L1-muon / RPC for Phase-2

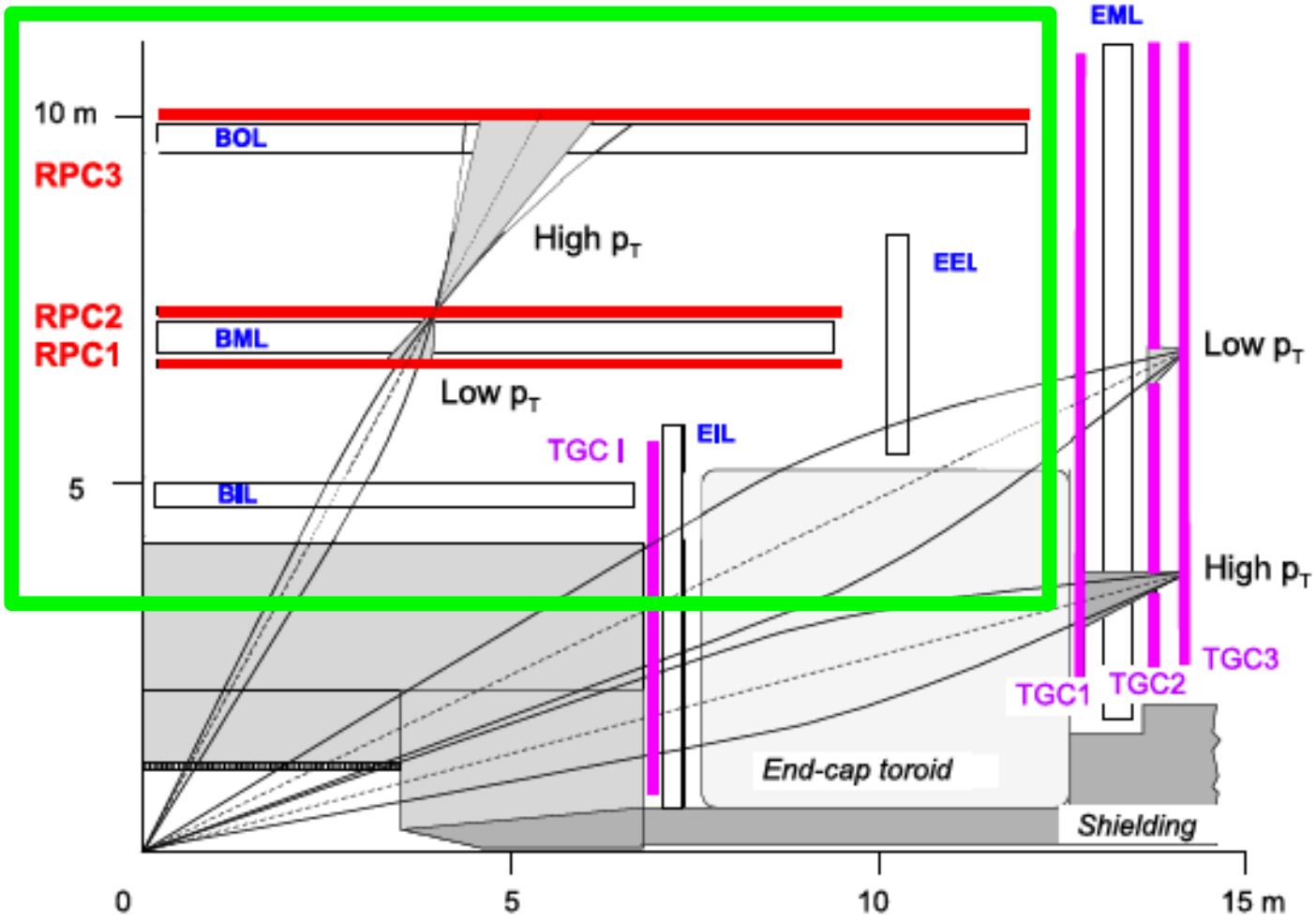
D.Boscherini
on behalf of the RPC/LVL1 group

ATLAS Italia - Bologna, 15/05/2015

Current L1 Muon Barrel Trigger Scheme

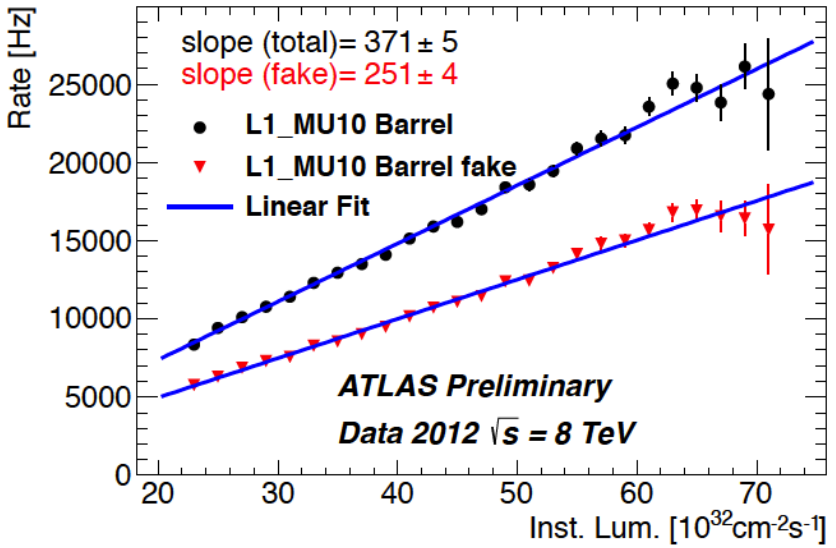
High-p_T
Low-pt && >=1 hit on RPC3

Low-p_T
3/4 hits on RPC1, RPC2

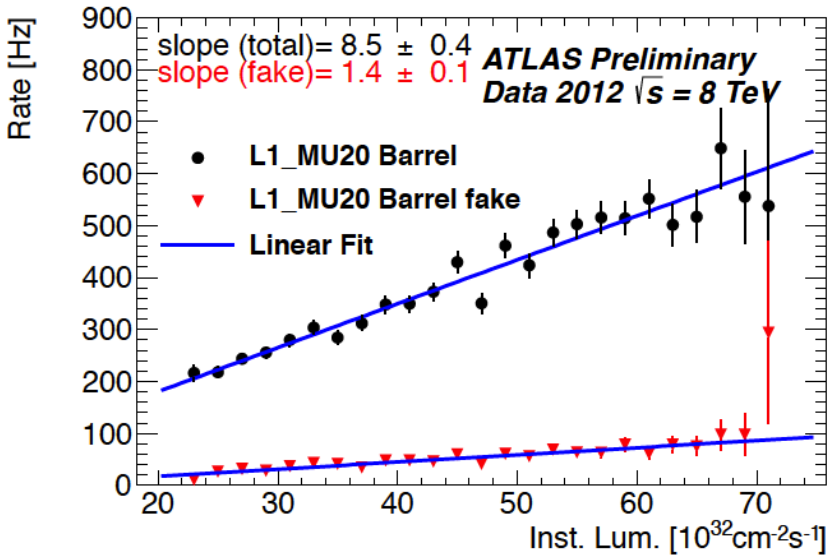


L1 Muon Barrel trigger rates in Run-1

Low-p_T (3/4 hits on RPC1, RPC2)
e.g. MU10
- ~70% fake muons
- used for multi-object triggers
- ε*A = 79%



High-pt (Low-pt && >=1 hit on RPC3)
e.g. MU11, MU15, MU20
- Low fake contamination
- used as single muon triggers
- ε*A = 73%



Rate scales linearly with luminosity in the measured range

TDAQ upgrade

Trigger scheme change: L1 → L0/L1

Current scheme

L1 max rate: **100 kHz**

L1 latency: **3 μs**

Phase-2 scheme

L0/L1 max rate: **1000/400 kHz**

L0/L1 latency: **10/60 μs**

→ need to replace RPC trigger electronics

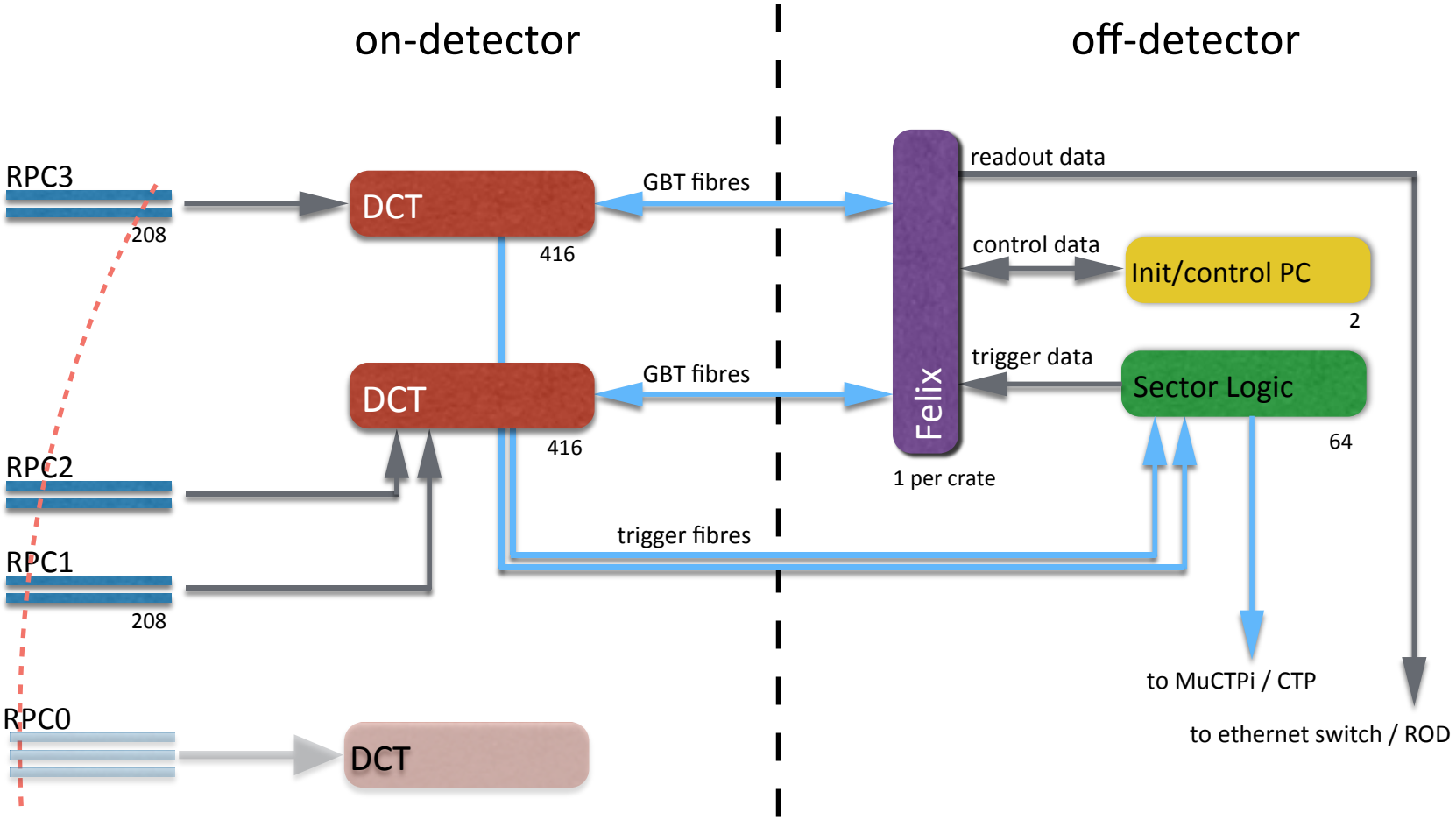
Muon trigger requirements

Max L1 trigger rate of **20 kHz** for **15-20 GeV single muons** in phase-0/1, ~50 kHz in phase-2

L1 Barrel Muon Trigger Phase-2 Upgrade

- The current barrel trigger system is not compatible with the Phase-2 requests (latency and rates)
- The current on-detector electronics will be replaced with the new boxes (Data Collector Transmitter, about 800 in total)
  - Use of FPGAs instead of ASICs for the on-detector electronics
  - The DCT box will collect RPC front-end data, and perform some simple logic before sending the data off-detector
- Most of the trigger logic will be located in the off-detector new Sector Logic boards (64 in total):
  - provide seed for MDT-based trigger
  - increased algorithm flexibility, easier operations and maintenance, no radiation
  - increased trigger coverage could be feasible by changing the trigger algorithm (and possibly by adding new RPCs in the inner barrel layer)
  - increased steepness of the trigger turn-on curve could be feasible thanks to the improved spatial resolution
  - possibility to use Time-over-Threshold to increase RPC spatial resolution (under study)
  - muon charge info could be added to the trigger data
  - trigger thresholds could be fully programmable and more flexible (possibly > 6)

Phase-2 L0 Muon Barrel Trigger System



Trigger logic moved from detector to counting room (USA-15)

Costs & Manpower

- Interest in the project expressed by the INFN groups:
  - Bologna, Napoli, Roma, Roma Tor Vergata

- Costs of new LVL1 trigger electronics:
  - 4.2 MCHF (RPCs)
  - 5.1 MCHF (RPCs + new RPCs in BI 4-6)
  - 5.9 MCHF (RPCs + new RPCs in BI)

  Money for evaluation boards (FPGA based, to test possible algorithms and performances) have been asked to INFN referees

RPC rate extrapolation

RPC BM rates (Hz/cm^2) at L=7*10^{34} cm^{-2} s^{-1}

Rate limit of 100 Hz/cm^2 assumed in ageing tests

Safe value exceeded in many chambers.

Sector	RPC unit Id. along Z direction																				Average
Φ Id.	-6.2	-6.1	-5.0	-4.0	-3.2	-3.1	-2.2	-2.1	-1.2	-1.1	1.1	1.2	2.1	2.2	3.1	3.2	4.0	5.0	6.1	6.2	
01.01	319	262	281	210	135	106	119	95		57	57	66	106	114	118	127	199	258	251	266	168
01.02	273	262	283	203	148	124	121	133		71	67	70	118	134	131	138	201	275	260	277	176
2	157	191	176	129	102	84	72	58	51	52	42	45	57	74	87	98	130	193	183	142	107
03.01	277	276	263	184	138	120	111	111	63	63	60	66	122	117	106	117	193	307	251	271	165
03.02	280	227	258	196	141	120	144	114	79	70	70	65	113	119	142	123	193	294	227	279	167
4	105	155	148	141	94	78	61	71	38	49	43	38	68	63	86	101	149	183	163	105	101
05.01	159	161	245	129	98	96	131	118	64	56	56	64	116	165	96	128	173	270	161	159	139
05.02	211	185	221	147	102	98	127	133	72	57	58	66	103	127	101	131	187	250	238	264	148
6	163	174	194	152	98	89	84	89	72	55	49	55	79	76	99	116	177	187	212	156	122
07.01	285	245	269	178	144	120	122	106		71	73		114	130	116	138	173	244	250	285	171
07.02	305	241	201	189	132	104	120	101		69	72		98	107	105	142	172	259	257	260	163
8	136	183	182	150	96	79	75	65	46	53	51	50	63	69	79	101	157	183	181	145	110
09.01	298	230	281	192	145	109	139	111		43	60		99	125	116	126	184	264	244	277	169
09.02	324	240	268	191	133	89	100	96		54	63		92	104	89	128	175	266	247	273	163
10	163	187	193	137	92	80	63	66	43	40	38	46	60	64	75	96	138	181	188	159	107
11.01	288	228	222	147	90	78	76	81		37	40		78	88	86	88	138	212	200	259	132
11.02	183	180	147	98	72	62	52	53		31	29		47	58	54	66	91	141	149	173	91
12						74	75	62	48	34	34	48	70	81	74						60
13.01	272	260	236		131	95	89	78	40	38	44	47	81	89	92	115		232	245	298	139
13.02	279	246	245		97	90	98	80	45	45	47	53	87	96	90	102		235	212	275	137
14						133	64	60	48	38	38	46	59	64	127						70
15.01	183	206	139	106	71	66	62	46		36	33		47	55	80	81	97	146	162	183	97
15.02	171	148	230	153	108	92	96	70		41	40		70	99	104	100	147	231	148	171	124
16	161	200	202	162	101	83	51	70	52	55	47	46	72	51	81	96	165	195	194	144	115
Average	214	208	218	156	111	94	90	82	52	49	48	52	80	90	96	111	160	224	206	206	128

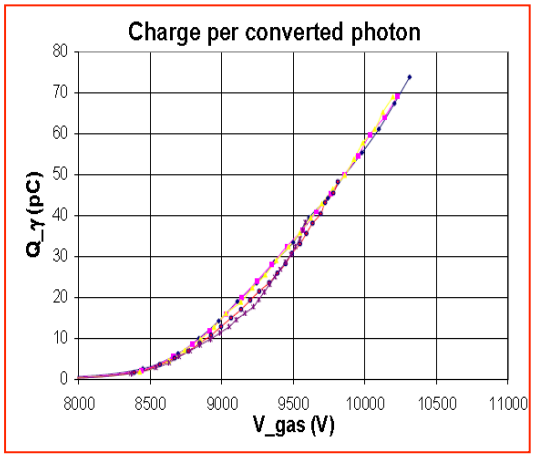
BI 4-6 | BI 1-3 | BI 4-6

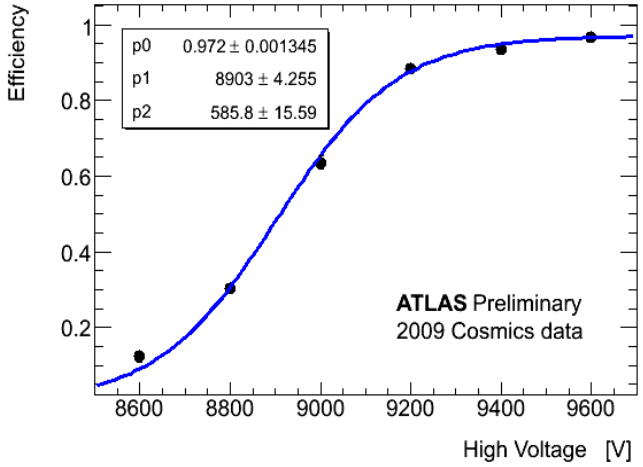
Safe operation of current RPCs

- Safe rate limit 100 Hz/cm^2 with nominal HV, exceeded in many chambers

- Plan to reduce HV to keep gap currents within the safety level

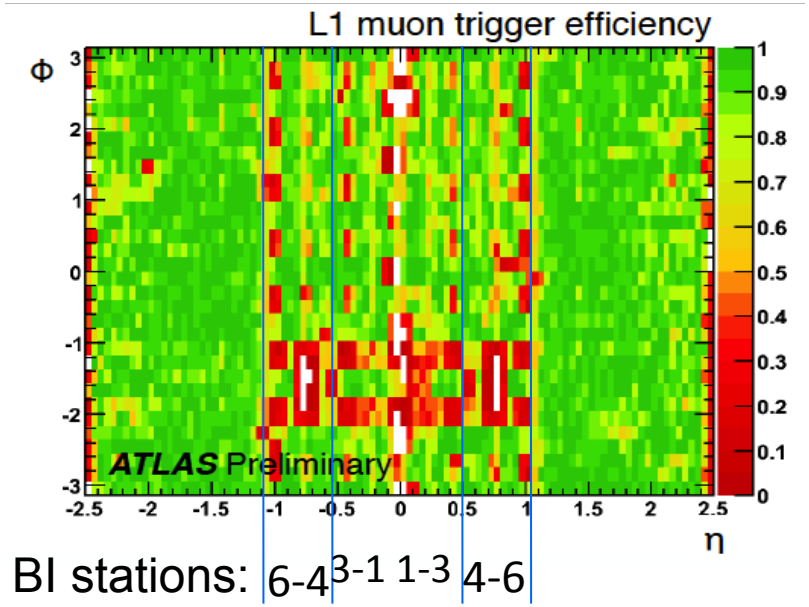
- Hit efficiency reduction with increasing eta, down to 65-75% in BML5-6 stations

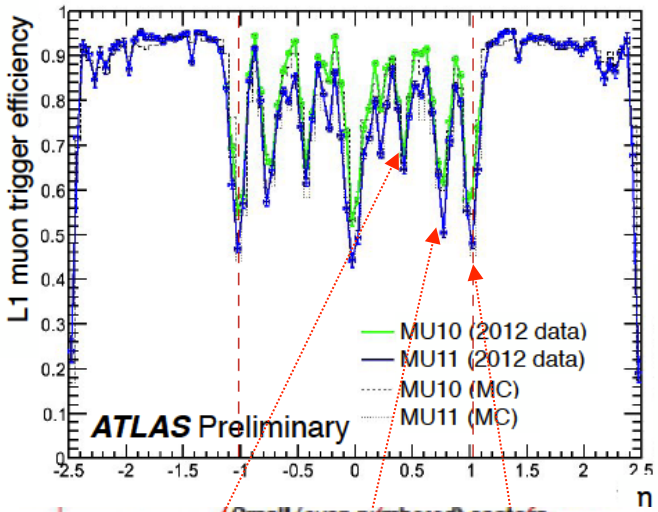


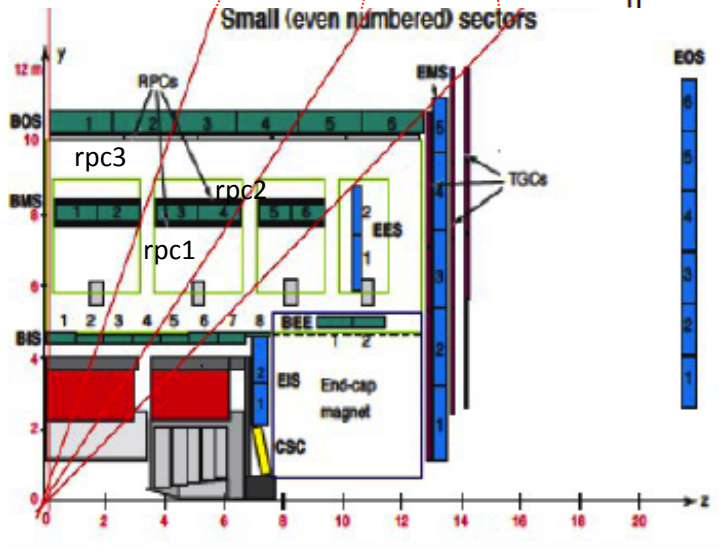


Acceptance of present L1 barrel trigger

- High-Pt requirement: 3 out of 3 stations, hole in one station => no trigger
- Holes in “small sectors” BM due to toroid coils and supports
- Run-1 eff x Acceptance ~73%





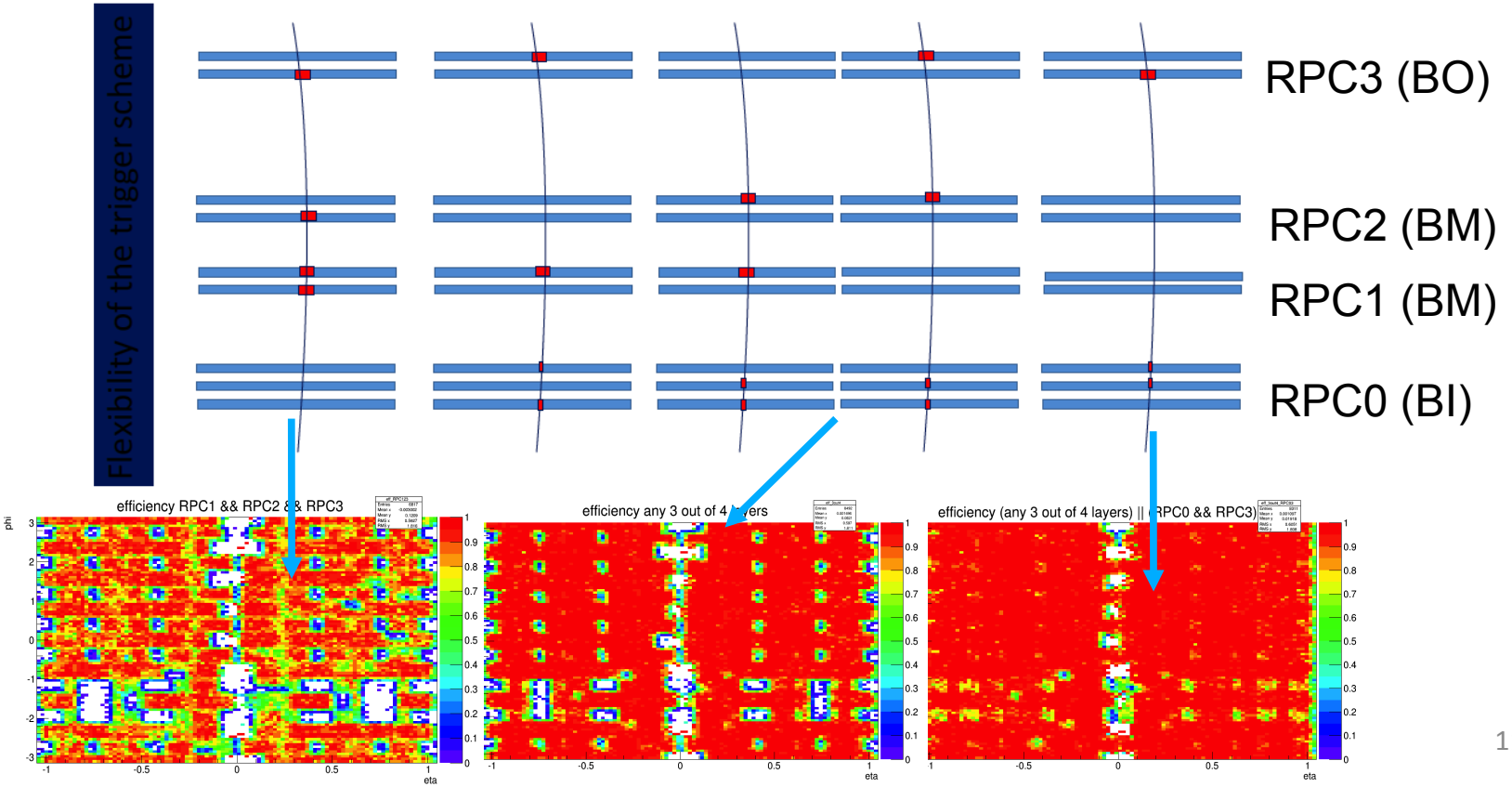


Benefits from new RPCs on BI stations

Using 3/4 station majority instead of 3/3 :

- recover RPC inefficiency (lower HV operation)
- recover holes on BM stations => acceptance ~88%
- using also (locally) BI-BO coincidences => acceptance ~95%

Requirement	rpc1 && rpc2 && rpc3	BI && (rpc1||rpc2) && rpc3	any 3 out of 4 layers	(any 3 out of 4) || (inner&&outer)
Acceptance wrt muid	73%	82%	88%	96%



New RPCs in BI stations

Main requirements:

1. Expected max rate in new inner layer ~**600 Hz/cm²**:

need to improve the long term RPC rate capability to sustain the HL- LHC

2. Limited space available for the installation in the inner layer: **~ 5cm**

Reduced gas gain:
- increased Signal/Noise in front-end electronics
- thinner gap 2 → 1 mm
- thinner electrodes (improved ratio prompt/total charge) 1.8 → 1.2 mm

Improved spatial and time resolution:
- timing is improved by reducing the gap thickness
- improve spatial resolution through charge centroid by exploiting electronics sensitivity

Reduced detector thickness
- higher-quality mechanical structures is required
- thinner electrodes and gas gaps

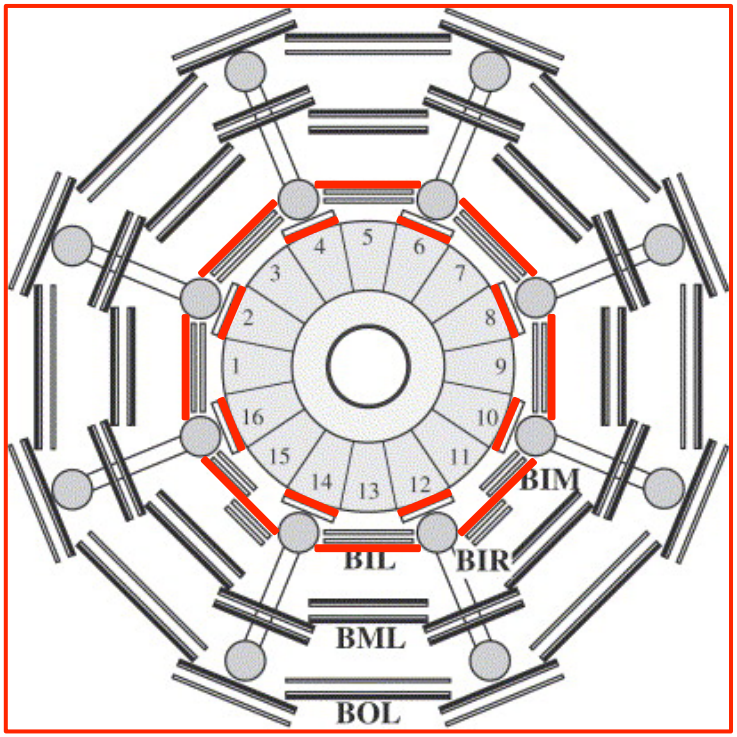
ATLAS RPC phase-2 proposal

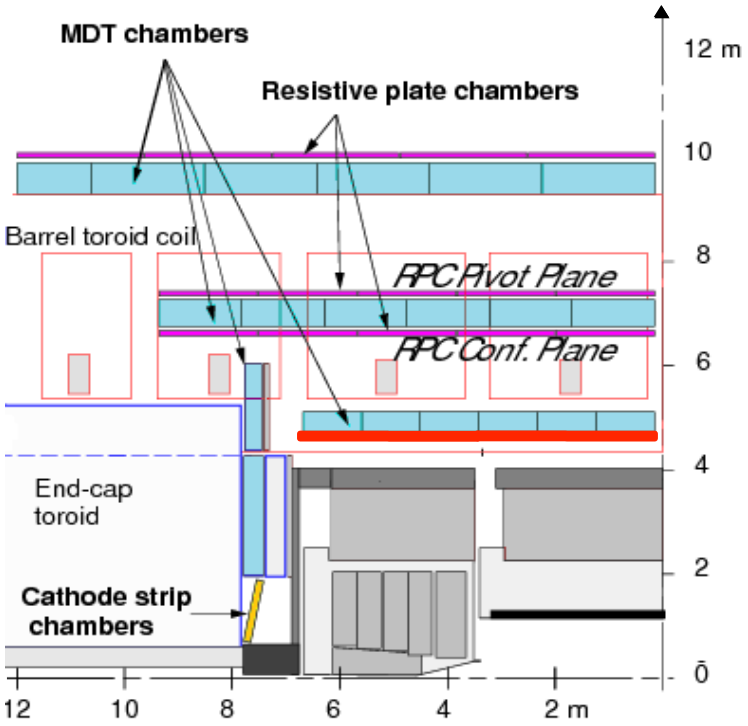
Completion of the detector for the barrel muon trigger via the installation of new trigger stations in the inner layer of the spectrometer (currently equipped only with MDTs)

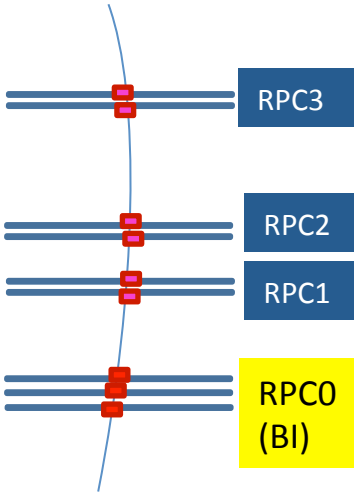
Increase the number of measurement stations from 2 → 3

Increase the number of independent layers from 6 → 9

Cost (very preliminary): 3 MCHF(detector+FE elx) + 1.7 MCHF trigger elx







RPC + MDT trigger at L0

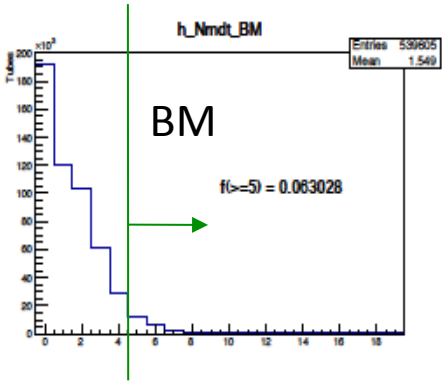
M.Corradi

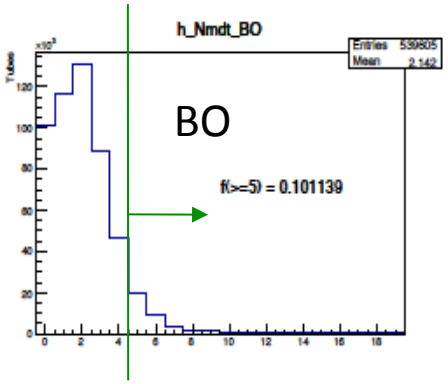
First studies with MDT L0 trigger, to be further investigated

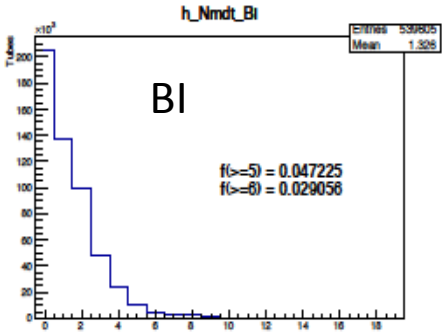
Not included in the draft document for LHCC

RPC + MDT “tube count” trigger

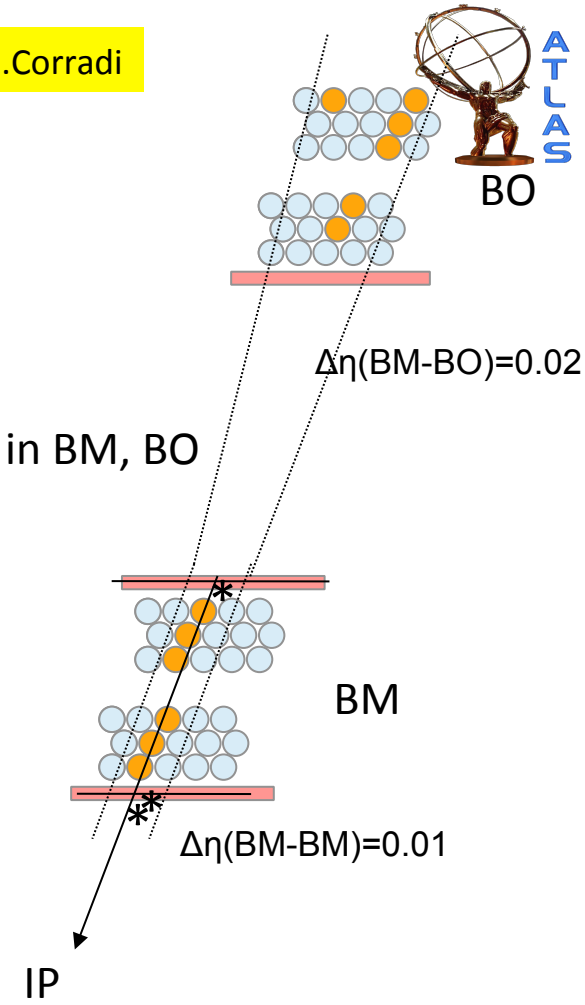
- “loose” RPC trigger (2/3 stations) and MDT tube segments in BM, BO
- ”tube segments” made in a road defined by the RPCs







Num of hits in “tube segments” data overlays with μ=140



See https://indico.cern.ch/event/355902/contribution/0/material/slides/0.pdf

Studies of RPC trigger performance

Evaluate efficiency and rates for:

- RPCs
- RPCs + new-RPCs on BI 4-6
- RPCs + new-RPCs on BI

- RPCs + MDT L0 (2 st.)
- RPCs + new-RPCs on BI + MDT L0 (3 st.)
- RPCs + new-RPCs on BI 4-6 + MDT L0 (3 st.)

RPC hit efficiency

Two scenarios considered (G. Aielli):

- constant RPC hit efficiencies at 80% everywhere
- variable RPC hit efficiency to keep rate current below equivalent of 100 kHz/cm2

Efficiency \ Station ID eta	0	1	2	3	4	5	6
BOL		90	90	82	82	76	74
BOS	89	90	90	90	89	66	60
BML		88	88	88	83	56	56
BMS		90	90	90	87	81	81

Note: present average efficiency ~95% (peak at 98%)

Two MC single muon samples:
- constant RPC efficiency
- variable RPC efficiency (chamber-by-chamber)

Trigger efficiency

Efficiency based on dedicated single-muon samples

Similar results obtained with the two RPC hit simulations

Trigger	RPC hit eff. 56-90%	RPC hit eff. 80%	
RPCs	0.65	0.63	Low
+BI RPCs (stations 4-6)	0.82	0.77	Medium
+BI RPCs (fulll)	0.94	0.94	High
RPCs + MDT BM-BO	0.81	0.81	
+BI RPCs (stations 4-6)	0.89	0.88	
+BI RPCs (full)	0.95	0.94	

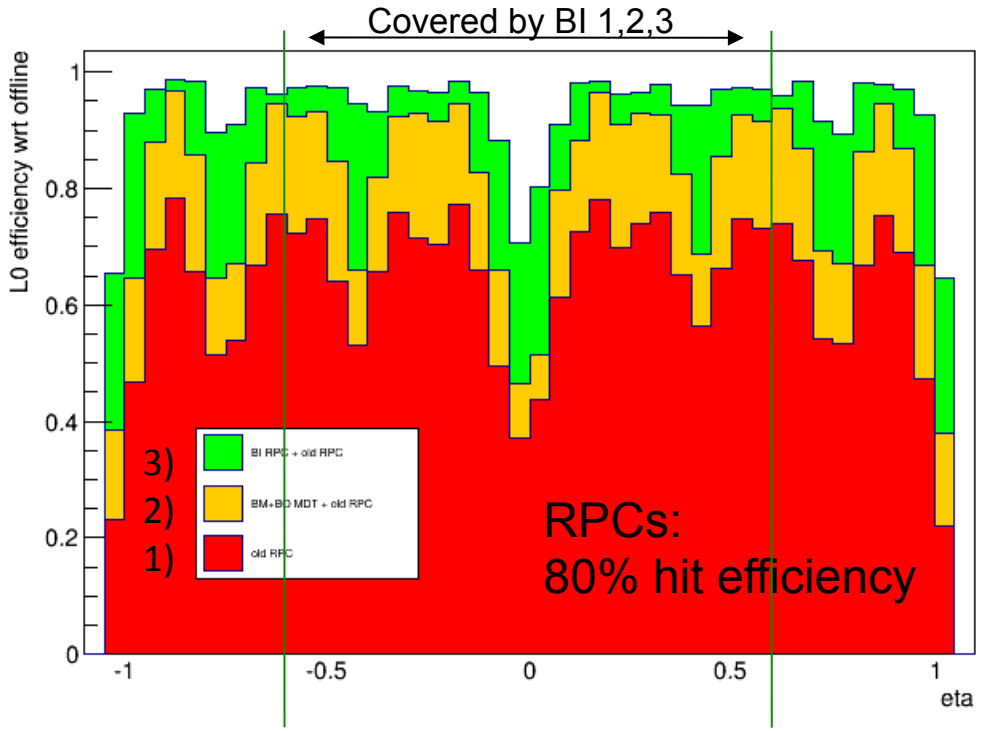
Table 2. Efficiency of the L0 trigger in the range $|\eta| < 1.05$, calculated with respect to offline reconstructed muons, for different trigger options and for different assumptions of the hit efficiency of the old RPCs.

Trigger efficiency vs eta

1) RPCs 3/3 stations [*majority: 3/4 (rpc1+rpc2) * 1/2 (rpc3)]*

2) (RPCs *2*/3 stations [*majority 3/6 layers*]
+ MDT "tube segments" on BM [maj. *5/6*] + BO [maj. *5/6*]) OR (1)

3) (BI RPCs + RPCs 3/4 stations [*majority: 2/3 BI, 3/6 old RPCs*])
OR (RPC BI * RPC BO) OR (1)



Rate estimation

Rate estimated with data overlays at ntuple level *(work in progress)*:

Mix zero-bias events from filled and empty bunches to emulate HL-LHC conditions
Start from run at 25 ns (no correction for energy and different layouts)

Results for μ=140 *(to be recalculated for μ=200 as from ATLAS requirements)*

Barrel Trigger cnfiguration	Rate (kHz)	Comments
RPCs	15	
RPCs + MDT(BM+BO)	52	without road optimization
RPCs + BI RPCs (3/4 layers)	<32	without road optimization

No BI RPC in data → BI rate difficult to estimate

Simple emulation with MDTs largely overestimates the rate
(no phi, long time window)

Studies of BI project feasibility

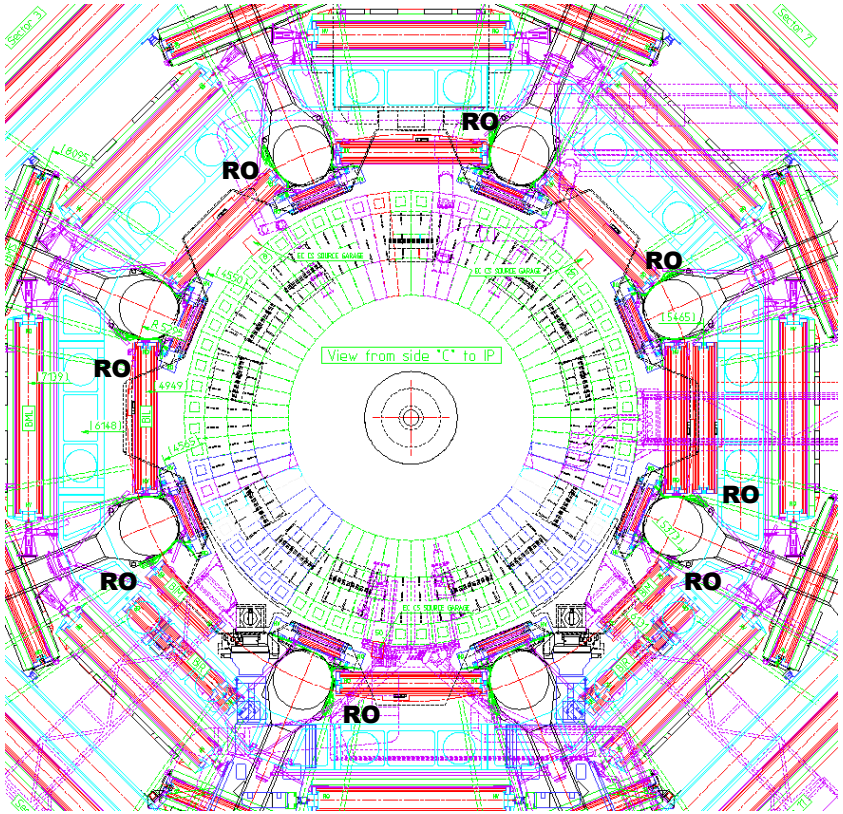
Tatiana Klioutchnikova

Actions to be performed:

- Replacement of BI layer MDT front end electronics
- RPC installation in BI layer of chambers

Two options considered (preliminary):

1. Moving BI chambers to surface
2. Without BI chambers removal to surface



Estimates for BI project

Tatiana Klioutchnikova

Already advanced for MDTs …

Option 1:

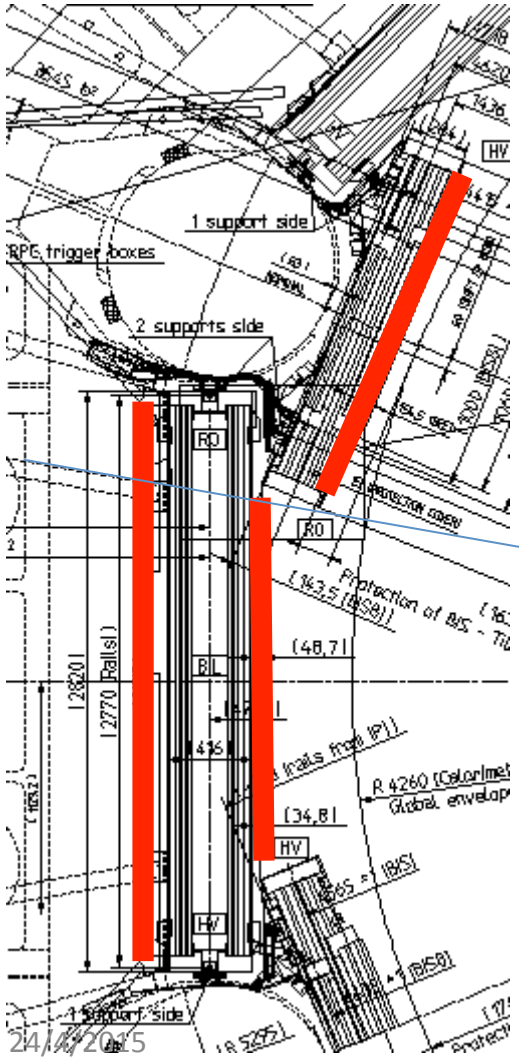
Detailed estimation of number of days for removal and re-installation of BIL, BIS chambers, replacement of electronics and tests in BB5 for sides A and C

Option 2:

Electronics accessible by sliding BIL chambers by ~60 cm
Need judgement from MDT electronics experts about replacement operation

Additional RPC in the BI region

Tatiana Klioutchnikova



Following variants can be proposed for the investigation:

For BIS:

- To insert RPC on the inner side between BIS and calorimeter surface
- To replace BIS chambers by sMDT with RPC attached to it taking together the same envelope as the existing MDT

For BIL:

- To install RPC on the MDT inner side
- To install RPC on the MDT outer side

No time nor manpower estimation yet

Work is in progress

Scoping document scenarios

Draft version to be presented at LHCC in June 2-4

Three options: 200 (Low), 235 (Medium), 275 (High) MCHF defined by ATLAS management/USC/project leaders

	LoI	Low	Medium	High
TGC electronics	yes	yes	yes	yes
RPC electronics	yes	yes	yes	yes
MDT electronics	BM,BO,EM	BM,BO,EM, (+EIL4)	BM,BO,EM, (+EIL4)	all
MDT L0 trigger	2-station	2-station	2-station	3-station
sTGC BW inner ring	yes	yes	yes	yes
sRPC on BI	no	no	BI4 to BI6	yes
sMDT on BI	no	no	BI4 to BI6	yes
High-Eta tagger	no	no	no	yes
Power system	no	yes	yes	yes

Muon working group for the scoping document

Muon costing group:

- Oliver Kortner (MDT electronics and trigger, sMDT chambers)
- Tatsuo Kawamoto (High-eta options)
- Agostino Lanza (Power System)
- Giulio Aielli (RPC chambers)
- Riccardo Vari (RPC trigger & chair)
- Osamu Sasaki (TGC trigger)

Cost estimates status:

- MDT: complete estimate for the three scenarios
- RPC: complete estimate for the three scenarios
- TGC: a few numbers missing
- High-eta tagger: estimate to be completed
- Power System: some initial discussions with CAEN planned for coming months, but do not expect a solid estimate on the time scale of the scoping document
- Cost detail in last Muon Week - Upgrade Cost session: https://indico.cern.ch/event/376177

Next steps:

- complete all the cost estimates, clearly separate TDAQ/Muon contributions
- compare assumptions between different areas and make them consistent, then systematic comparisons and scrutiny

Summary

- Trigger electronics has to be replaced
- Barrel trigger options are the main addition to LoI:
  - "efficiency loss scenario" for RPCs defined
  - RPC efficiency consistently re-evaluated
  - rate estimates in progress
- Project feasibility studies ongoing (accessibility/installation issues)
- Costing group finalizing the cost estimates