A proposal to upgrade the ATLAS RPC system for the High Luminosity LHC

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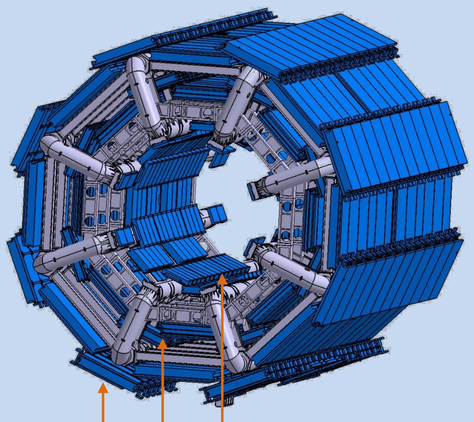
The architecture of the present trigger system in the ATLAS Muon Barrel was designed according to a reference luminosity of 10^{34} cm^{-2} s^{-1} with a safety factor of 5, with respect to the simulated background rates, now confirmed by LHC Run-1 data. HL-LHC will provide a luminosity 5 to 7 times higher, and a consequent higher background. As a result, the performance demand increases, while the detector being susceptible to ageing effects. Moreover, the present muon trigger acceptance in the barrel is just above 70%, due to the presence of the barrel toroid structures. This scenario induced the ATLAS muon collaboration to propose an appropriate upgrade plan, involving both detector and trigger-readout electronics, to guarantee the performance required by the physics program for the 20 years scheduled. This consists in installing a layer of new generation RPCs in the inner barrel, to increase the redundancy and the background rejection, and to provide almost full acceptance. The first 10% of the system, corresponding to the edges of the inner barrel even sectors (BIS), has been already approved by ATLAS and will be installed in 2018, to reinforce the trigger in the region between barrel and endcap. To match the performance requirements (higher hit rate capability), the new smaller gap RPCs will have a different structure and materials, and a high performance front-end electronics. We will illustrate the performance of the new detectors and trigger system, as well as the impact on the ATLAS physics performance.

The current ATLAS RPC Muon Barrel System

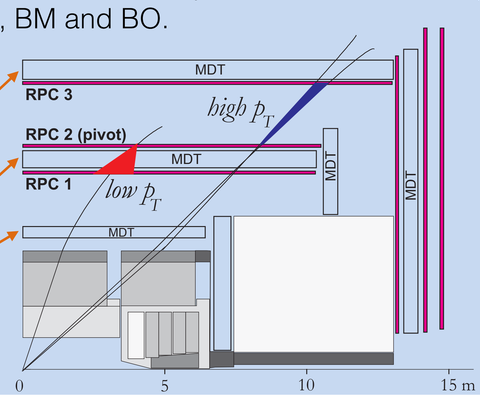


- The trigger algorithm is based on hit coincidence of three concentric RPC stations.
- Each station has 2 gas gaps, read-out with eta and phi strips.
- The Low-p_T trigger (< 10 GeV) makes use of the two inner stations (inner and middle).
- The High-p_T trigger (> 10 GeV) requires an additional confirmation on the third external station (outer).
- MDT detector is used for precise muon tracking, installed in BI, BM and BO.

BO (Barrel Outer): one RPC doublet + MDT

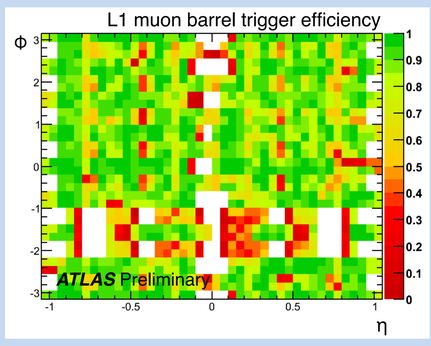
BM (Barrel Middle): 2 RPC doublets + MDT

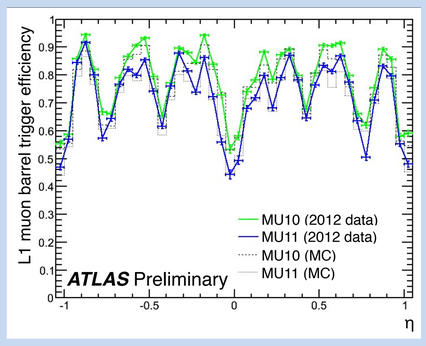
BI: (Barrel Inner): currently MDT only



RPC detector coverage

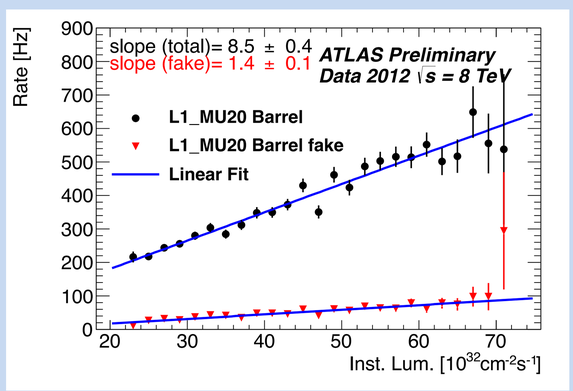
- RPC detector coverage is limited to 73% because of the ATLAS mechanical support structure.
- Main inefficiencies are in the BM region, because of the toroid ribs in small sectors, and in the feet region, because of the toroid feet structure.
- Feet region coverage will be partly recovered (~4%) in Run-2 using additional RPC chambers installed outside the feet structure.
- One possibility to increase the current detector coverage is to use additional RPC chambers in the BI region, where there are no mechanical structures.





RPC trigger efficiency for muons with p_T > 10 GeV. Orange and red regions represent lower trigger efficiency, due to the reduced RPC detector geometrical acceptance in the regions where there are toroid mechanical supports. The regions where there are no RPC detectors at all are marked as white.

RPC trigger rates and extrapolations for high luminosity



- The plot shows the L1 MU20 Barrel muon rates as a function of the instantaneous luminosity (2012 data).
- Fake triggers are mainly due to secondary particles, like protons produced in dense materials such as the magnets.

RPC AGEING TESTS

- Ageing tests have been done for detector longevity certification of 100 Hz/cm^2 in 10 years.
- This was the nominal value (including safety factors) originally requested for 10 years of LHC operations at L=10^{34} cm^{-2} s^{-1}.
- Test done at CERN GIF facility over 3 years.
- Conditions: ageing acceleration factor ~3.5 (300-400 Hz/cm^2), peak rate capability of 1 kHz/cm^2 for a limited time, gas flow 2 change/hour.
- Results: no change in performance at 100 Hz/cm^2. Resistivity increased by a factor of 10, but stabilised.

- TEST RESULTS:
  - The test showed that the 100 Hz/cm^2 RPC hit rate limit cannot be exceeded.

RPC background map with 2012 data on the BM RPC station

Sector Φ Id.	ATLAS RPC BM extrapolated average rate density (RPC unit Id. along Z direction)																										Average (Hz/cm²)
	-7	-6.2	-6.1	-5	-4	-3.2	-3.1	-2.2	-2.1	-1.2	-1.1	1.1	1.2	2.1	2.2	3.1	3.2	4	5	6.1	6.2	7	ATLAS *preliminary*				
1.1	40	42	37	36	29	19	14	17	13		9	8	9	14	15	16	18	26	36	34	36	30					23
1.2		38	35	38	28	21	16	18	16		10	9	10	15	17	17	19	28	40	35	39	38					24
2		16	26	24	18	14	12	10	9	7	7	6	7	9	10	13	12	18	26	25	21						15
3.1		37	37	38	26	18	16	15	14	9	9	9	10	16	16	16	17	26	38	34	36						23
3.2		38	36	39	27	19	16	18	15	11	10	10	9	16	17	19	19	26	38	33	37						23
4		14	23	23	20	14	12	9	10	7	7	6	7	10	10	12	14	20	24	23	20						15
5.1	35	27	27	32	21	13	13	16	15	9	9	9	10	15	20	13	15	22	31	24	24	27					19
5.2		29	29	28	18	14	15	16	16	10	8	9	10	14	16	13	16	21	29	32	32						19
6		16	24	25	19	13	12	11	11	8	7	6	8	10	10	12	14	21	24	26	22						15
7.1	34	37	34	35	25	21	17	16	15		10	10		15	18	16	20	24	35	34	37	32					24
7.2		40	33	30	16	18	14	16	13		10	10		13	16	15	20	15	39	35	32	36					21
8		15	25	24	20	13	11	10	9	7	7	6	7	8	9	11	14	20	24	24	22						15
9.1	28	39	32	37	26	20	15	17	14		7	9		13	16	18	25	35	34	36	28						23
9.2		40	33	35	25	19	14	14	13		8	10		13	14	13	18	24	35	32	35						22
10		16	26	26	18	11	11	9	9	6	6	5	7	9	9	10	11	18	24	25	23						14
11.1	29	37	31	30	20	14	11	12	10		6	5		10	11	12	13	19	29	28	33	22					18
11.2		25	23	20	14	11	9	7	7		5	5		7	8	8	10	13	19	21	23	32					13
12						14	13	10	9	6	5	5	6	9	11	13	14										9
13.1	40	37	34	30		17	13	12	11	6	6	6	7	11	12	11	16		30	33	37	30					19
13.2		37	33	28		14	12	13	11	6	7	7	7	12	13	12	15		27	29	35	31					18
14						15	18	10	8	6	5	5	6	8	10	17	15										10
15.1	25	23	25	19	14	11	9	9	7		5	5		7	8	10	12	14	19	22	23	24					13
15.2	34	24	21	31	20	16	12	13	10		6	6		10	13	14	15	20	31	24	27						18
16		16	27	27	21	13	11	8	9	8	7	7	7	9	8	11	13	21	26	26	21						15
Average (Hz/cm²)	34	25	29	29	21	15	13	12	11	7	7	7	8	11	12	13	15	21	29	28	28	29					17

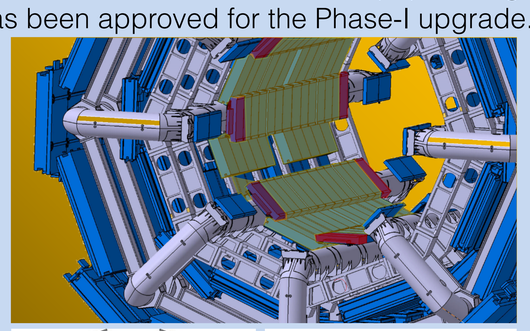
Extrapolation @ L=7x10^{34} cm^{-2} s^{-1}
foreseen max rate: ~300 Hz

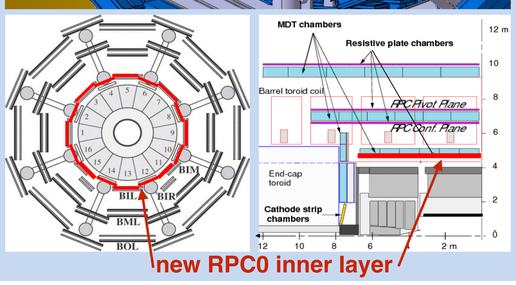
- The figure shows the RPC counting hit rate in Hz/cm^2 measured at L=6x10^{33} cm^{-2} s^{-1} (data from 2012) and normalised at 10^{34} cm^{-2} s^{-1} at 13 TeV.
- Rates are measured on the BM RPC station.
- The average measured value is 17 Hz/cm^2, while the maximum rate is 40 Hz on the large sectors, high eta.
- The maximum value foreseen for HL-LHC is not sustainable for the detector, which has been realised for a much lower luminosity.
- Extrapolating 2012 data to Phase-II luminosity: ~150 Hz/cm^2 in average, ~300 Hz/cm^2 in the hot sectors.

- CONCLUSIONS:
  - Phase-II exceeds the RPC validation limits far beyond the safety margin.

RPC inner layer upgrade proposal for HL-LHC

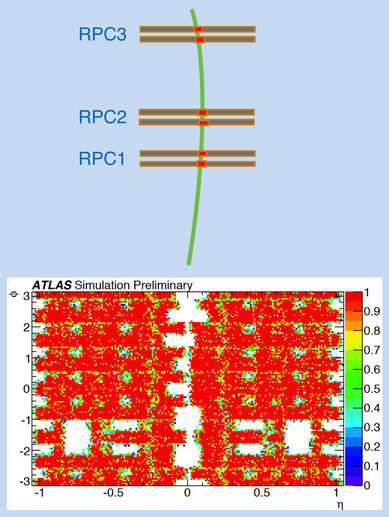
Completing the BIS78 Phase-I upgrade RPC installation in Barrel Inner (BI) 7-8 region has been approved for the Phase-I upgrade.



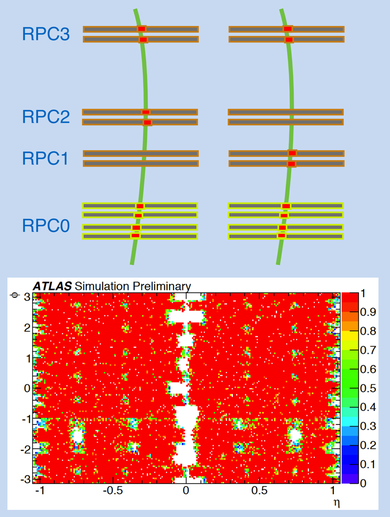


- The insertion of a new RPC inner layer (triplet or quadruplet) can allow to increase the current detector coverage up to 96%.
- 4 concentric RPC chambers, 10 layers.
- The increased redundancy allows to cope with the HL-LHC foreseen RPC hit rates.
- The BM station can be used with a 2/4 majority instead of the 3/4, allowing a consistent reduction of gap efficiency without affecting the trigger efficiency.
- For most of the chambers the new operating point restores a reasonable safety factor.
- Trigger robustness is increased as well.
- The new generation of RPCs can work at hit rates > 20 kHz/cm^2.
- Pileup insensitive due to high space-time RPC granularity ~0.5 cm^2 x 0.5 ns.
- The increased lever arm allows for a sharper momentum threshold.

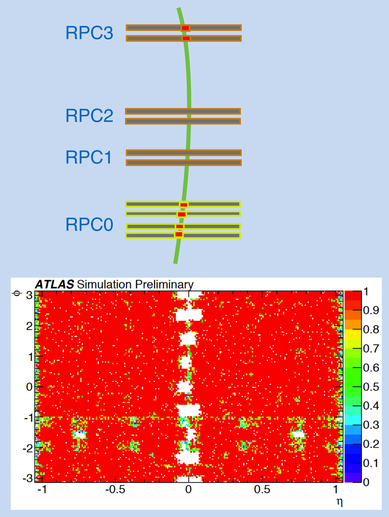
RPC efficiency ~73%
current trigger algorithm requires hits on (RPC1 and RPC2 and RPC3)



RPC efficiency ~88%
hits on (any 3 out of 4) RPCs required



RPC efficiency ~96
(any 3 out of 4) OR inner layer RPC0



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ATLAS EXPERIMENT