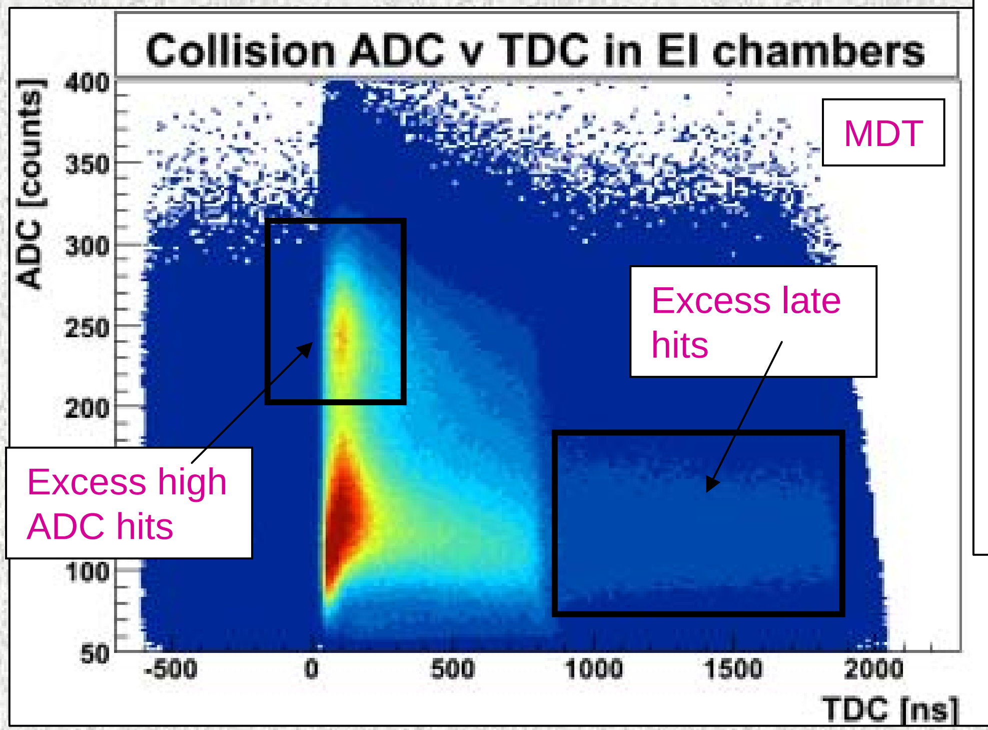
- charged component of background significant
- magnetic field must be considered in future simulations !

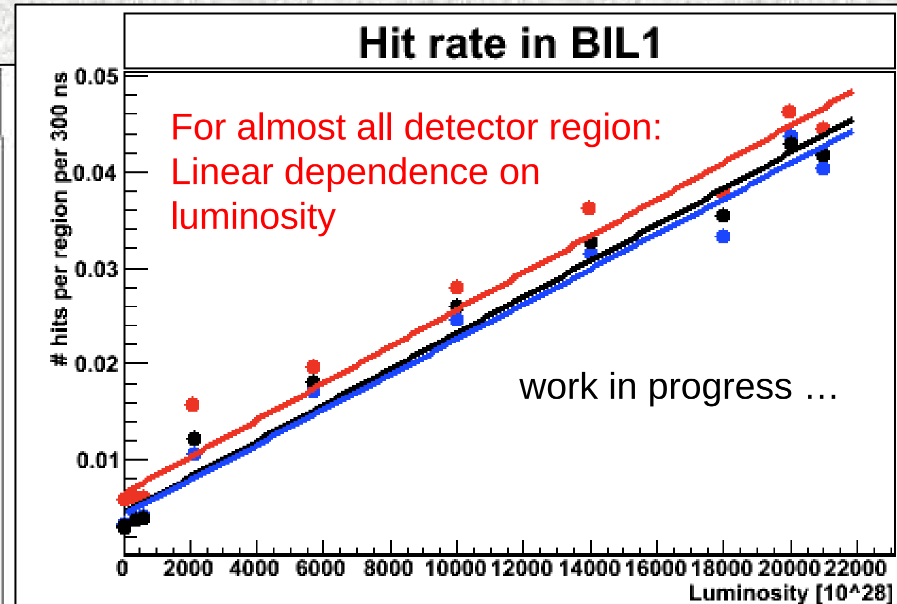


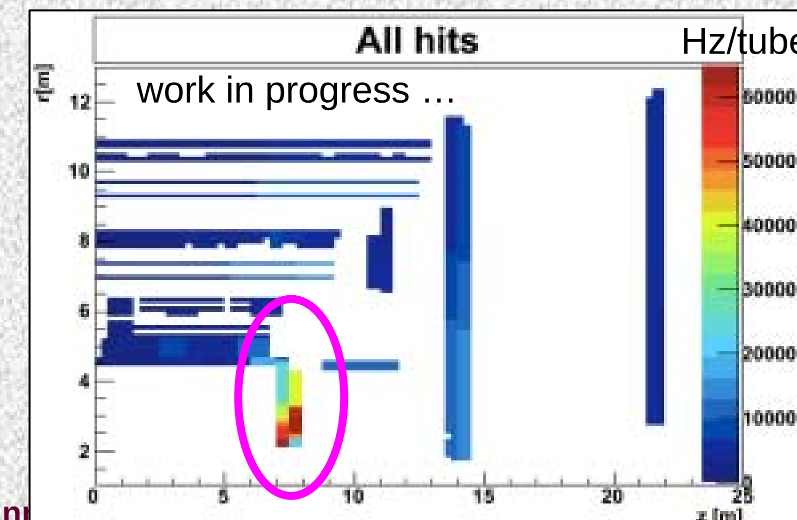
Background studies: MDT

Main tools for background studies: hits with very high pulse charge; late or early hits.

Above L~ 10^{32}: HV currents per multilayer







Extrapolations from **data** to nominal L = 10^{34} cm^{-1}s^{-2} (7TeV)

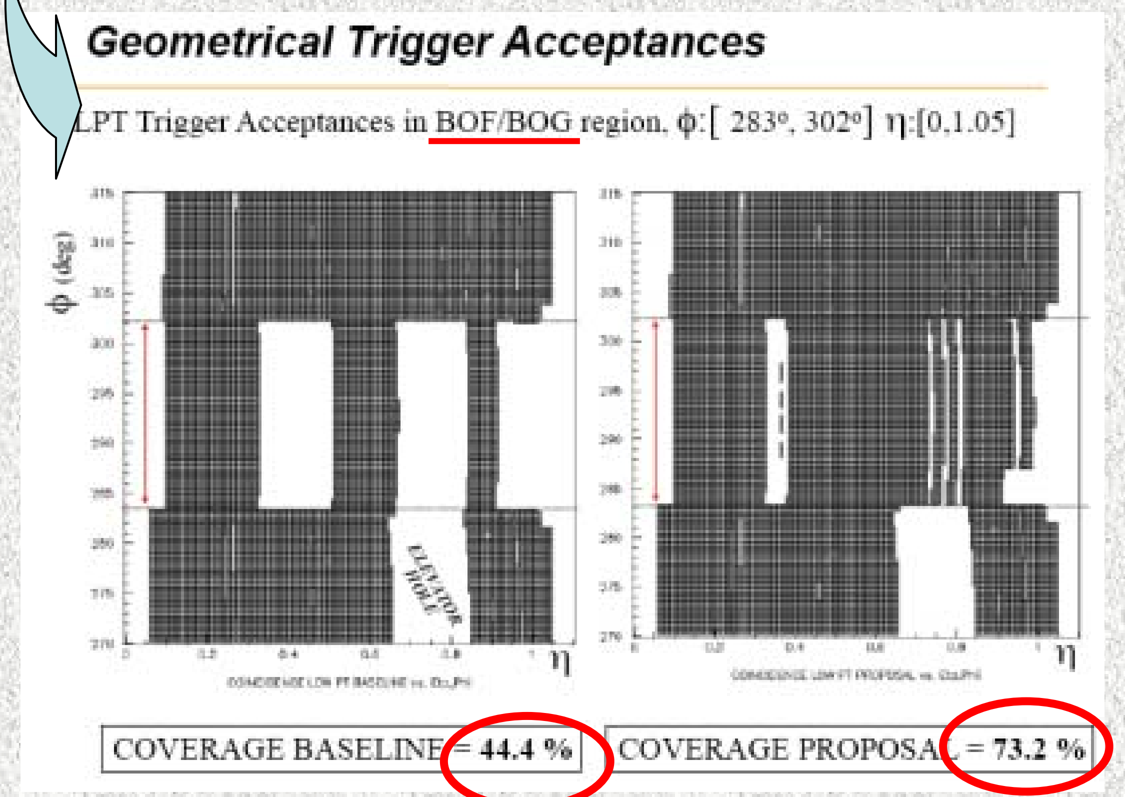
- Highest rates are ~ 60kHz in EI chambers (small wheel)
- Fine structure to be understood …

Upgrade Plans – Near Future …

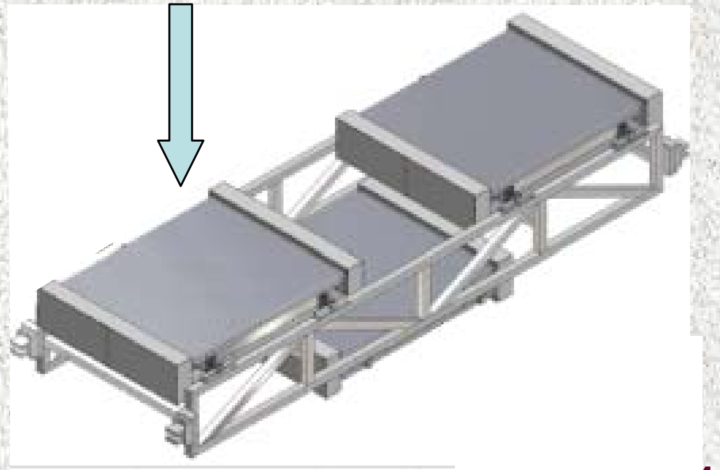
2012/13 shutdown:

- Complete EE MDT wheel (52 chambers not yet installed)
- Equip 2nd already installed RPC planes in Barrel feet region with trigger electronics: gain 20% in trigger acceptance in feet region

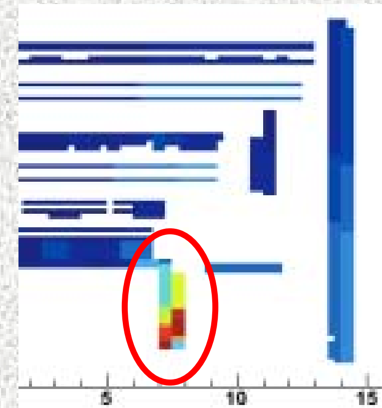
- Proposal to install additional chambers in bottom sector 13 in so called "elevator holes"



  - Gain $\Delta\varphi \times \Delta\eta = 0.35 \times 0.3$
  - Special chamber geometry needed to preserve access
  - Proposal is to use small tube design which is also studied for new small wheel …
  - Decision very soon …



Upgrade Plans: Medium term …

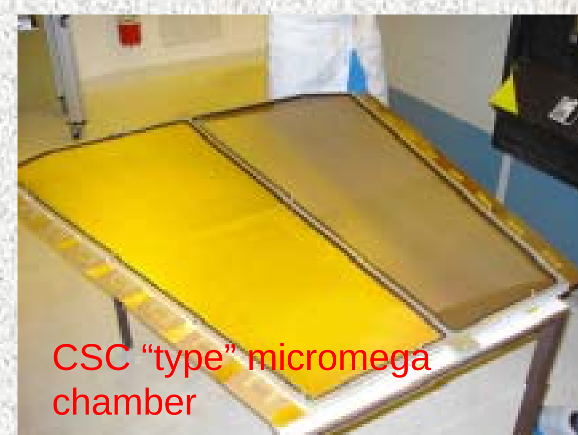


Rebuild Muon Small Wheels,

- Ready for installation during long shutdown 2016/17
- Technical coordinator (J. Dubbert, MPI) and Small Wheel project leader (T. Kawamoto, Tokio) recently endorsed for 1 year term of office
- Prepare Technical Design Report by autumn 2011

Several detector technologies currently being evaluated

1. Replace CSC and current MDT chambers by drift tubes with smaller radius → reduced occupancy. Full scale prototype evaluated in H8 CERN testbeam this summer
2. Micromegas based design, performance validated in several recent test beam studies, next step is test of a CSC sized chamber …
3. New generation Thin Gap Chambers …



Conclusions

- First year of data taking for ATLAS Muons was very successful
- All muon detectors are in a healthy state, with lessons learned for future detector developments
- Some hardware problems will be tackled during the Xmas break
- Upgrade plans
  - Well defined list for 2012/13 shutdown
  - 2016/17 "New Small Wheel" Project kicked into high gear recently