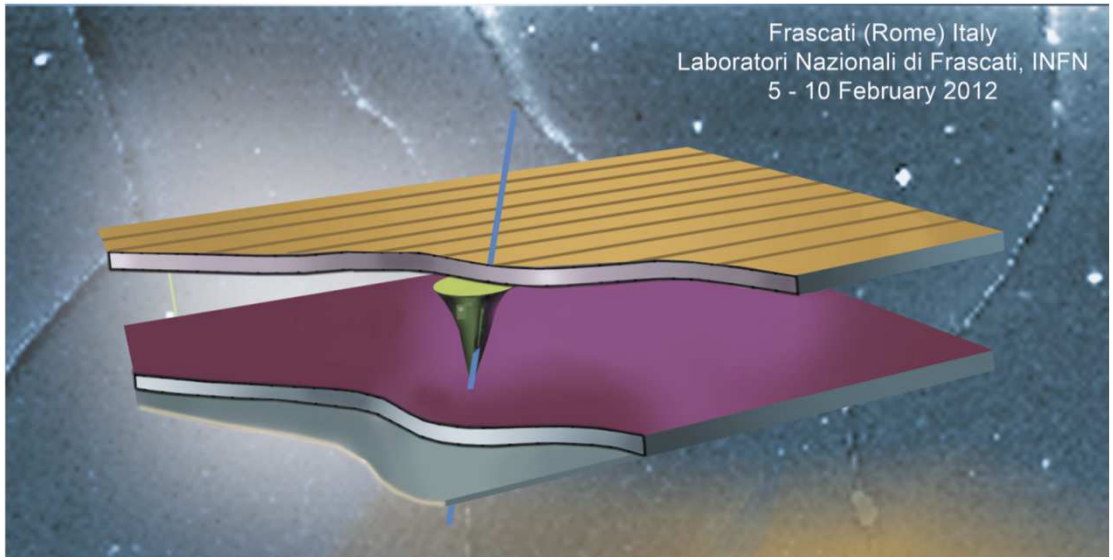
ATLAS RPC detector as Luminosity monitor

Marcello Bindi,
on behalf of ATLAS MUON Collaboration



XI workshop on Resistive Plate Chambers and Related Detector

07-02-2011

Outline and introduction

- Motivations and measurement overview:
  - from cavern background to luminosity
- RPC analog currents :
  - the measurement technique
  - overview of the main systematics (environmental factors, activation,…)
- Results obtained through RPC Standalone measurement
  - 2010 vs. 2011 comparison
  - activation signal observed and quantified
- First comparisons with ATLAS Luminosity Monitors
- Conclusions and outlook for 2012 LHC run

Starting point of the measurement: background studies with RPC

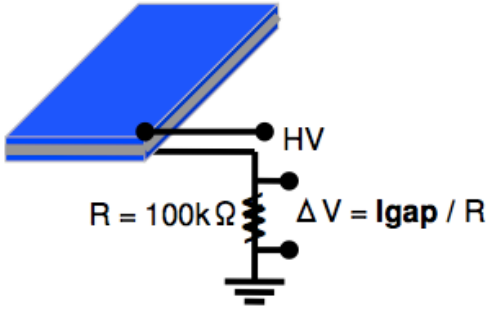
- Muon detectors are the largest instrumented volume in the ATLAS cavern; crucial for cavern background measurements (→*see G.Aielli talk for details*)
- **RPC** are spread on a wide surface (~4000 m^2) on the ATLAS Barrel Toroid: $|\eta|<1$ and $\rho > 7$ m (not influenced by beam halo).
- Possibility to give a completely independent measurement, able to cross-check data from several ATLAS Luminosity algorithms
- Assumption that background currents in the barrel and luminosity scale linearly. This should be true unless the conditions of the beam background suddenly change

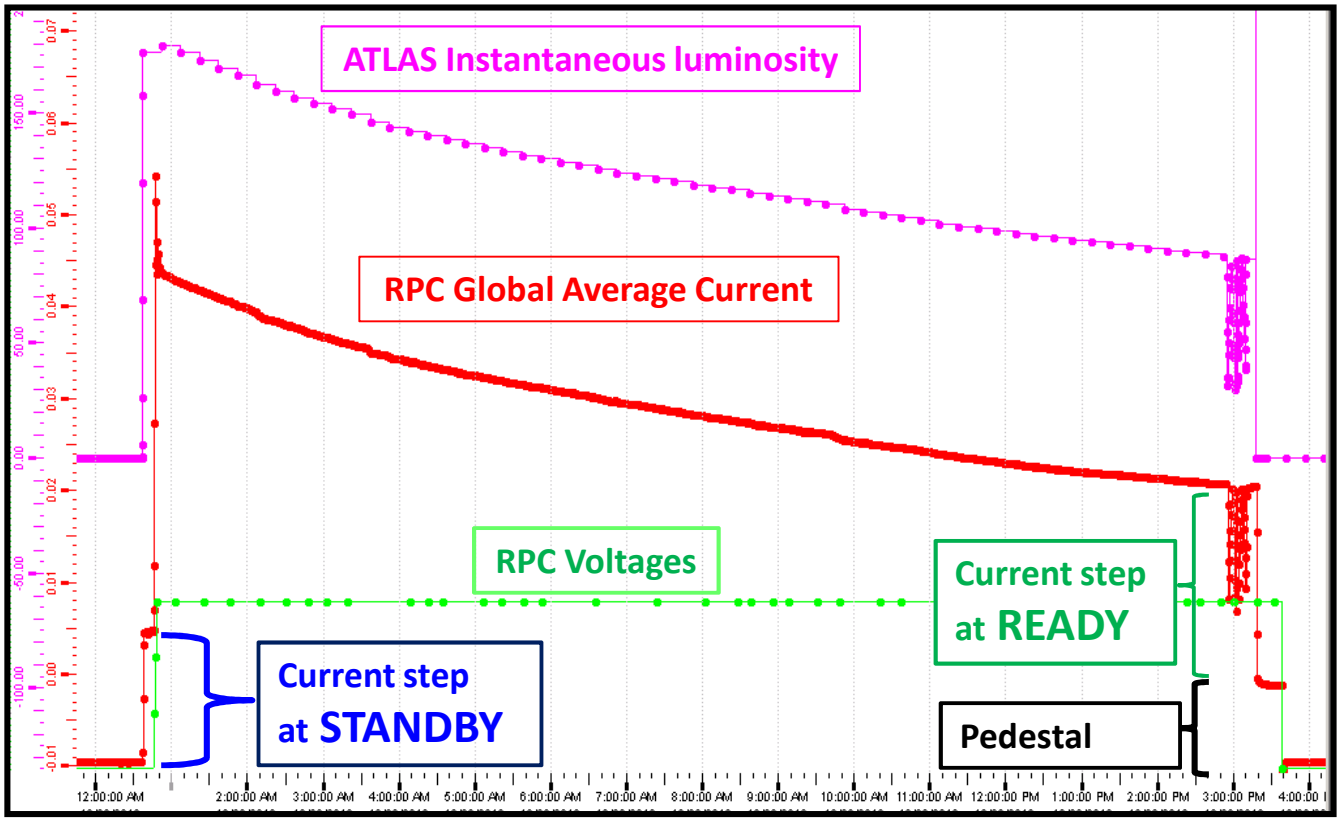
☺ Measurement done and monitored in real-time through the DCS
→ **DAQ and pile-up independent; unbiased by trigger configuration**
☺ Very low RPC current noise → **High sensitivity**

☹ Long integration time (~ 30 seconds): needed during the initial phase at low luminosity to have an accurate value (good signal/background ratio)
→ Faster spikes are integrated
☹ No particle discrimination and granularity limited to a gas volume

RPC GAP currents measurement

Current readout scheme





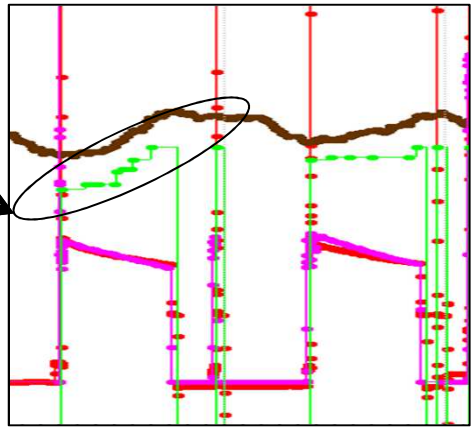
- 3592 gas gaps (~2 m^2 each) distributed in the barrel and individually read out:

→ measuring **RPC Average Current Density step** vs. **ATLAS Inst. Luminosity** at **Injection (STANDBY)** and at **Dump (READY)**

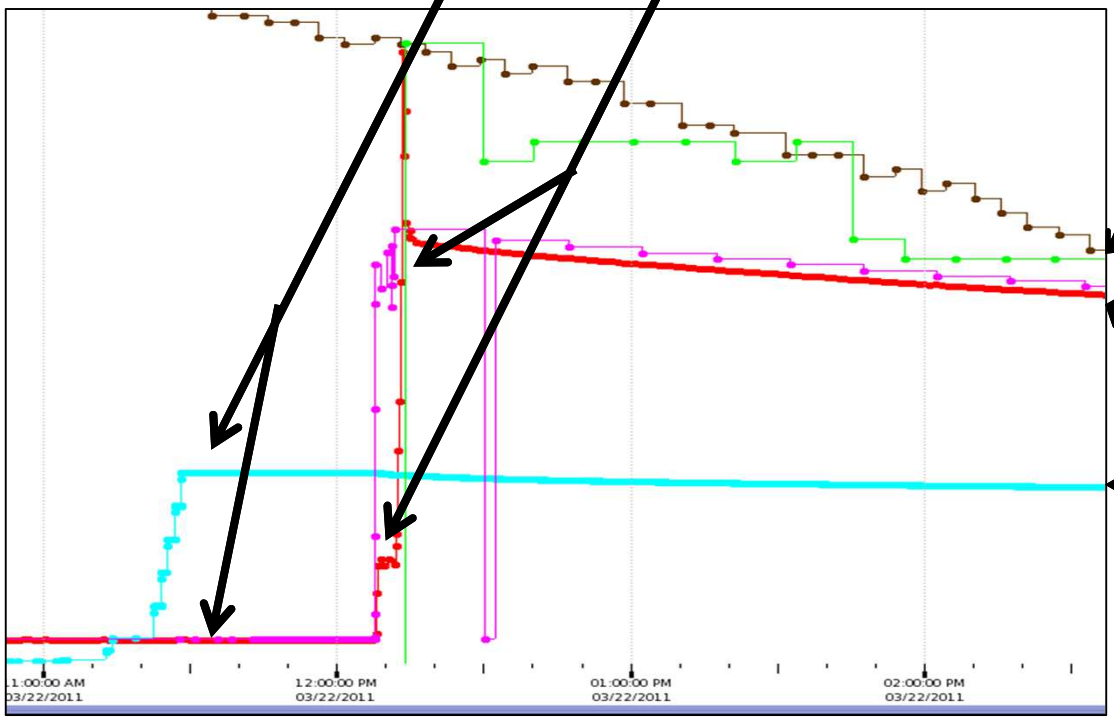
- Importance to remove the pedestal given by the detector current at READY without beam in the machine (~0.01 nA/m^2 ↔ L~10^{29})

Qualitative considerations about RPC average current

- **RPC average current "<u>follows" properly the luminosity slope</u>**
  only after a proper <u>optimization of the working point</u>
  (Temp, <u>Press</u>, Humid) (→*see A. Polini talk for details*)



- **RPC average current <u>does not change at the early INJECTION</u>**
  → <u>start increasing</u> after the separation bump is removed



Atmospheric pressure

RPC Voltages

ATLAS Instantaneous luminosity

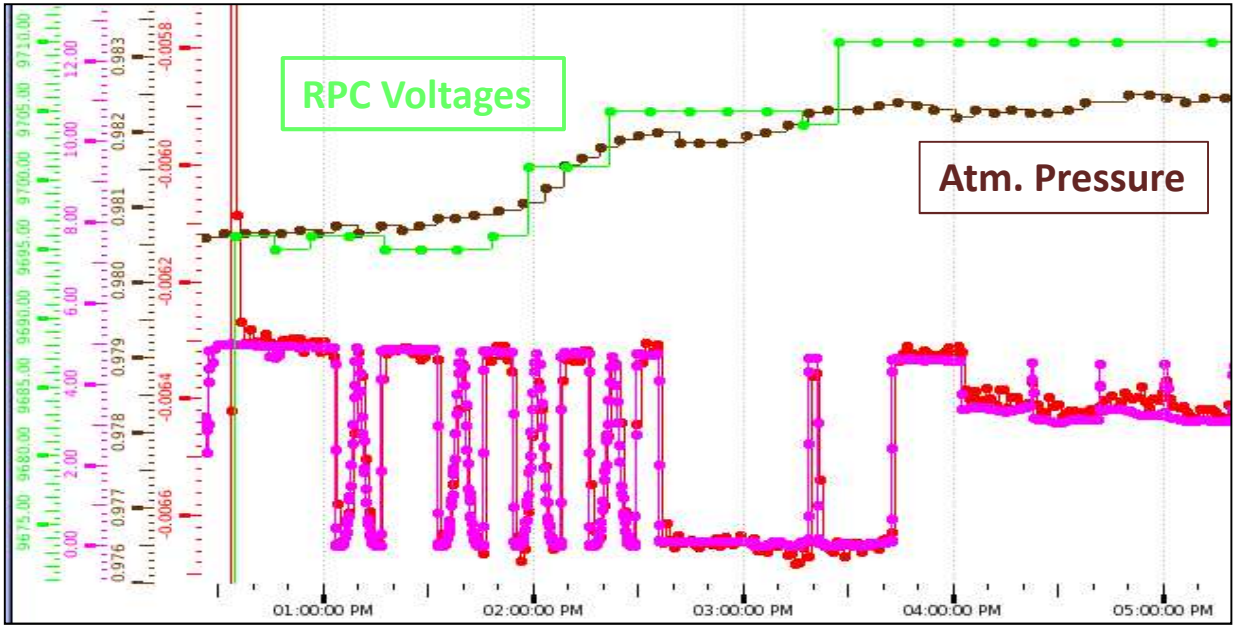
RPC global average current

Beam Intensity

Luminosity (or beam-separation) scans with RPC current

- Calibration of the ATLAS luminosity scale based on dedicated Lumi-scans
- During 2010 and 2011 few scans have been done
- RPC was READY at full voltage during these test RUNS

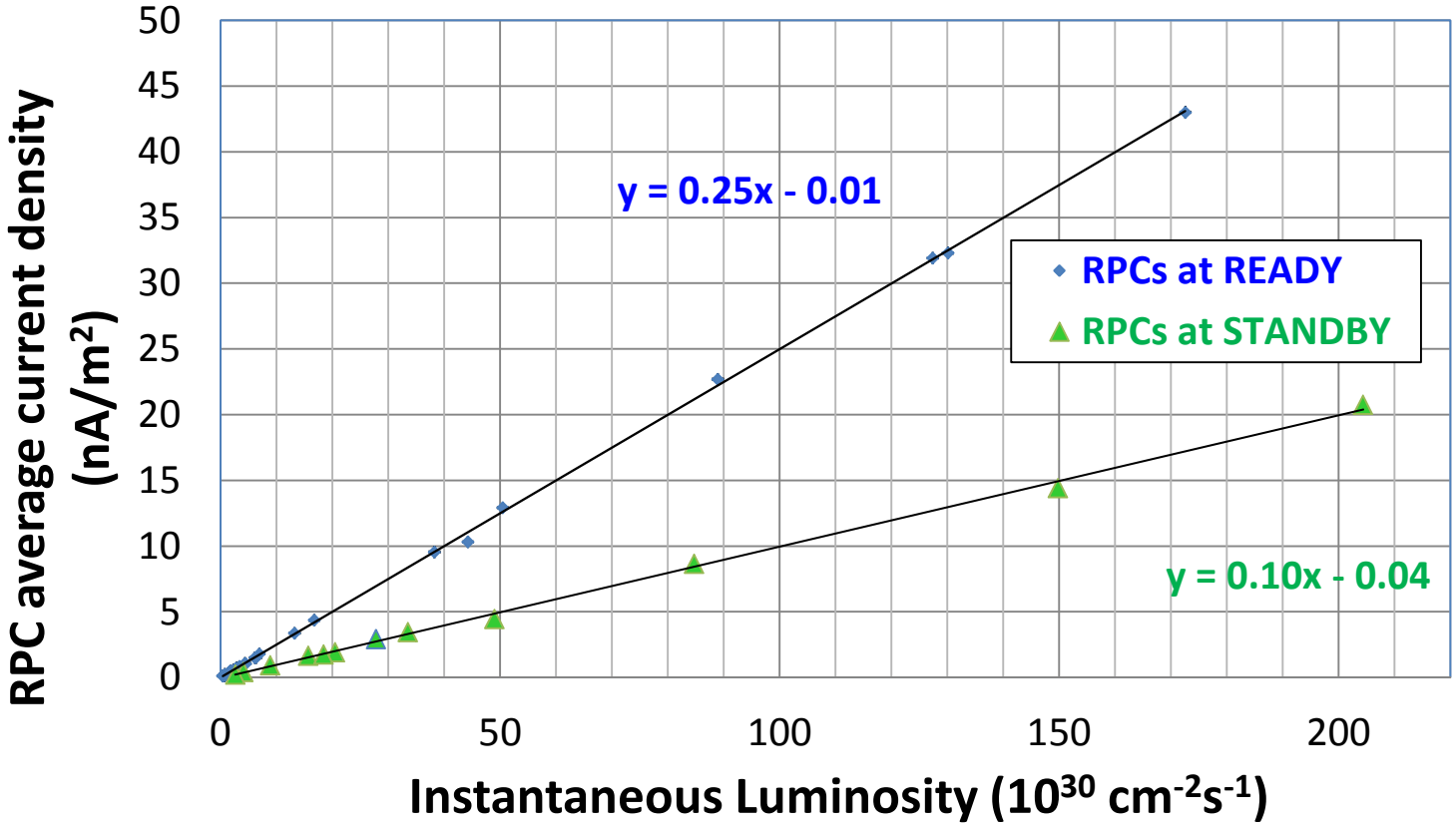
  → the detector has been carefully following the scan on beam position along x and y coordinates first, on z coordinate after (Lumi ~10^{30})



ATLAS Instantaneous luminosity

RPC global average

RPC current vs. Luminosity during 2010 run

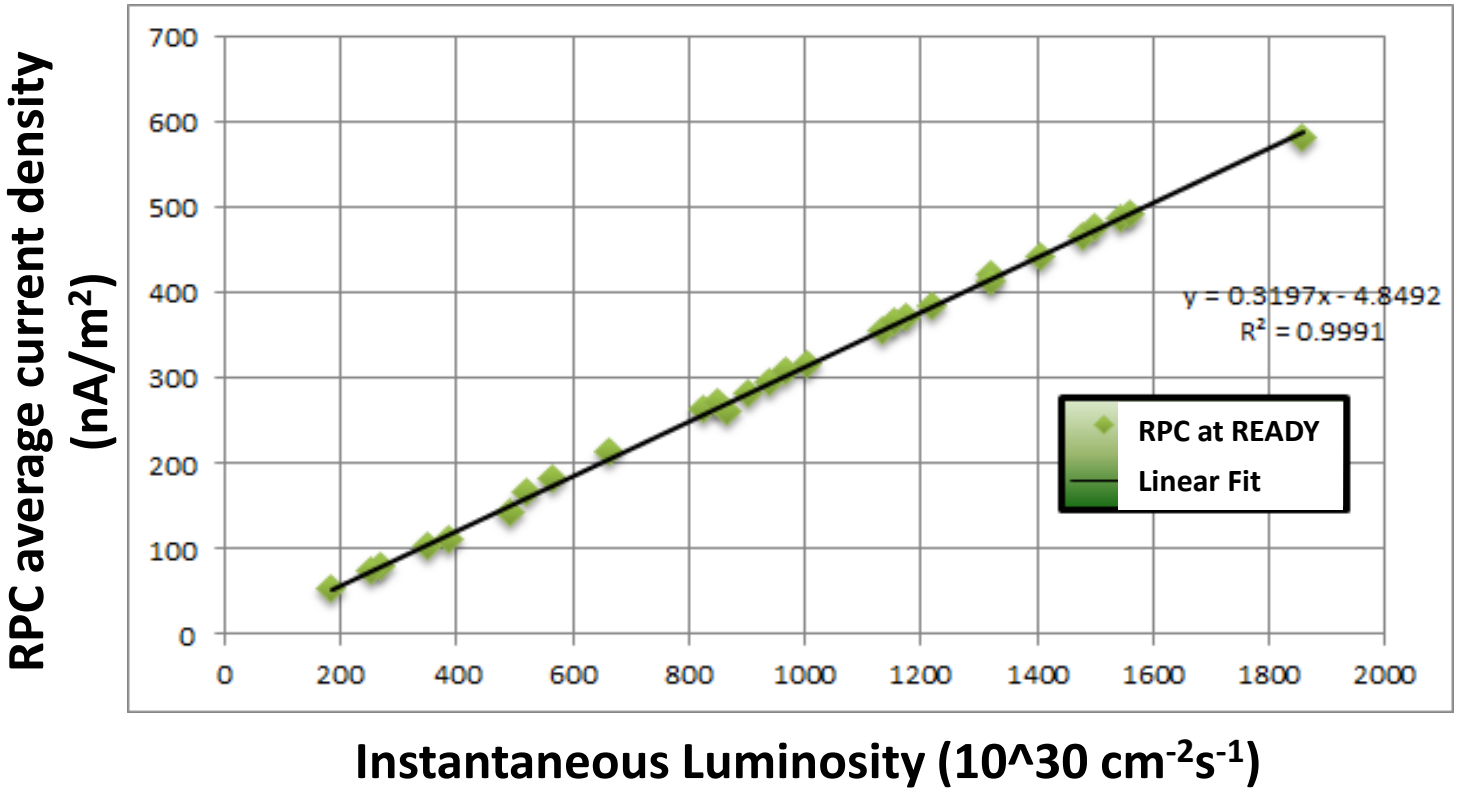


- Sample of the collected data since June 2010; sensitivity down to L~10^{29} $cm^{-2}s^{-1}$
- The slope was compatible with a straight line for almost 3 decades (L~$10^{29\text{-}32}$)

  → 0.25 $nA \cdot m^{-2}/10^{30}$ $cm^{-2}s^{-1}$ measured at beam dump (READY)

  → 0.10 $nA \cdot m^{-2}/10^{30}$ $cm^{-2}s^{-1}$ measured at beam injection (STANDBY)

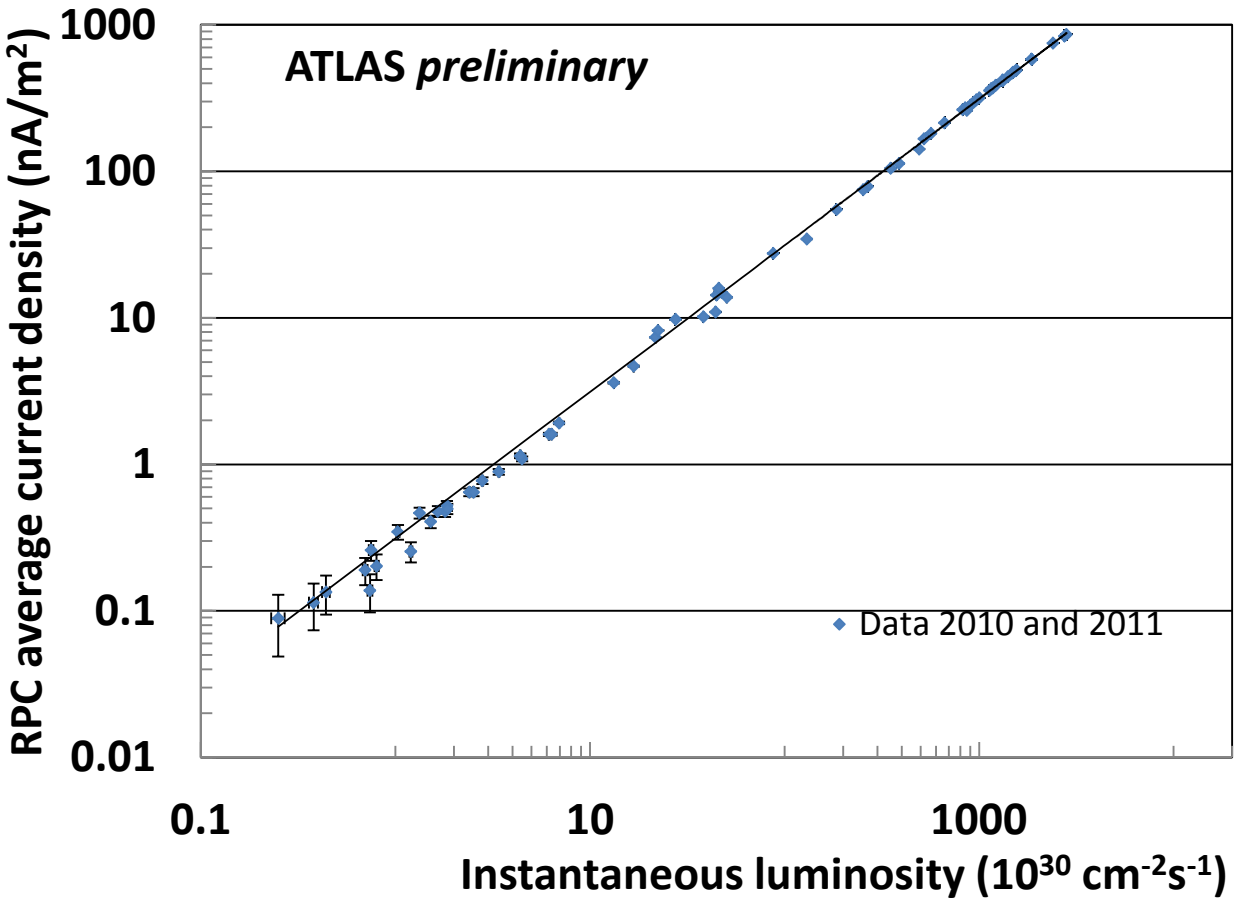
RPC current vs. Luminosity during 2011 run



- Sample of the collected data since February 2011;
- The slope was compatible with a straight line for almost 2 decades ($L \sim 10^{31\text{-}33}$)

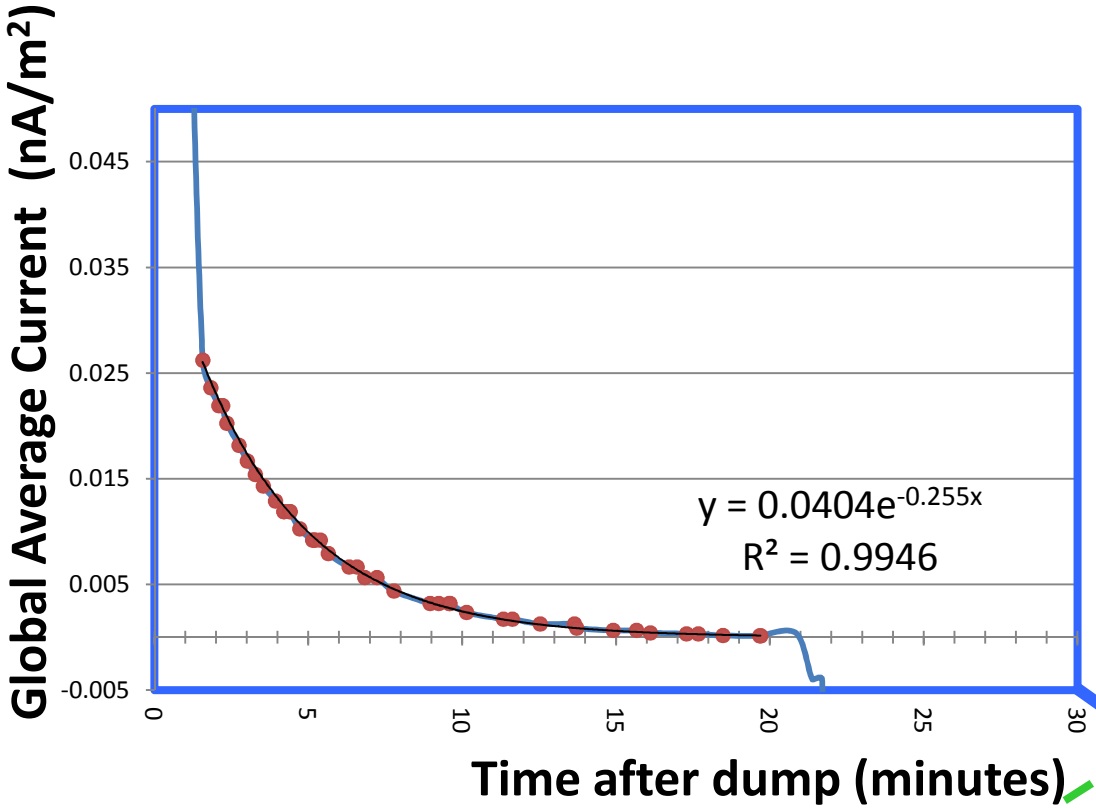
  → slope ~0.32 $nA \cdot m^{-2}/10^{30}\, cm^{-2}s^{-1}$ measured at **beam dump (READY)**
- <u>The main difference is the implementation of the working point correction (as a function of Pressure and Temperature) on the system; this effect has been corrected offline for 2010 data</u>

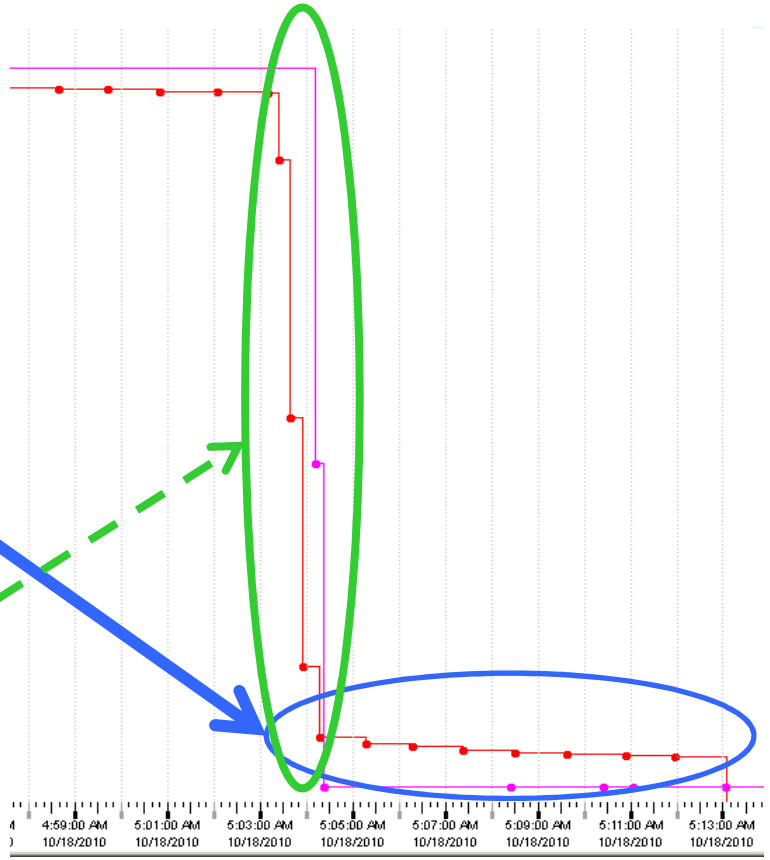
RPC current vs Luminosity (2010 and 2011)



- **RPC average current density (beam induced)** vs. **luminosity**, measured at beam dump in 2010 and 2011 LHC run
- The measurement extends over a range of more than 4 decades ($L \sim 10^{29\text{-}33}$)
- Data are fitted with a straight line with a negligible intercept: the angular coefficient is $(0.312 \pm 0.001)\ nA \cdot m^{-2} / 10^{30}\ cm^{-2}s^{-1}$

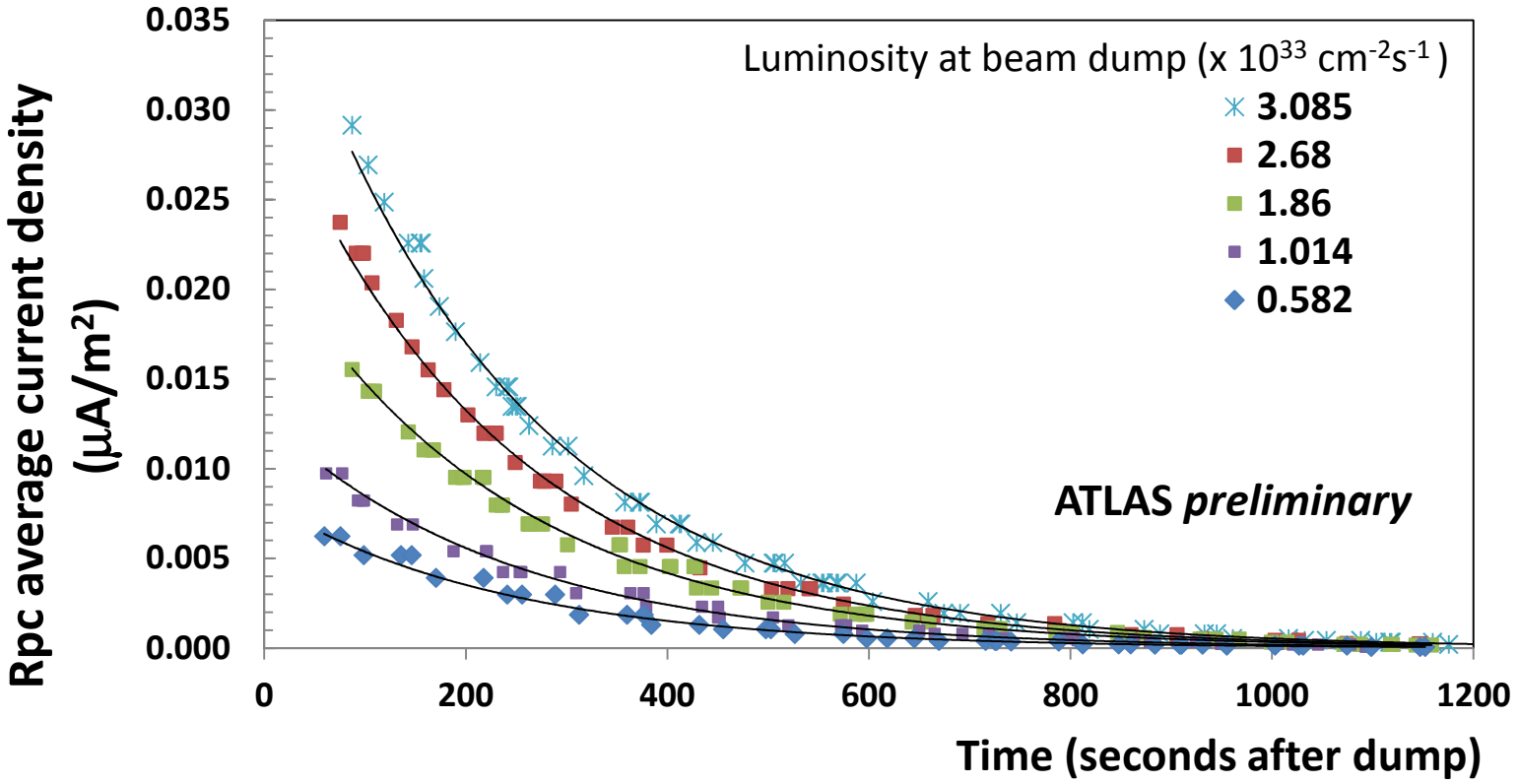
RPC average current after beam dump: first signals of activations?





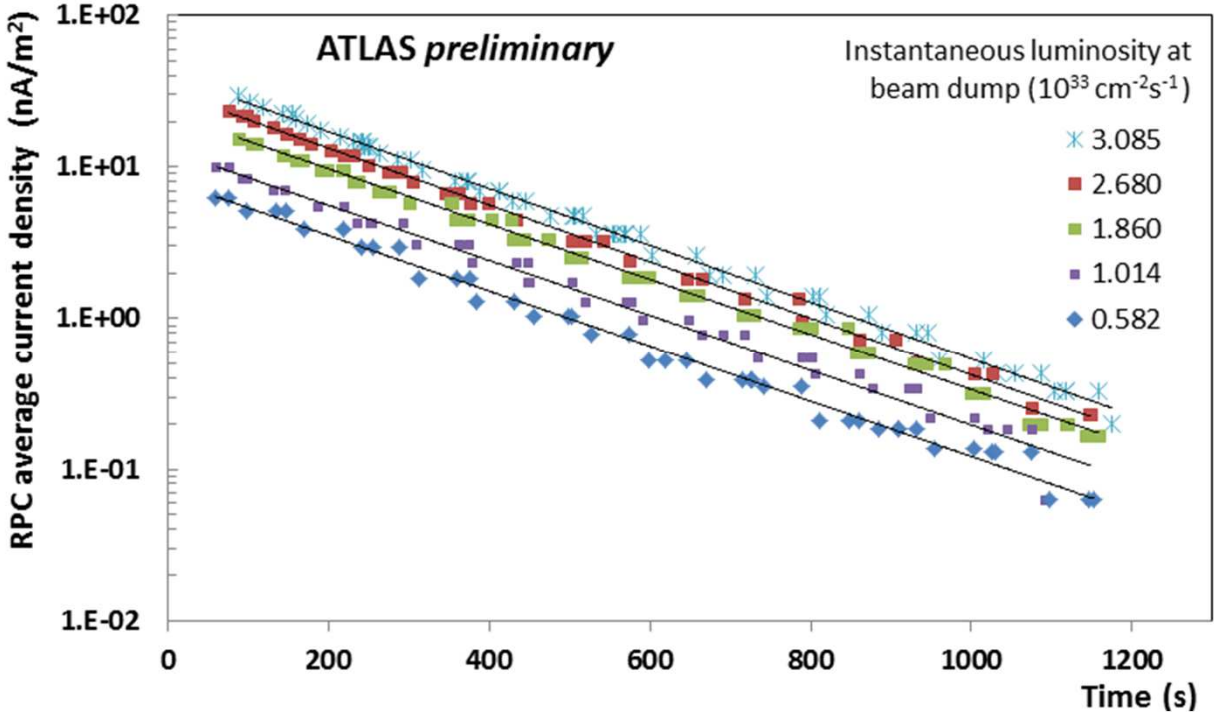
- Associated exponential fit
  - t1=40 s (DCS integration)
  - t2=234 s

Cavern activation measurement (II)



- RPC average current density trend after the beam dump for different instantaneous luminosities
- The trends are fitted with an exponential decay function $y=A_0*\exp(-t/\tau)$

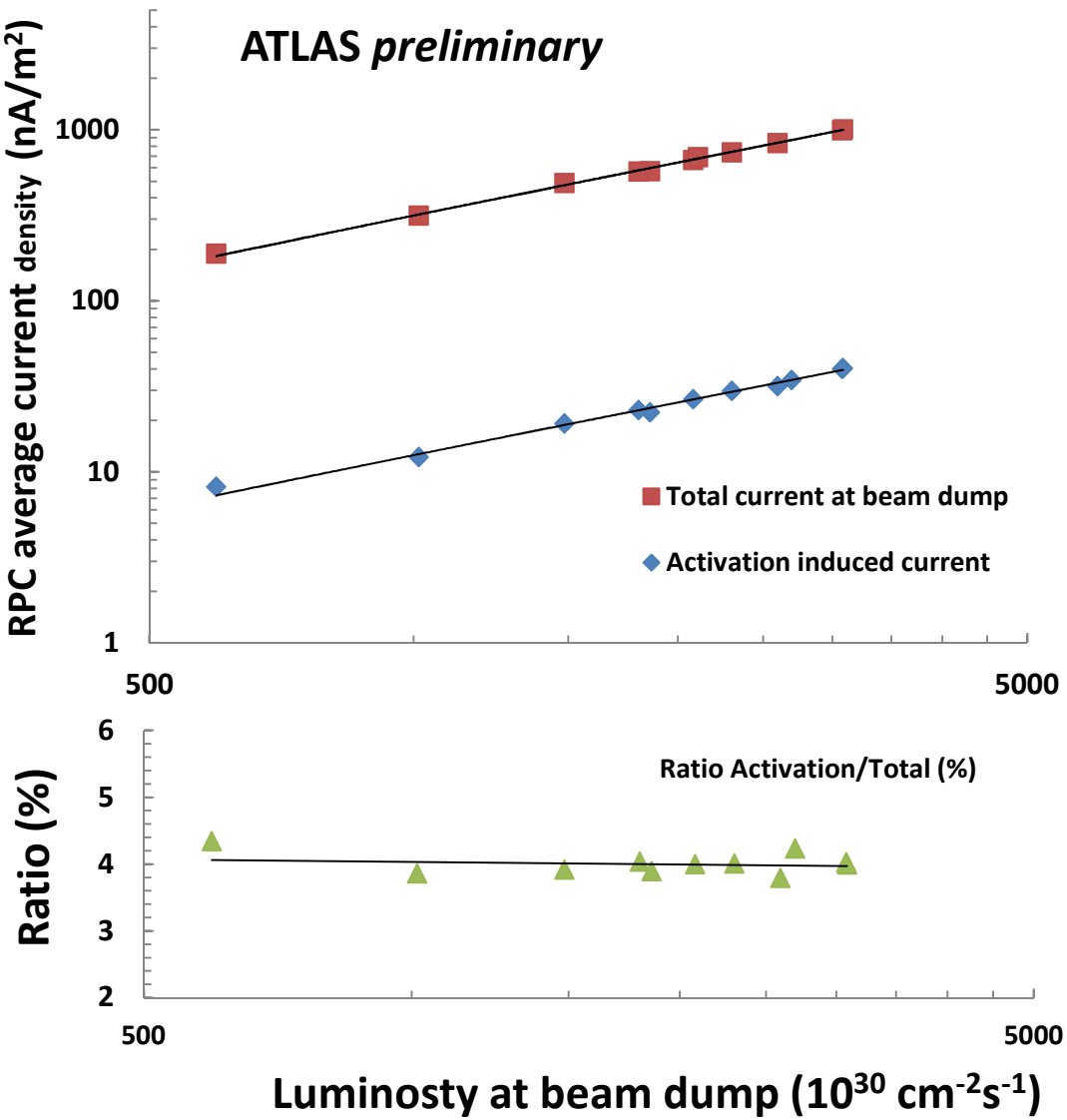
Cavern activation measurement(I)



- The decay rate is almost independent from the luminosity and estimated as **$\langle\tau\rangle$ = (234 ± 1) s**
- The amplitude coefficient (A_0) is instead accurately proportional the luminosity

$y = A_0 * exp\text{-}t/\tau$			$\langle\tau\rangle$ = 234 ± 1 s	
Istantaneous Luminosity (x 10^{33} cm^{-2} s^{-1})	A_0 (nA/m^2)	δA_0 (nA/m^2)	τ (s)	$\delta\tau$ (s)
3.085	40	1	232	2
2.680	31	1	232	2
1.860	22	1	235	3
1.014	13	1	234	5
0.582	8	1	237	4

Cavern activation measurement (2)



- **Total current**, **activation induced current** and the **ratio Activation/Total** vs. instantaneous luminosity at beam dump
- The activation current is obtained from the exponential fit of the current trends after beam dump
- Activation depends linearly on the instantaneous luminosity at dump
- The ratio of (4.1±0.1) % is almost constant with luminosity

How to measure “Luminosity” with RPC?

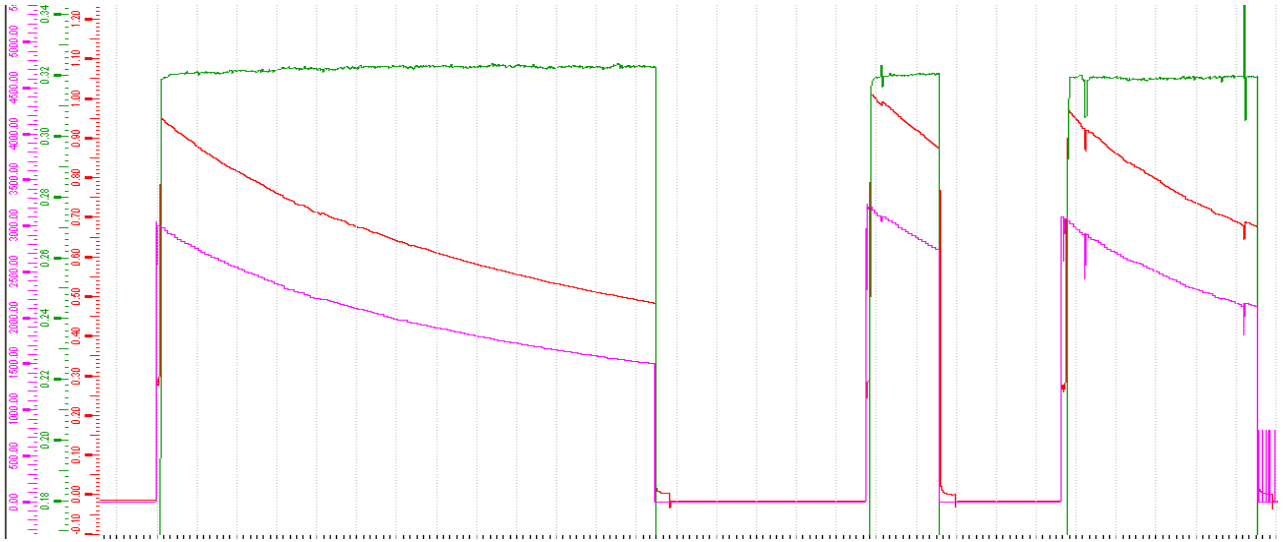
- Monitoring online the ratio :

$$R(t) = \frac{I_{RPC}\ \text{(RPC current)}}{L_{ATLAS}\ \text{(ATLAS Instantaneous Luminosity)}}$$

L_{ATLAS}

I_{RPC}

$R(t)$



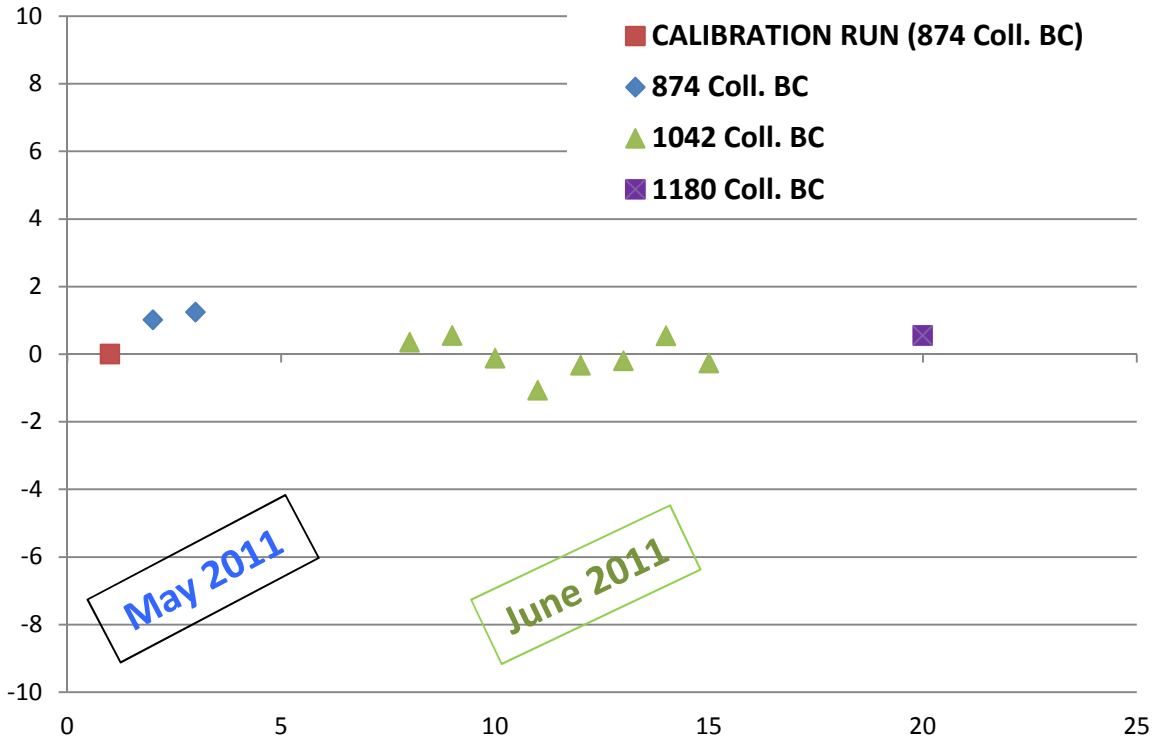
- Ideally R(t) should be flat along the fill

- As a first exercise we checked **R(t)** for different fills

- To publish on-line a **“RPCtoAtlasLuminosity”** value, we have to multiply the ratio ***R(t)*** by a conversion factor that represents the inter-calibration constant K_0 , extracted from the following equation at a fixed time t=t_0 → $R(t_0) \cdot K_0 = 1$

Comparisons with ATLAS Luminosity monitors

- First comparison obtained by calculating the ratios ***R(t)*** for several fills with different Bunch Crossings colliding and different luminosity at BEAM DUMP, once the pedestal from no-beam detector current at READY is removed.



#colliding bunches:

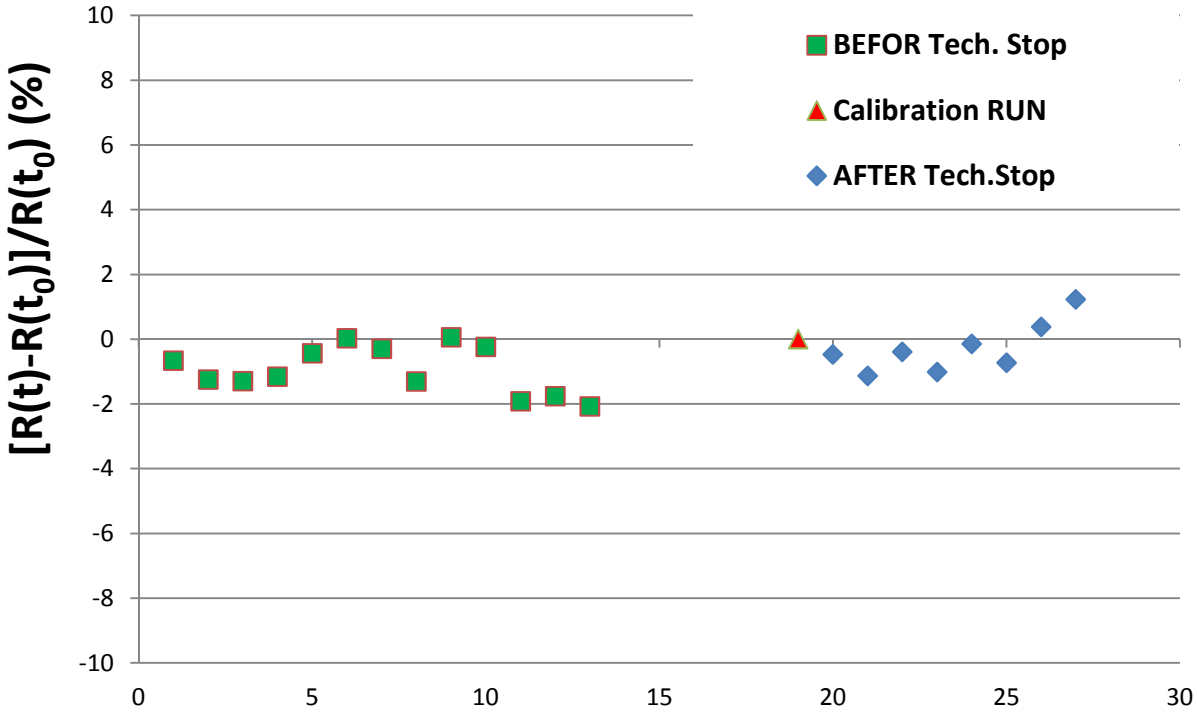
- 874
- 1042
- 1180

Pretty stable (in time and BC colliding) measurement:

- **within 1% respect to the calibration RUN**

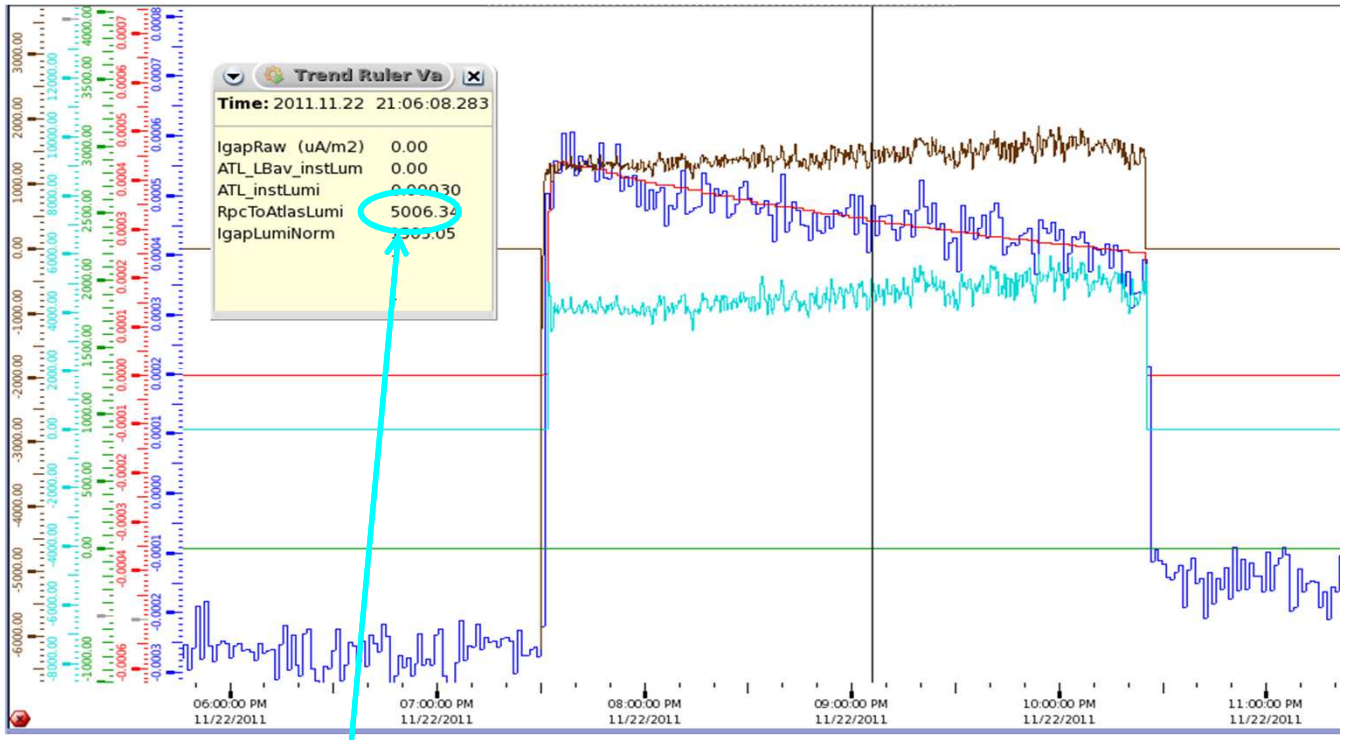
Comparisons with ATLAS Luminosity monitors/2

- Second comparison: ***R(t)*** for several fills with different luminosity at BEAM DUMP, once the pedestal from no-beam detector current at READY is removed
- Contribution to RPC current given by the activation is factorized because constant as a function of the luminosity (4%)



- Pretty stable (in time) measurement
- **Within 2% respect to the calibration RUN**
- **To be continued comparing also with the integrated Luminosity**

RPC Current vs. Luminosity with Heavy Ions



- I_{RPC}
- L_{ATLAS}
- R
- RPCtoATLASLumi

- The RPC current is about 0.5 nA for $L=3*10^{26}$. It was 1μA at $L=3*10^{33}$ p-p
- If the RPCtoAtlasLumi value that was ~1 in the calibration run with p-p collision, is now ~ 5000 !!

Conclusions and outlook for 2012

What we found….

- Good sensitivity and linearity (Luminosity vs Current) seen by the RPC over a large scale (**from L~10^{29} to L~10^{33}**)
- Systematics due to environmental parameters are now under control:
  proper real-time correction of the HV made the difference
- The cavern **Activation** has been detected and estimated to be **constant (~4%)**

….what we are doing….

- Our results have been obtained with the instantaneous values at beam dump:
  → already started **integrating the currents over each fill** as crosscheck
- Monitoring of the RATIO between ATLAS Luminosity and "RPC Luminosity" has started through DCS
  → **pretty stable behavior observed at beam dump;**
  ~1-2% variation respect to ATLAS Instantaneous Luminosity monitors

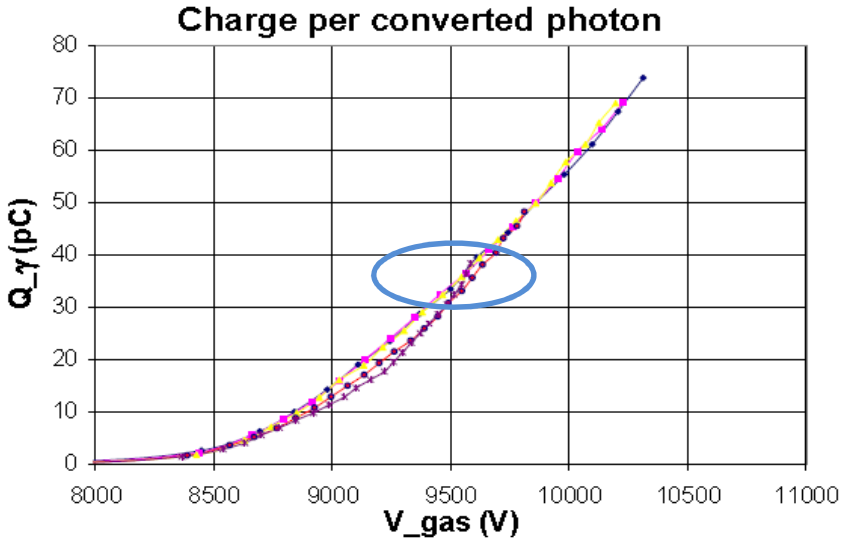
……what we are going to do….

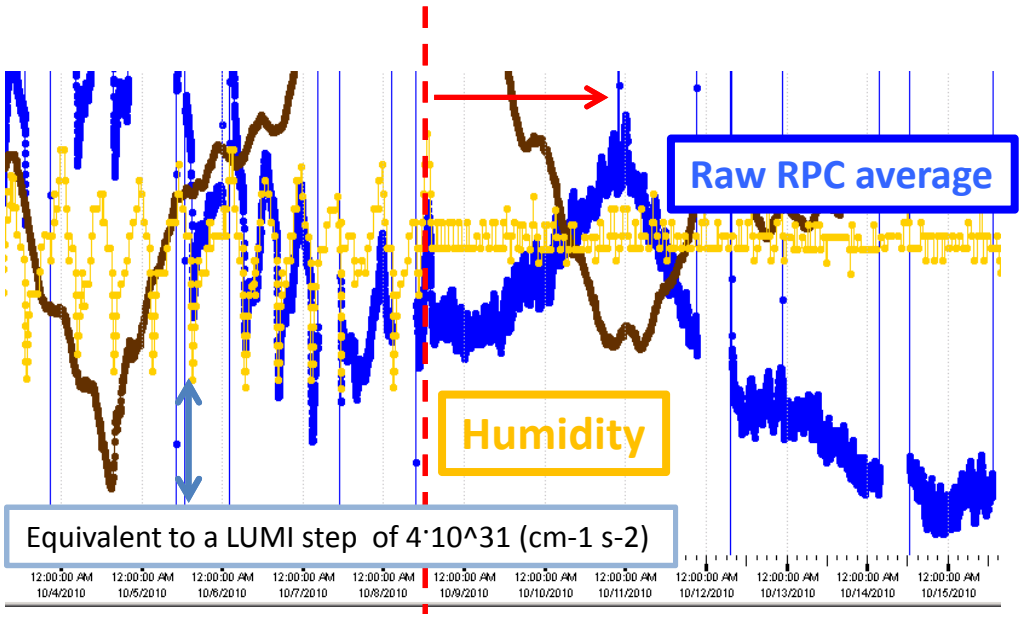
- Create an "ad hoc" script for the measurement of the luminosity with a refined selection of the gap currents
- Analysis Offline will be done as a major systematic check to avoid any error introduced by real-time DCS averaging script

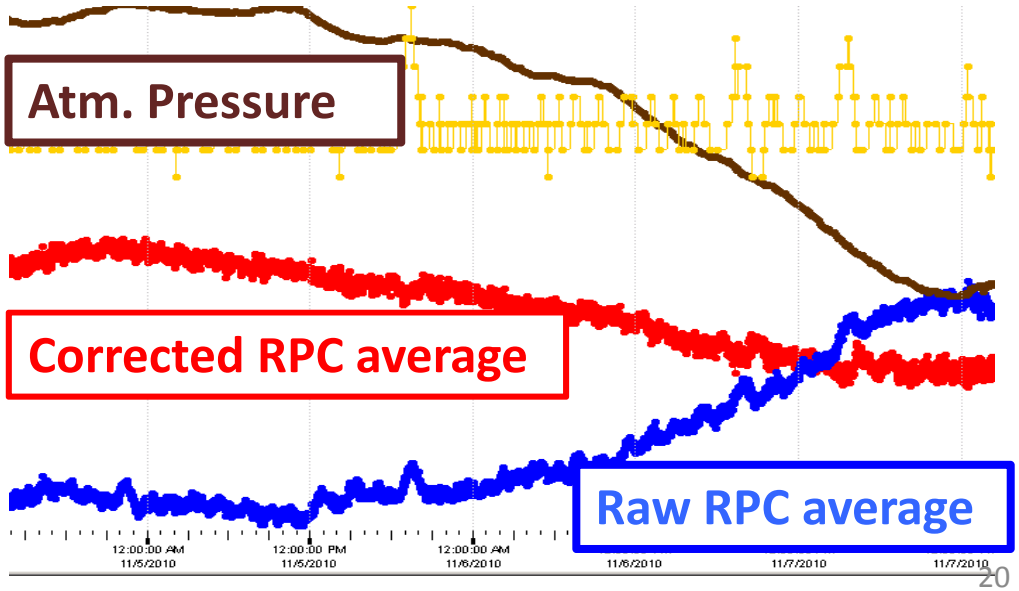
Back up

RPC GAP currents measurement /2

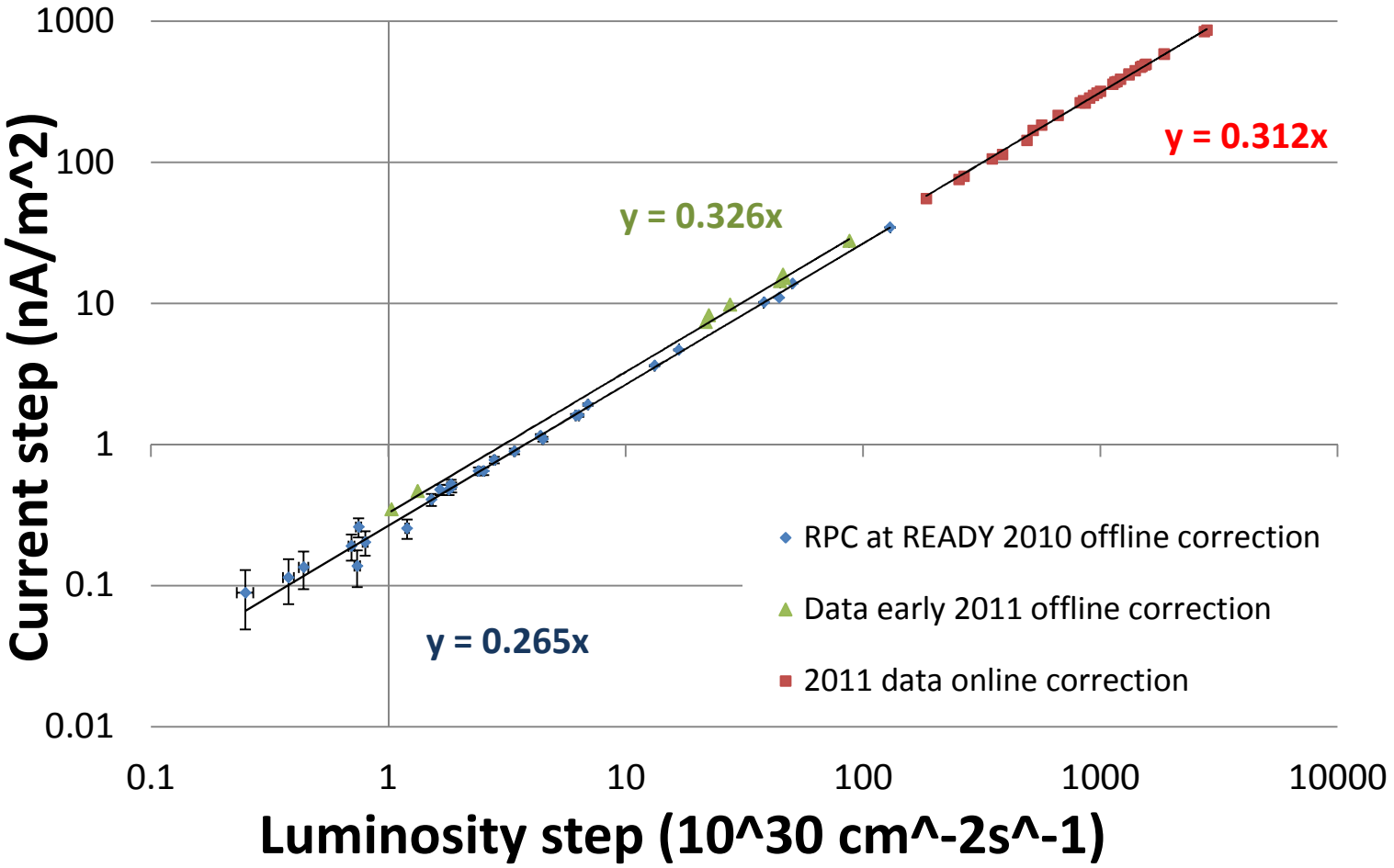
- Almost constant Ohmic leak term
- Fluctuating term due to avalanche counting (particles + noise)
  - ~ 30 pC/photon (GIF)
  - ~ 15 pC/MIP
  - neutrons to be measured
- Systematic effects from **humidity** and **pressure**
  - Real-time HV environmental correction successfully implemented in 2011 !!!







Comparison 2010 vs 2011



Comparisons with ATLAS Luminosity monitors/2

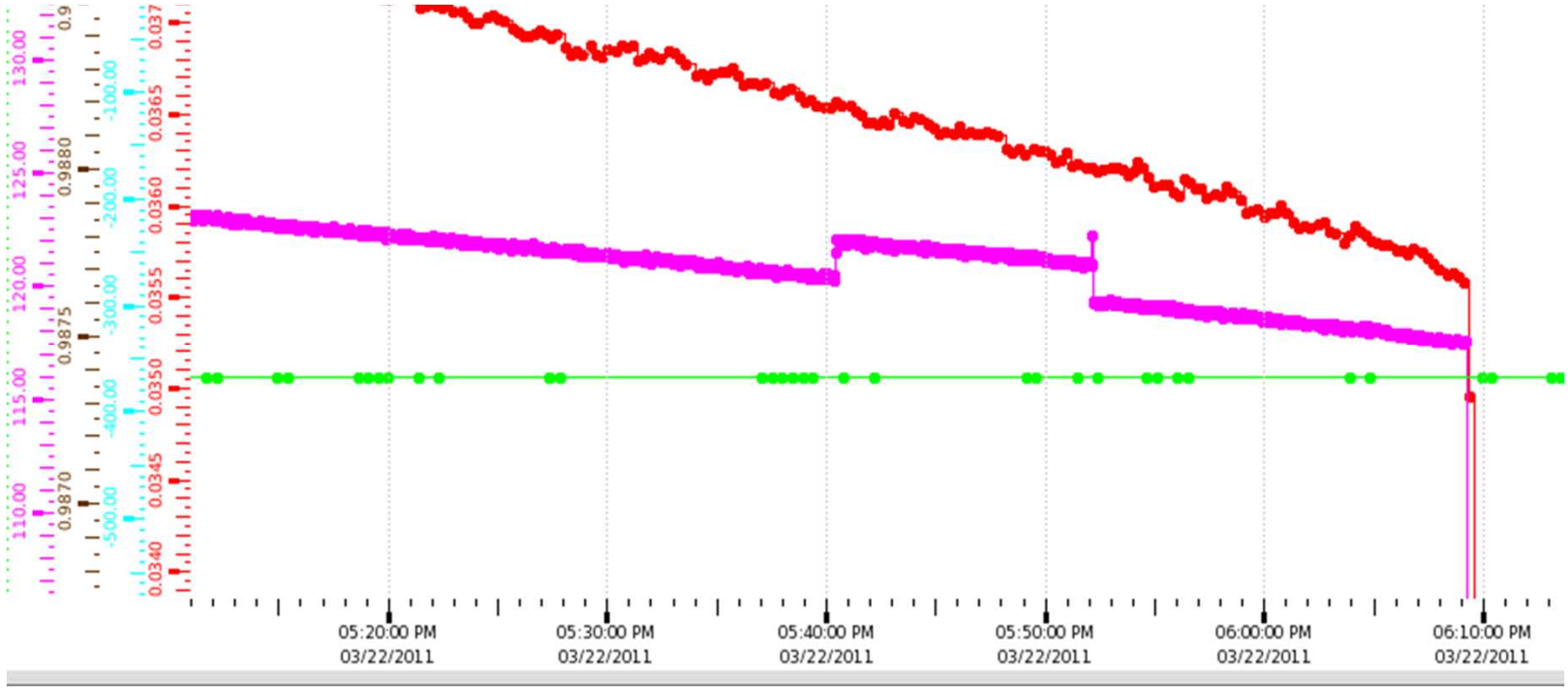
RUN Number (1317 bunches)	ATLAS Inst Lumi @ DUMP (10^30 cm^-2 s^-1)	% Diff to Calibration
186178	1544.44	-0.66
186180	1486.7	-1.25
186182	1531.96	-1.29
186214	1520.27	-1.15
186216	1158.78	-0.43
186217	1323.17	0.03
186275	939.63	-0.29
186361	1407.89	-1.30
186396	967.69	0.06
186456	1216.41	-0.24
186532	1900.67	-1.91
186673	1264.04	-1.76
186729	767.31	-2.08
189090	2843.29	-2.46
189280	1266.63	0.00
189288	1266.63	-0.47
189483	1764.83	-1.13
189561	1496.13	-0.40
189600	1327.63	-1.02
189610	1781.96	-0.14
189719	1891.52	-0.73
189751	1919.86	0.38
189781	2118.18	1.22

Before August Technical Stop

189280 CALIBRATION RUN

First answer, obtained by using directly DCS data: pretty stable measurement, **within 2% respect to the calibration RUN**

Example of fake Luminosity step not seen by RPC current



Effects of HV trips on RPC average current

In both cases there were HV trips at the start of the fill: 2/284 Hv channels