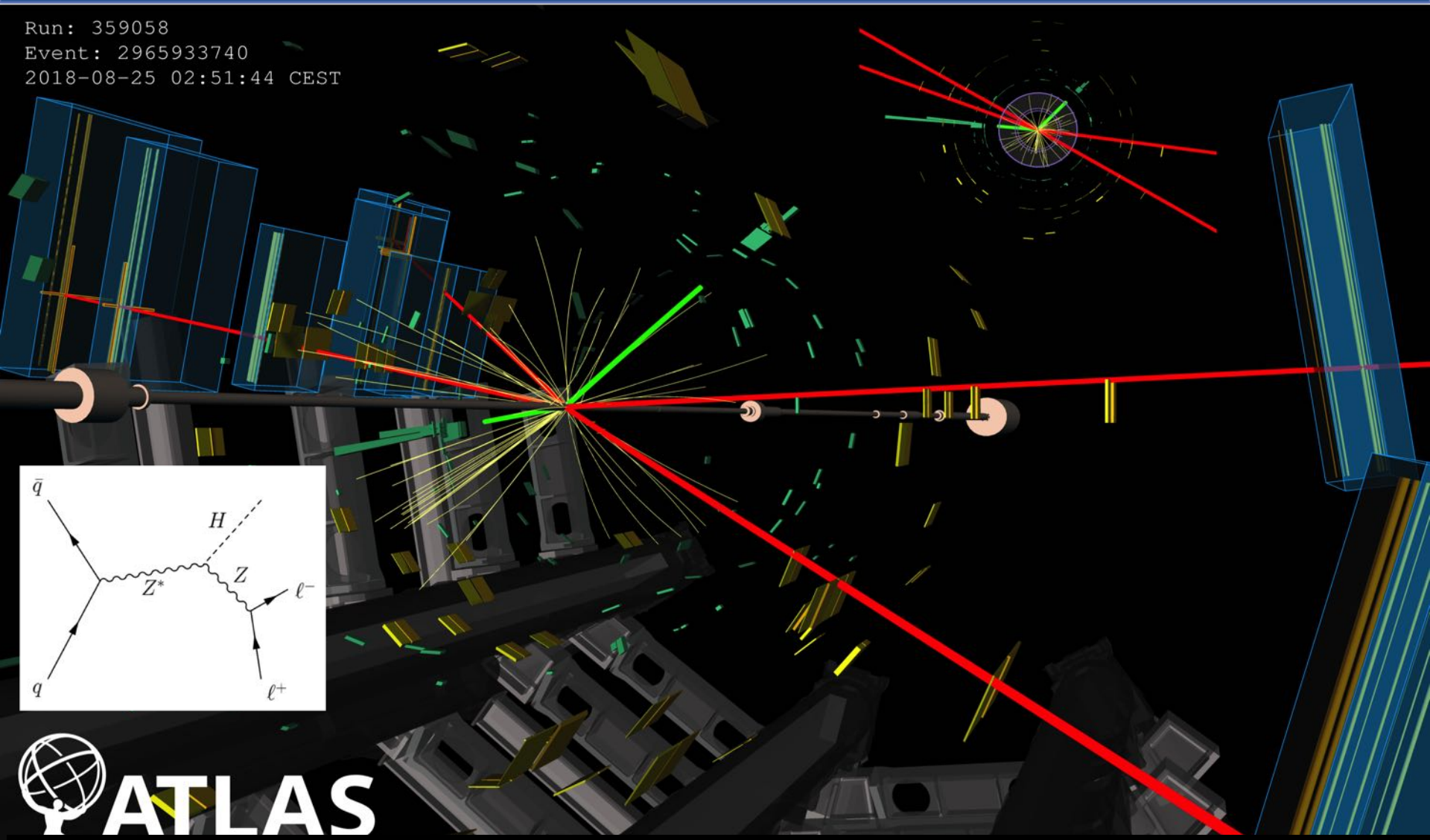
Studies of gas gaps current density in the ATLAS RPC detector during 2018 data taking at Large Hadron Collider

Dimitrii Krasnopevtsev* on behalf of ATLAS Muon Collaboration

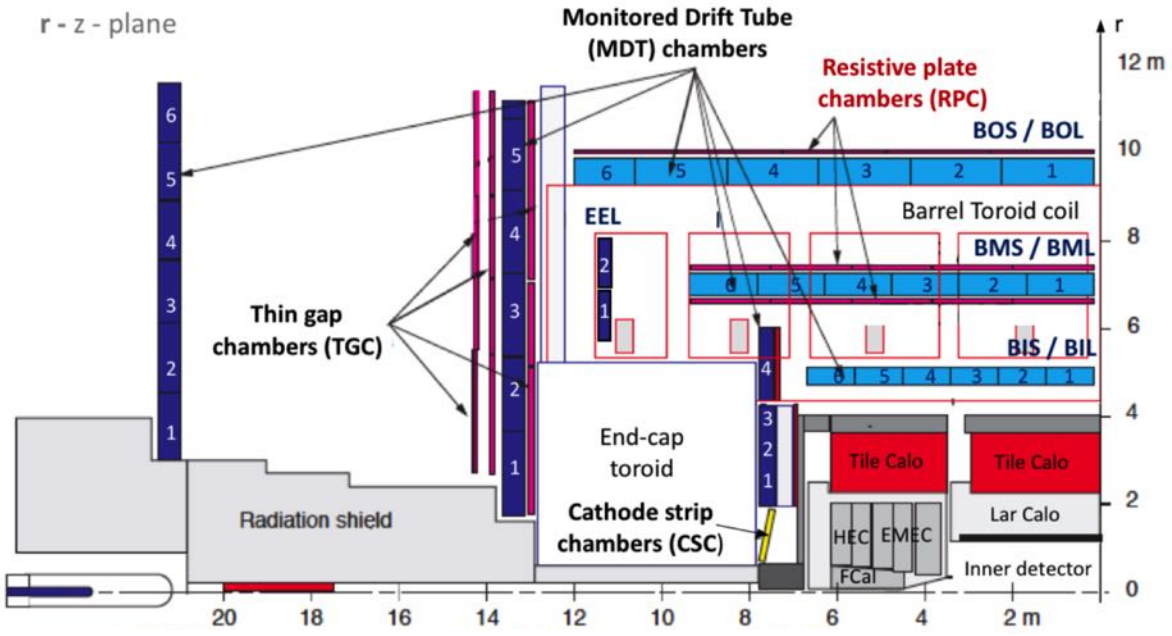
**University of Science and Technology of China*

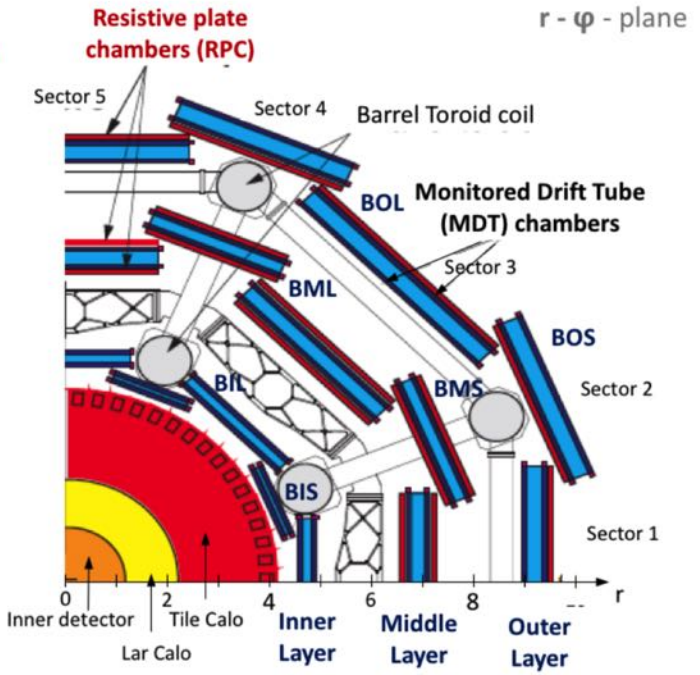
Z(μμ)H->Z(μμ)Z(ee) candidate



RPC successfully contributes to ATLAS Level 1 trigger since first collisions at LHC in 2009.

ATLAS RPC



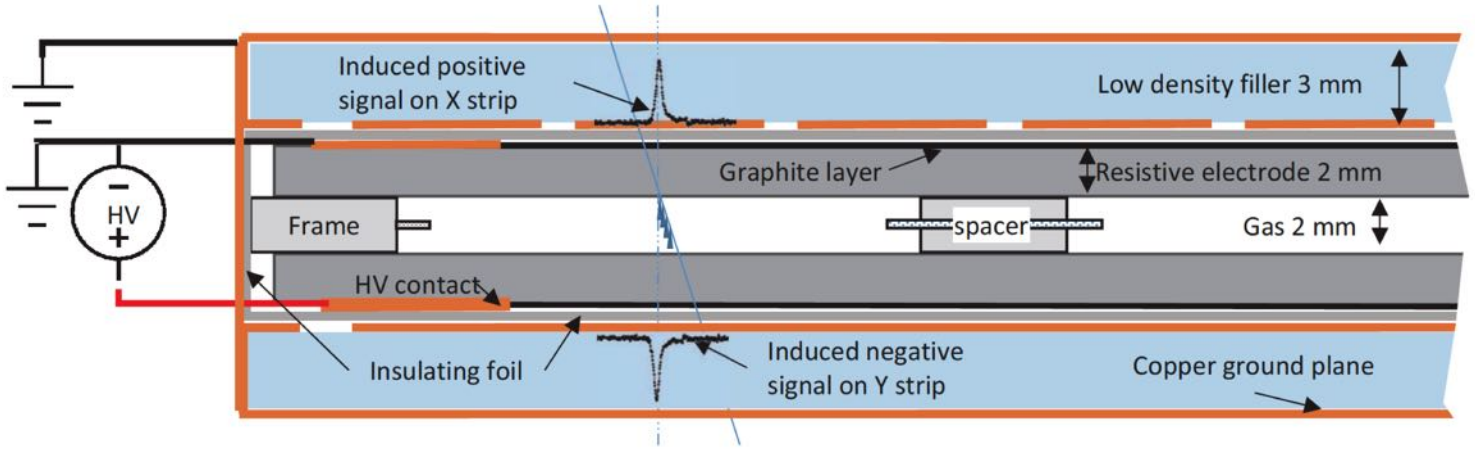


- The RPCs are placed in the barrel region of the ATLAS experiment: they are arranged in three concentric double layers at radius 7 m and 10 m, operating in a toroidal magnetic field ~0.5 T
- RPC detectors cover the pseudo-rapidity range $|\eta| < 1.05$ for a total surface of about 4000 m² and ~3700 gas volumes: 16 sectors in φ direction and 12 stations in η directions.
- The ATLAS RPCs have been certified to operate up to an integrated charge of 0.3 C/cm². This corresponds to ten years of LHC operation at a counting rate of 100 Hz/cm².

More details in Heng's talk and also in backup.

RPC gas volume

- Each RPV detector is made of two bakelite gas volumes with a 2 mm gap, operated in avalanche mode at 4.8 kV/mm with automatic correction for temperature and pressure variations with respect to the reference values of 24° C and 970 mbar.
- Gas mixture: tetrafluoroethane, iso-butane, sulphur hexafluoride - 94.7 : 5.0 : 0.3 %.
- Detector operates in saturated avalanche mode at 9.6 kV (standby mode – 9.0 kV).
- All gas volumes have individual readout, measurements are available through ATLAS Detector Data Control System (DCS).



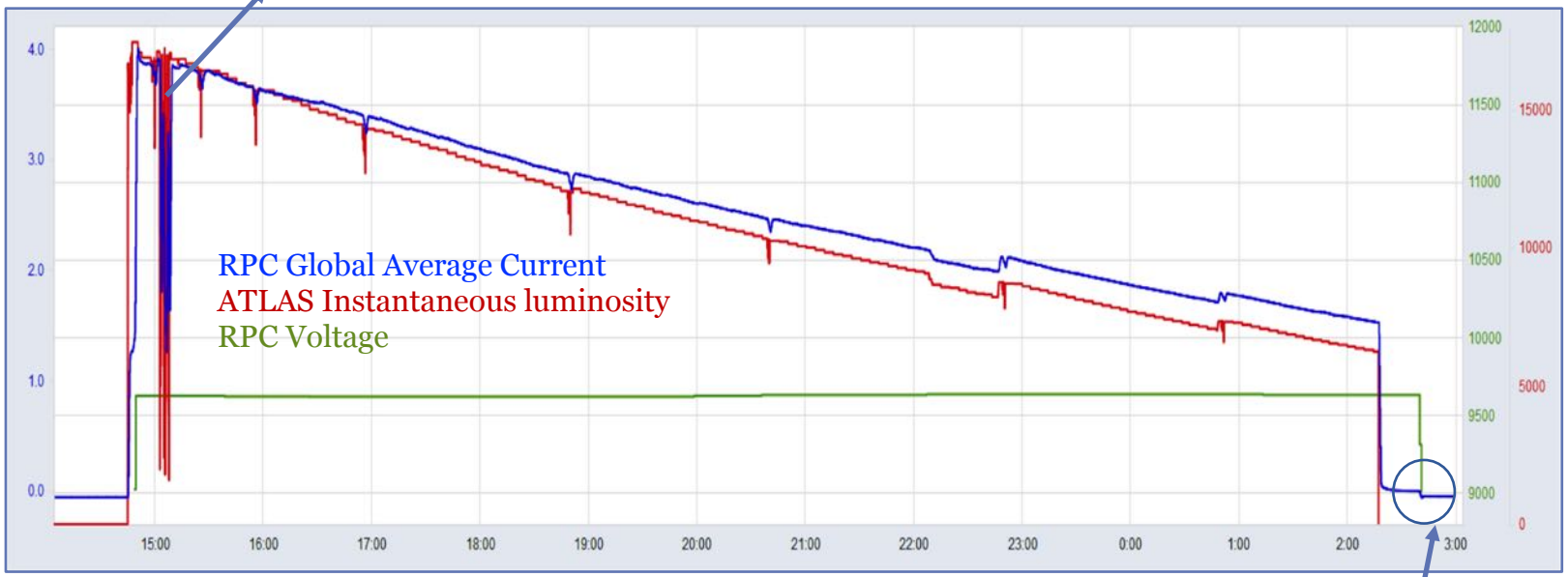
Gas gap current studies: motivation

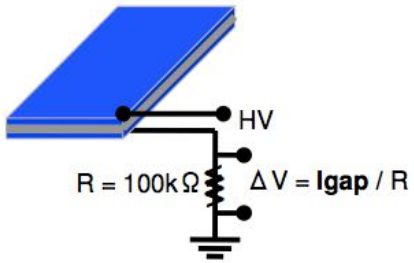
- Confirm expected linear increase of gas volumes current up to the highest instantaneous luminosities – crucial feature for stable RPC performance;
- Understand gas volume current density at different voltages during data taking in 2018 and make extrapolations for future (High Luminosity LHC regime);
- Check the status of RPC gas volumes: gas purity, surface issues.

Studies with the collisions

Gas volume current measurements

Time intervals during beam positions adjustment are excluded from the study.

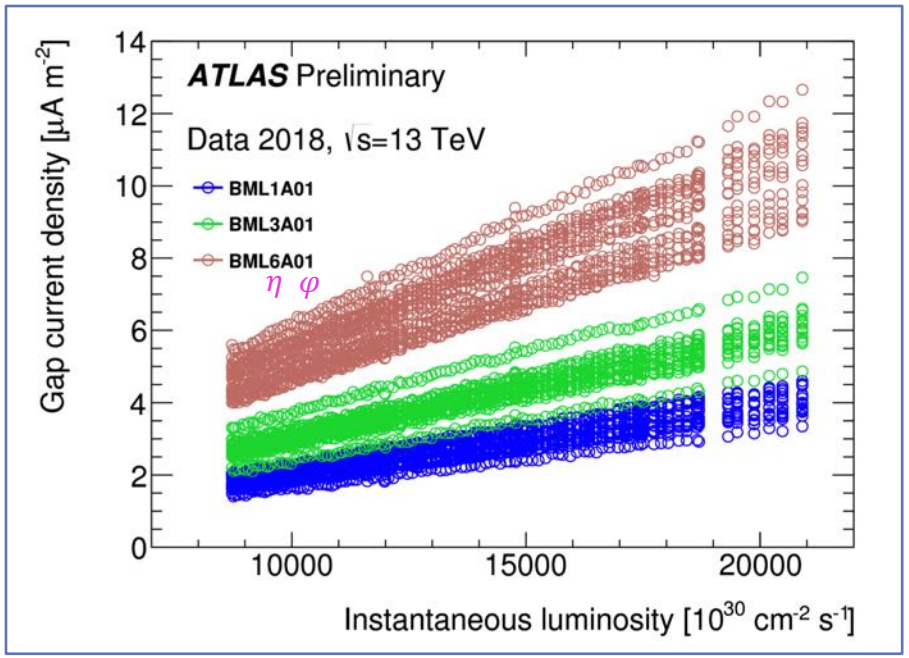


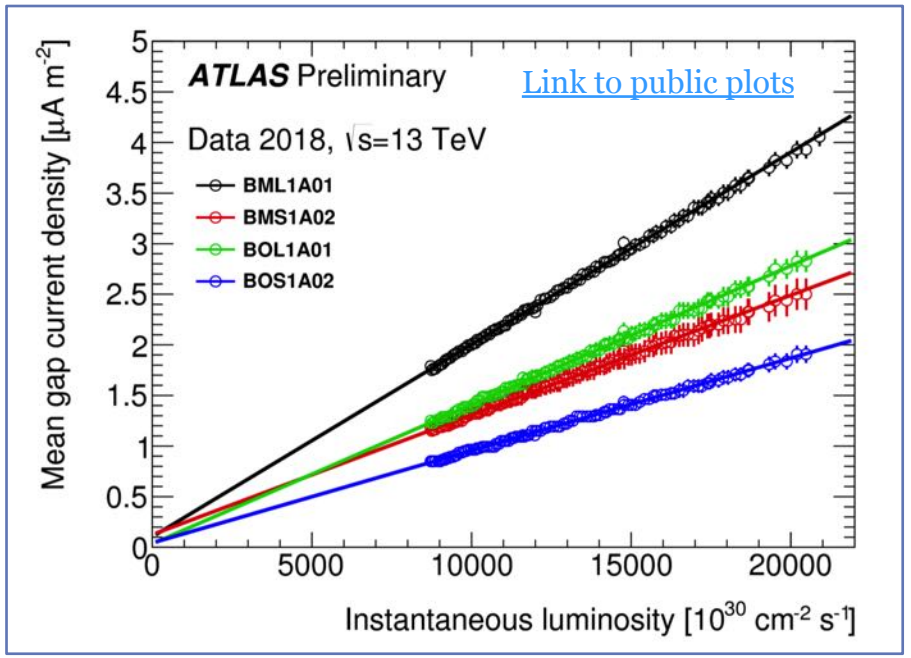


- Current in gas volumes at nominal voltage but without collisions (calibration current) was subtracted .
- Gas volumes currents are normalized to gap area.

Current vs instantaneous luminosity

✓ Representative collection of highly performing gas volumes are selected.



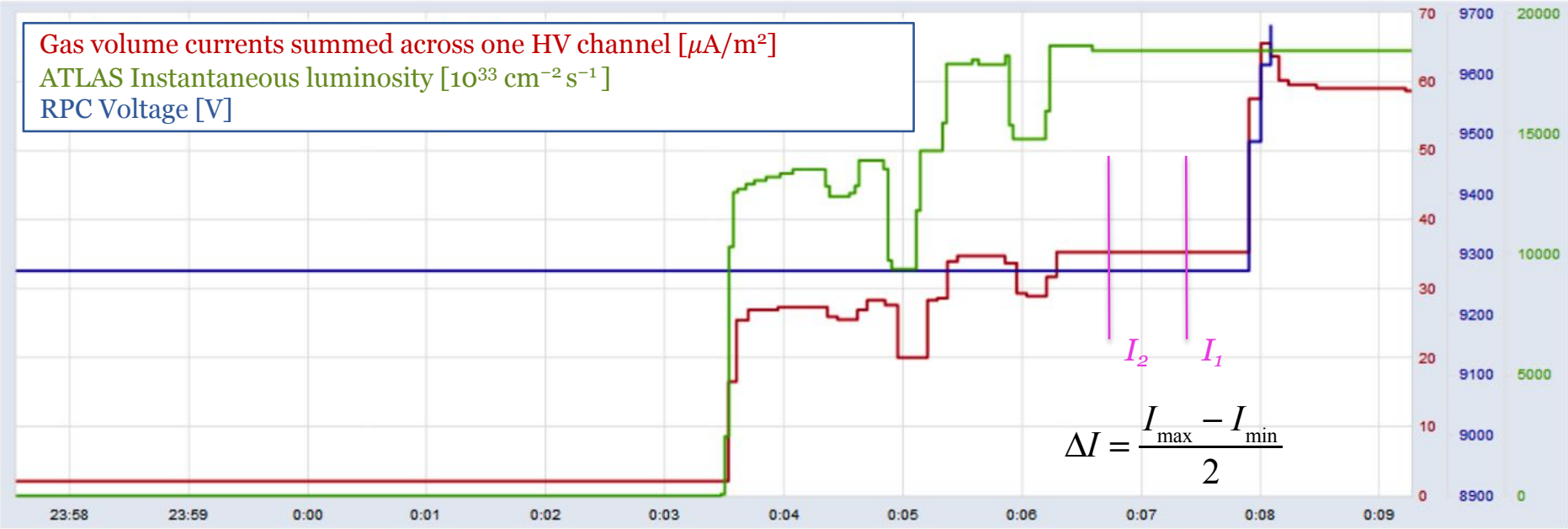


Expected linear increase was confirmed up to the highest instantaneous luminosity during the 2nd data taking period for various RPC gas volumes.

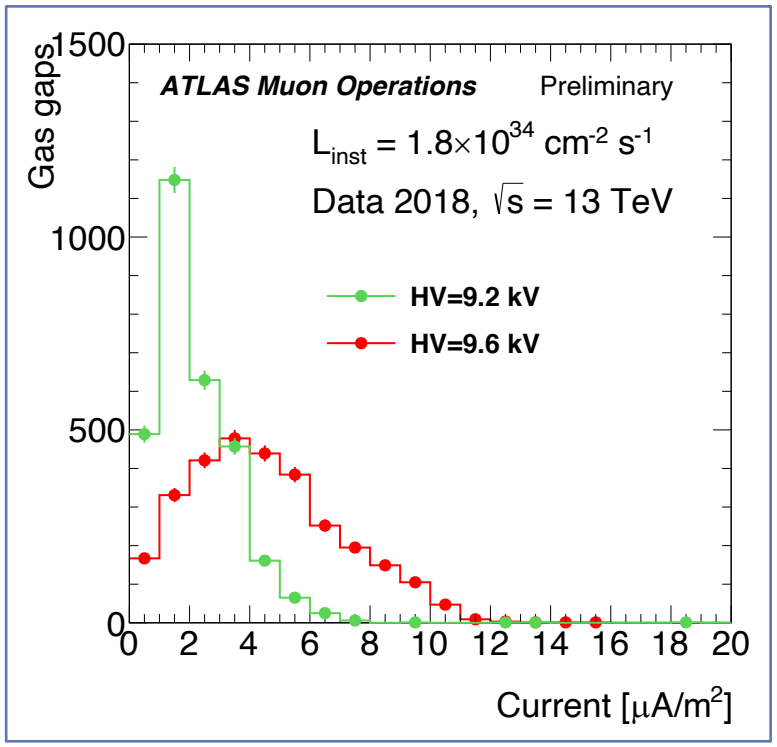
HV scans

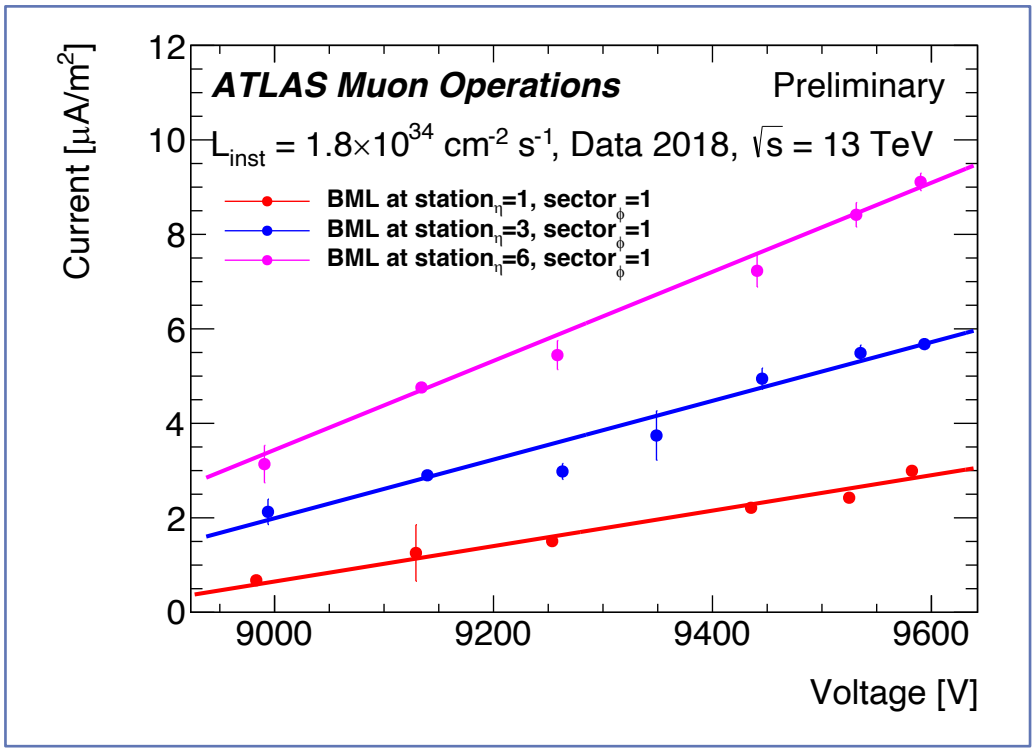
Procedure:

- 5 scans (~ 5 min each) at the beginning of physics runs with HV=9.1/9.2/9.3/9.4/9.5 kV – *range is chosen to address future possible RPC working conditions;*
- two standard working points: HV=9.0/9.6 kV;
- luminosities are corrected to $L=1.8\times10^{34}\ cm^{-2}\ s^{-1}$ (largest correction 3%);
- HV values are corrected for temperature and pressure effects;
- data extraction was performed 2 times to estimate systematic uncertainty.



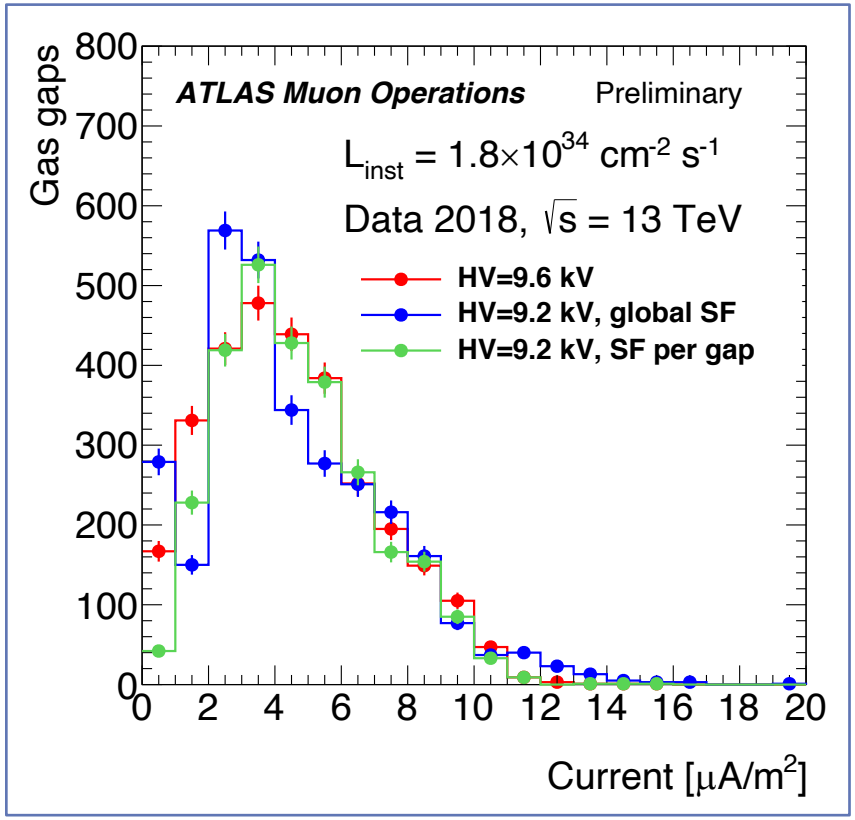
Current vs HV





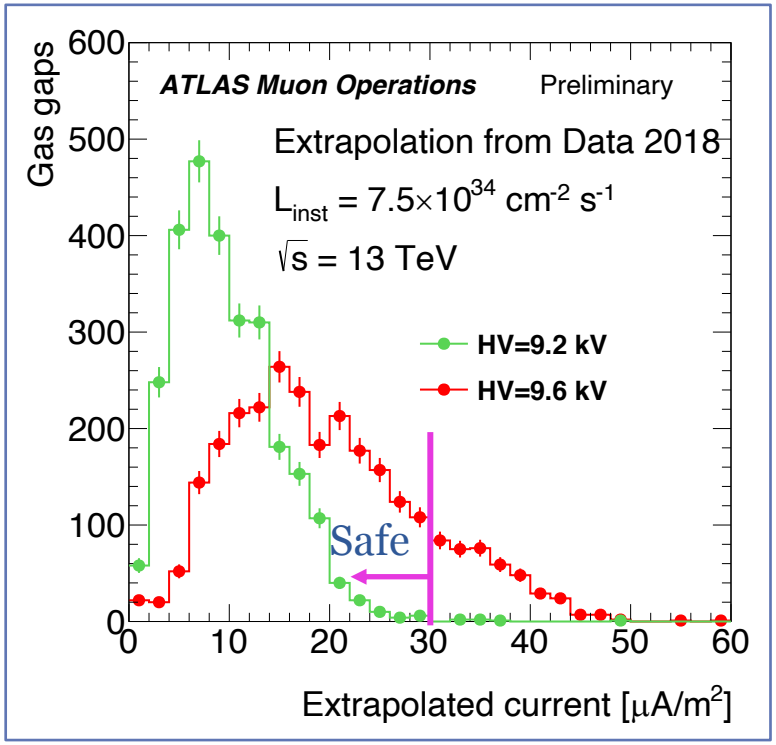
- ✓ Gas volumes currents do not exceed 12 μA/m^2 at HV=9.6 kV and instantaneous luminosity 1.8x10^{34} cm^{-2} s^{-1} during data taking in 2018.
- ✓ Gas volumes current density dependence from HV at beam conditions can be linearly described at V=9-9.6 kV.

Current vs HV



- ✓ Scale factors are derived from the linear fit of gas volume current density as function of voltage:
  - ➢ global SF=2.13 is based on the most common linear fit parameters along all gas volumes;
  - ➢ Individual SFs are derived per gas volume.
- ✓ SFs from linear approximation can be used to obtain gas volume current densities within HV=9-9.6kV. Scaling per gas volume is more precise.

Current vs HV and extrapolation at HL-LHC



Luminosity scaling:
Gas volume current linearly depends on instantaneous luminosity => scale factor=7.5/1.8

Safe threshold for current: 30 μA/m²
based on results reported in Muon Phase II upgrade report ATLAS-TDR-026, i.e. RPC integrated charge is less than 30 mC/cm² per year (assuming LHC run 33% of time).

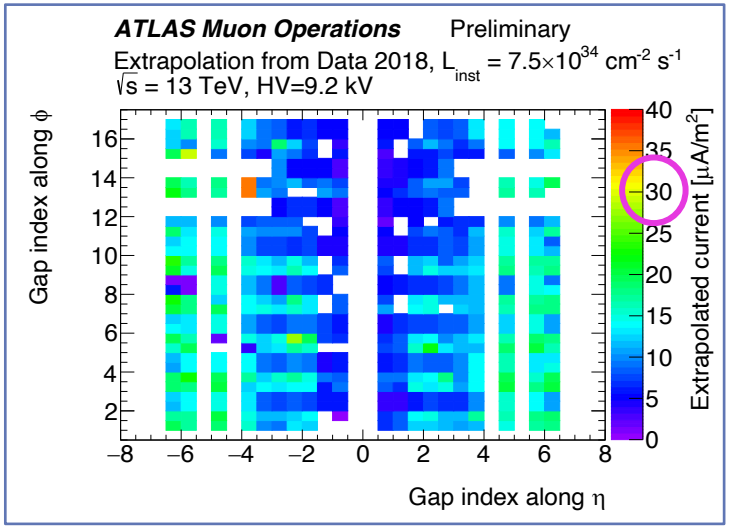
In some gas volumes current exceed safe threshold at V=9.6 kV and L=7.5x10^{34} cm^{-2}s^{-1}.
It can be solved by lowering HV from 9.6 to 9.2 kV, but reducing efficiency.

Current vs HV, HL LHC

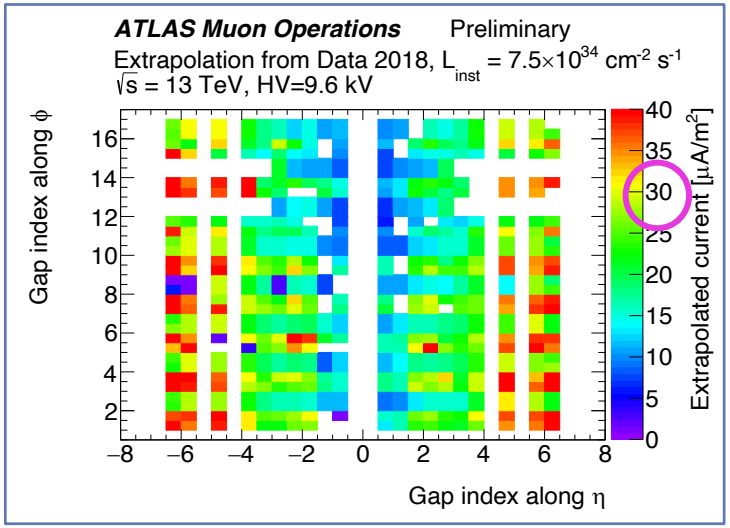
Safe thresholds are shown by pink circles,
rate map includes additional safety factor of 2

9.6 kV

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	342	280	301	225	145	114	128	101		61	61	71	113	122	127	136	214	276	269	285	180
01.02	293	281	303	218	159	133	129	143		76	71	75	127	143	140	148	215	295	278	297	188
2	168	204	188	138	109	90	77	63	55	56	45	48	61	79	94	104	140	207	196	152	115
03.01	297	296	281	198	148	128	119	119	68	67	65	71	131	125	114	125	207	329	268	290	177
03.02	300	243	277	210	151	129	155	122	85	75	75	70	122	127	152	132	207	315	243	299	179
4	112	166	158	151	101	83	65	77	41	53	46	41	73	68	92	108	160	196	175	112	101
05.01	171	173	263	138	105	102	140	127	68	60	60	69	124	177	102	137	185	290	173	171	149
05.02	227	198	237	158	109	105	136	143	77	61	63	71	111	136	108	141	200	267	255	282	159
6	175	186	208	163	105	95	90	95	77	59	52	59	84	81	106	124	189	200	227	167	131
07.01	305	263	288	191	154	129	131	114		76	78		122	139	124	148	185	261	268	305	183
07.02	327	258	216	203	141	112	129	108		74	77		105	114	112	152	184	278	276	279	175
8	146	196	195	161	103	85	80	70	50	57	54	54	67	74	85	108	168	196	194	156	118
09.01	319	246	301	206	155	117	149	119		46	64		106	134	124	135	197	283	262	297	181
09.02	347	258	287	205	143	95	107	103		58	67		99	112	95	137	188	285	265	292	174
10	174	201	207	147	99	86	68	71	46	43	41	50	64	69	80	103	148	193	201	170	115
11.01	308	244	237	157	97	84	81	87		40	43		83	94	92	94	148	227	215	278	132
11.02	196	193	157	105	78	66	55	57		33	31		50	62	58	71	98	151	160	185	98
12						80	81	66	51	36	36	51	75	87	80						64
13.01	291	278	253		140	102	96	84	43	41	47	50	87	95	99	123		249	263	319	149
13.02	299	264	262		104	97	105	86	49	48	50	56	93	103	97	110		252	227	294	146
14						142	68	64	52	41	40	49	63	68	136						76
15.01	196	221	148	113	76	71	67	49		38	36		50	59	86	87	104	156	173	196	104
15.02	183	159	246	164	116	98	103	75		44	43		75	106	112	107	158	248	159	183	133
16	173	214	216	173	108	89	54	75	56	59	50	50	77	54	87	103	177	209	208	154	124
Average	229	223	234	167	118	101	86	88	56	52	51	56	86	97	103	118	171	240	221	221	137

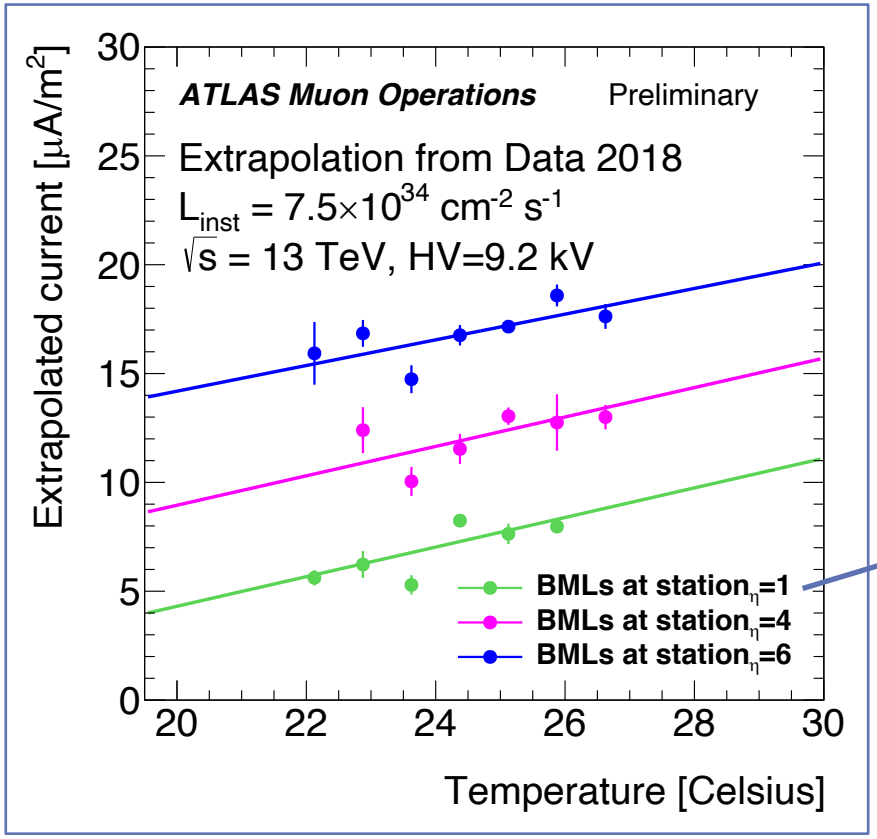


BM chambers

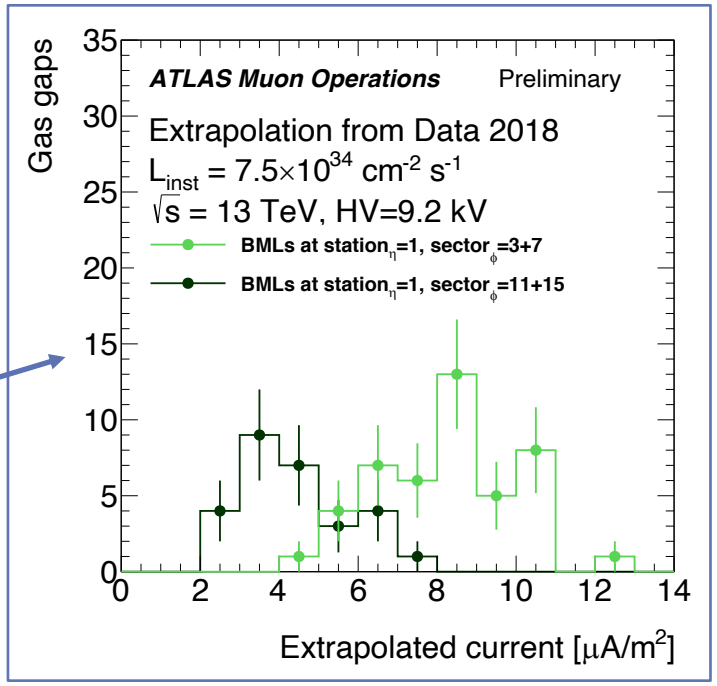


- 2D φ-η map confirms that lowering HV to 9.2 kV helps to address the issue with overcurrent in affected gas volumes at HL LHC conditions.
- Right plots show some increase of gas volume current density as function of φ index, which is consistent with the temperature increase gradient in ATLAS cavern (please see next slide).

Temperature studies



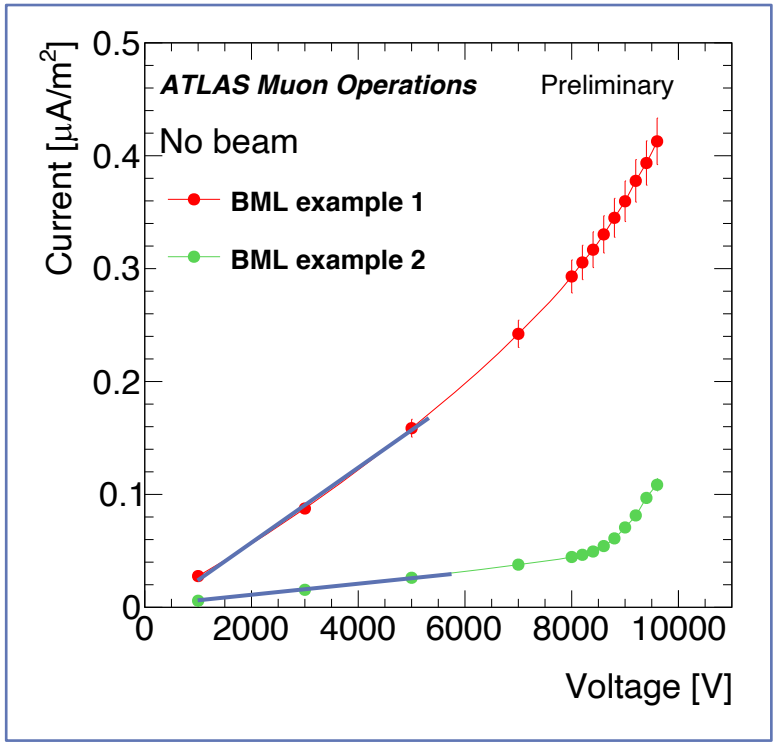
RPCs at φ sectors 3 and 7 (in the top half of ATLAS) have higher temperature than sectors 11 and 15 placed symmetrically on bottom of the detector.

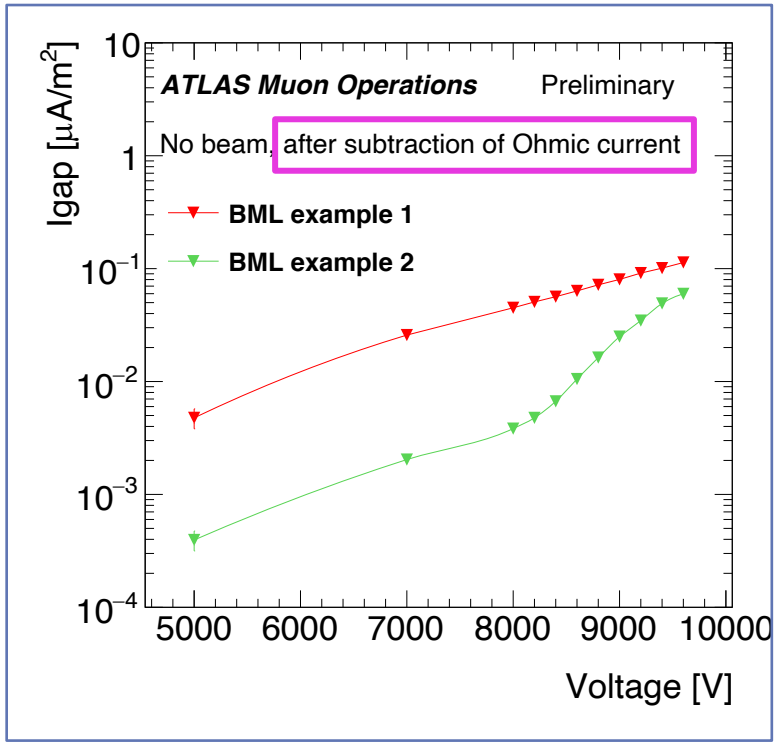


- Consistent increase of gas volume current density with temperature across the whole RPC was observed (~ 6 μA/m^2 per 10^{o}C).
- Gas volume current density increases from upper (3,7) to lower (11,15) φ sectors, confirming the previous statement.

Studies without the collisions

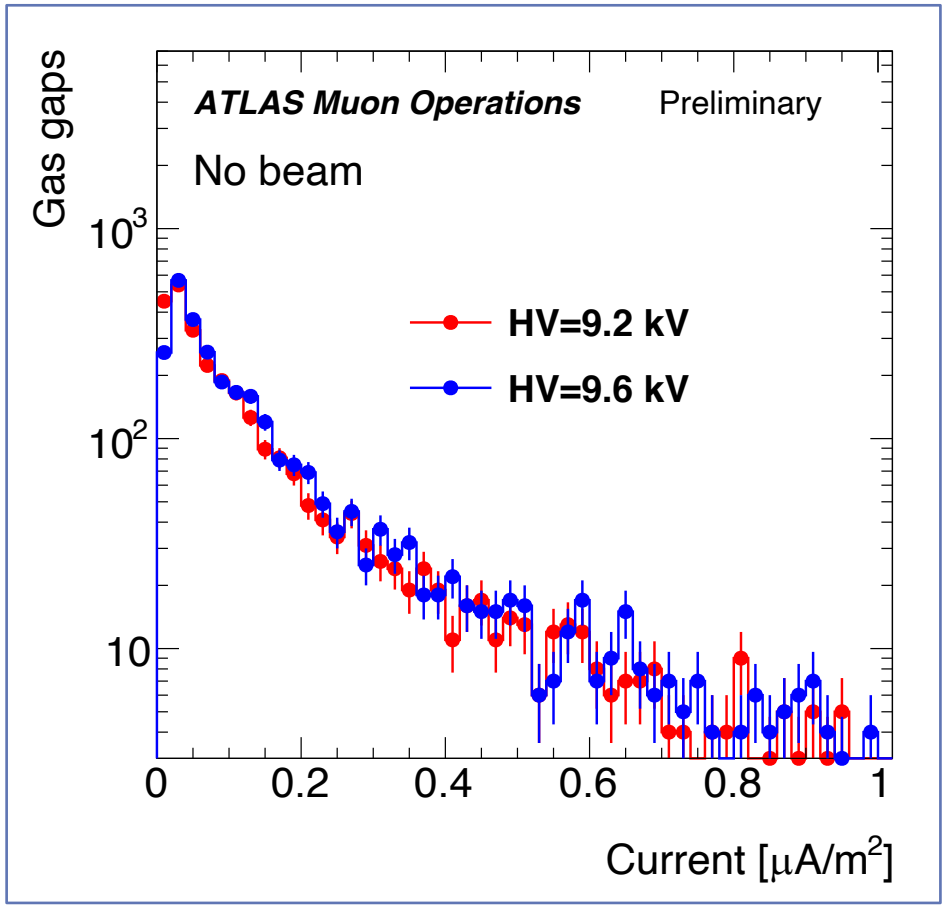
Current vs HV, no collisions





- Gas volumes current dependence from HV at beam conditions can be linearly described up to HV=6 kV (Ohm's law), then current density starts to increase exponentially with voltage. Right plot shows same curves after subtraction of Ohmic current contribution:
- Discrepancies between these two curves indicate difference in operation mode of this gas. For instance generally discrepancies in linear slopes are connected to a different level of cleanliness or deposition on frame and spacer surfaces. *Studies are ongoing*.

Current vs HV, no collisions



Through the entire detector a mean of gas volumes current density distribution increase by 15% from HV=9.2 kV to HV=9.6 kV, where 5% increase comes from the Ohmic contribution and the rest is from the avalanche growth. This result confirms good quality of gaps.

Summary

- RPC gas volumes currents were studied as a function of instantaneous luminosity, voltage and temperature for the condition with and without pp collisions.

- Studies at various luminosity and voltage showed:
  - expected linear increase of gas volume current was confirmed up to the highest instantaneous luminosity during the 2nd data taking period of LHC for various RPCs;
  - gas volumes current dependence from voltage at beam conditions can be linearly described at V=9-9.6 kV. Therefore gas volume currents can be scaled in a straightforward way between different voltages.

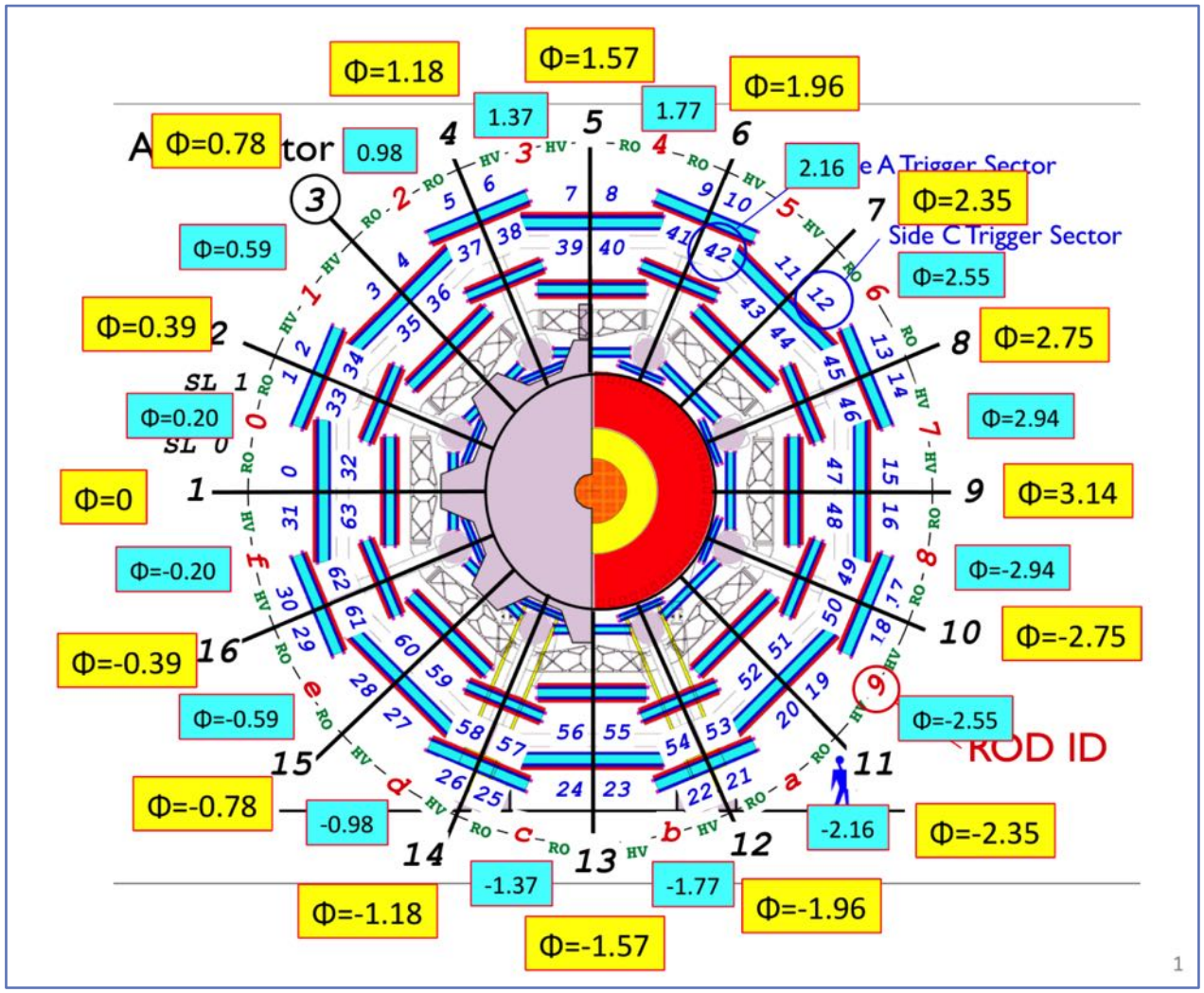
- Studies of gas volume current density extrapolations to HL LHC conditions showed:
  - lowering HV to 9.2 kV helps to address the overcurrent in affected gas volumes at HL LHC conditions, however with some drop of efficiency;
  - consistent increase of gas volume current density with temperature across the whole RPC was observed (~ 6 $\mu A/m^2$ per 10°C).

- Curves of gas volumes current as function of HV (without collisions condition) are efficient instrument to monitor gaps state.

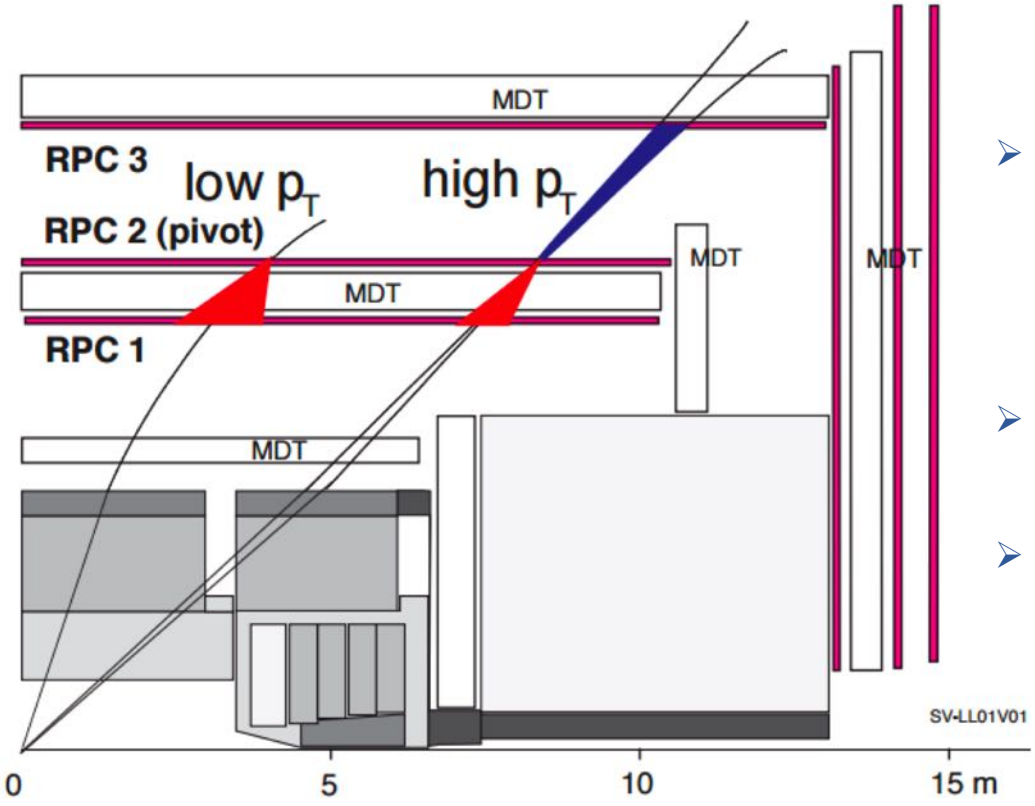
The end, thank you.

Backup

ATLAS RPC details view



RPC as a trigger



- L1 Muon Barrel trigger uses RPCs to detect muon trigger candidates at 40 MHz rate
  - Custom-built on-detector electronics making decision within 2.1 μs after collision
  - 3328 detector regions of 0.1x0.1 in $\Delta\eta$x$\Delta\varphi$
- 3 low pT thresholds:
  - Requires 3/4 coincidence within trigger road in the two inner doublet layers
- 3 high pT thresholds:
  - Requires low pT trigger and 1/2 coincidence in the outer doublet layer

Efficiency vs HV vs high gain threshold