

LGAD在ATLAS束流亮度快速测量中的应用

报告人：樊云云

fanyy@ihep.ac.cn

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Outline

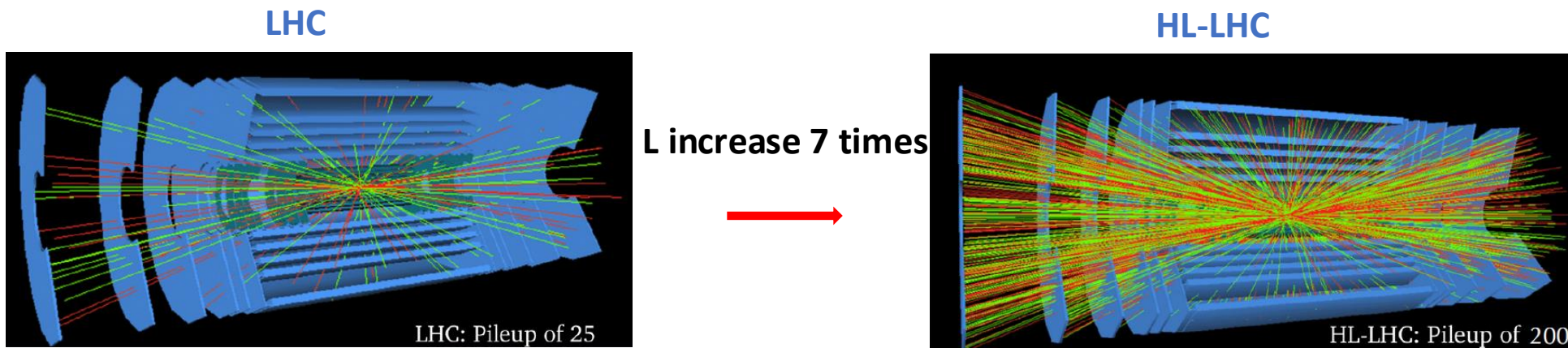
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- **Motivation**
- **Luminosity of the ATLAS at HL-LHC with IHEP-IME LGAD**
- **Design for CEPC fast luminosity measurement**
- **Summary**

Motivation

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- **The importance of the luminosity measurement**
 - Affect the physics goals: precision measurement of the Higgs ...
 - fast feedback for the beam adjustment: efficient beam steering, machine optimization and fast checking of running conditions
- **High luminosity Large Hadron Collider**
 - Instantaneous luminosity $7.5 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$
 - The uncertainty decrease from $<2\%$ to $< 1\%$ (off line) (LHC is 2%) **very challenging !**

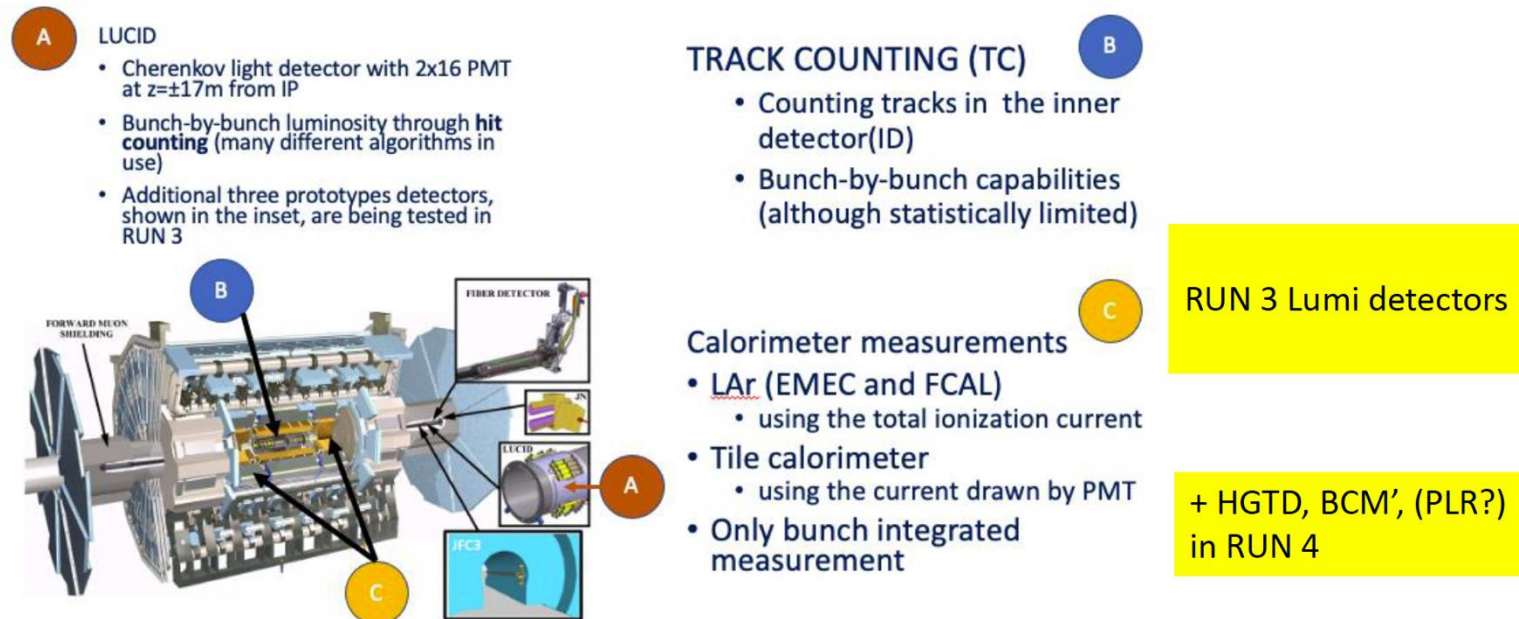


Challenges for luminosity measurement

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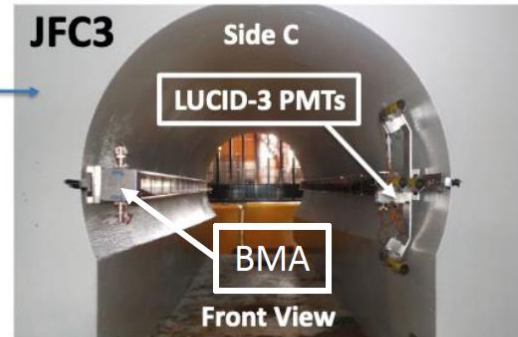
- Experience we got from the LHC ?
 - **Linearity and stability is most important**
 - Several luminosity detectors work together to decrease the uncertainty to 1%.
- **LGAD to do the luminosity measurement (new technology)**
 - Fast time resolution, excellent radiation hardness

Luminosity measurement detectors

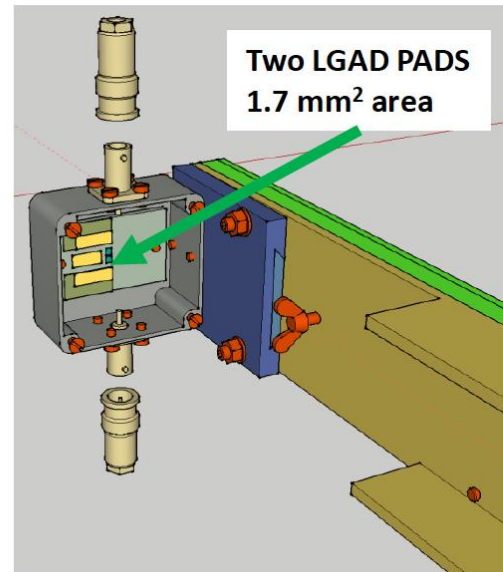


Beam Monitor of ATLAS with LGAD

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- BMA is a prototype for an additional ATLAS monitor for the HL-LHC
- Installed in 2022
- Main characteristics (to cope with $\mu_b \sim 60 \rightarrow \sim 200$)
 - Low geometrical acceptance
 - Smaller systematics effects (non linearities with pile-up)
 - Potentially less μ dependence $\rightarrow$ good performances at high lumi
 - In the present prototype version can not be absolutely calibrated during van der Meer scans
- Placed in the ATLAS Forward shielding
 - can be replaced at the end of every year $\rightarrow$ limited radiation damage
 - easy to install and uninstall
 - No cooling needed (good thermal contact with the forward shielding, an ideal heat reservoir)



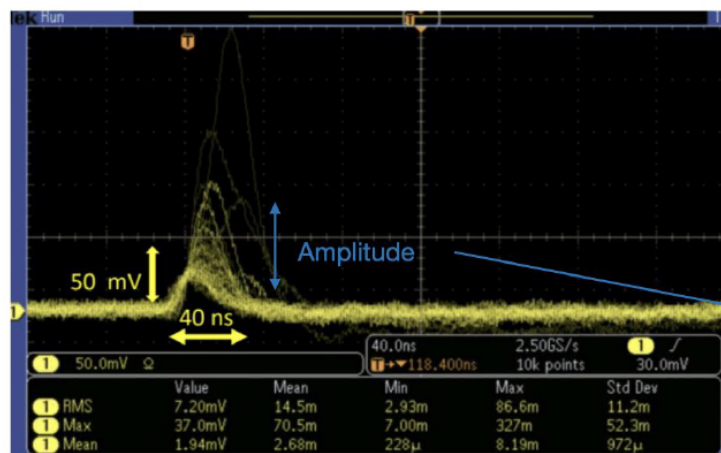
[More on this:](#)
[Talk at TIPP 2023](#)

The signal of the BMA with LGAD

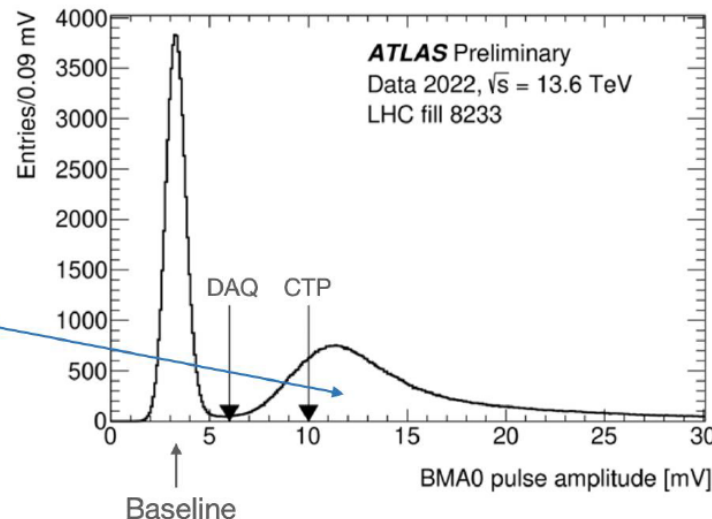
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- 2022
 - CTP: standard NIM trigger with threshold at 10 mV
- 2023
 - using BMA LUCROD integrated in the OLC
 - DAQ: with a lower threshold at 7.3 mV
 - DAQ (gain-corrected): same as DAQ but increasing the LUCROD amplification to compensate for detector gain losses

BMA signal waveforms



BMA pulse amplitude spectra

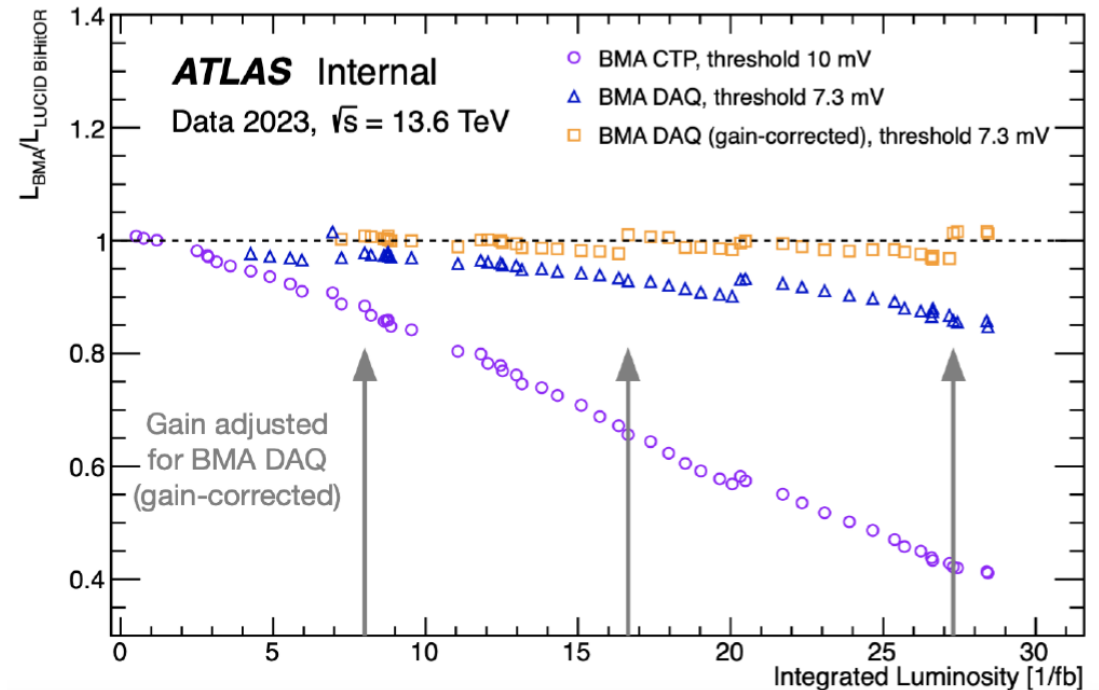


- S/N ~ 24!
- Very low acceptance: $\sigma_{vis} \sim 80 \mu\text{barn}$
- BMA pulse amplitude spectra can be considered as **SINGLE MIP** spectra ($\sim$ independent from μ value)
- Calibration technique is very promising: under study

Efficiency vs integrated luminosity

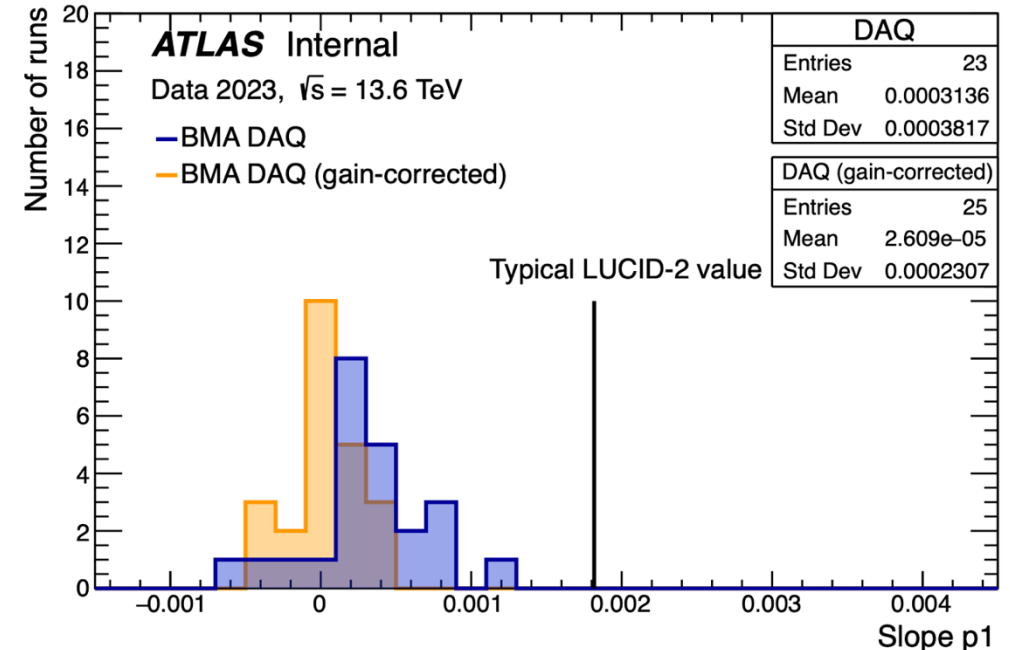
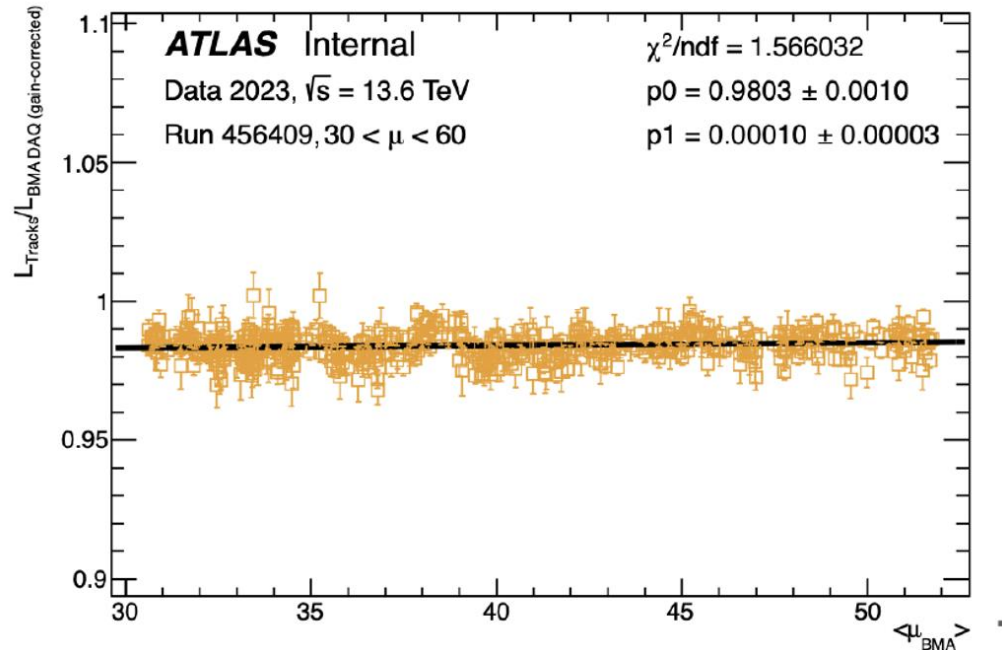
- **BMA CTP** has a linear decrease with around 2.5% per /fb
The first channel of **BMA DAQ** has a linear decrease with around 0.7% per /fb (between 10-20 /fb) and 1.25% per /fb (between 20-28 /fb)
- For the second channel, **BMA DAQ (gain-corrected)**, the gain was adjusted three times: May 17th (around 8 /fb), June 8th (around 16 /fb) and July 12th (around 28 /fb)
- **BMA DAQ (gain-corrected)** follows LUCID somewhat closely with a total difference less than 2%
- The efficiency loss is dominated by gain loss
- The efficiency and stability can be improved by adjusting the gain regularly!

Ratio of the run-integrated-luminosity of BMA wrt to LUCID



Linearity : μ dependence

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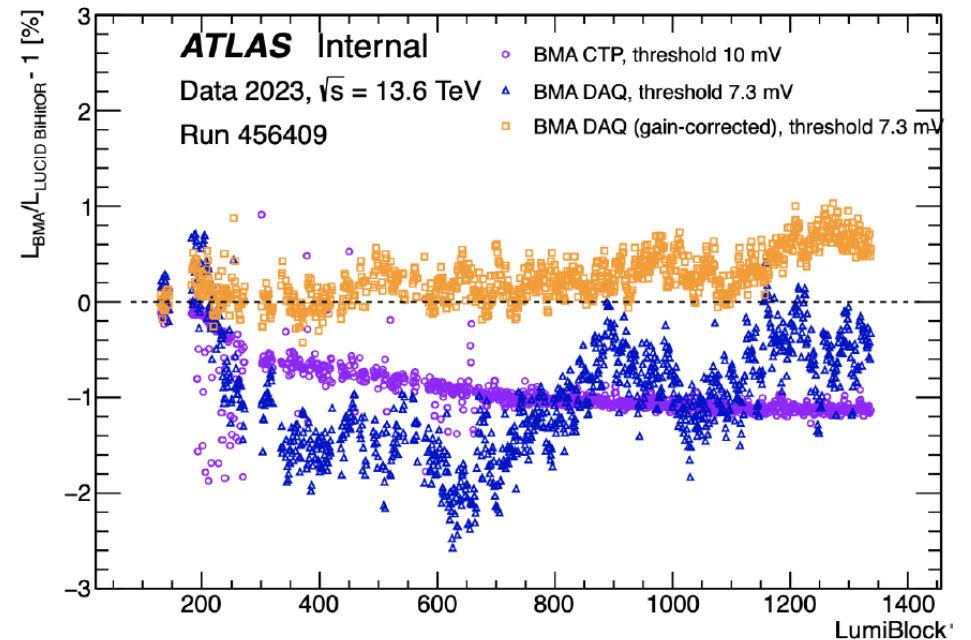
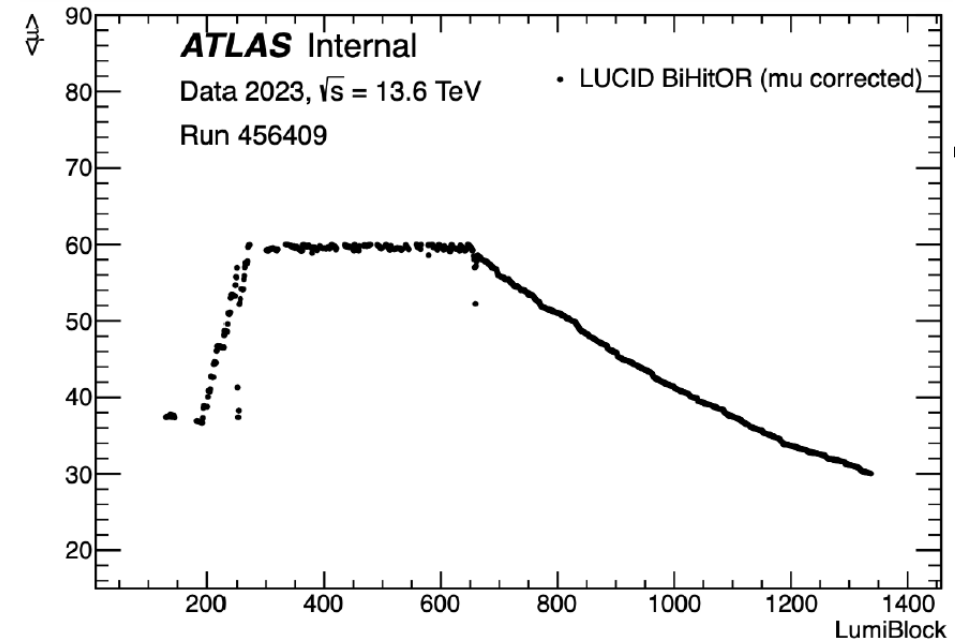
- ✓ μ dependence: Any detector response systematic effect which will affect the linearity of the luminosity measurement
- ✓ The data points were fitted with straight line. (P1 is the slope)

- ✓ The BMA DAQ (gain-corrected) has the lowest P1 Which means the highest linearity
 - One order better than the LUCID



Physics performance

- Study of BMA performance for run 456409 the 12-13th of July, with an integrated luminosity of 0.9616 /fb
- The upper plot shows the bunch-averaged μ as a function of LumiBlock for LUCID BiHitOR (the current best luminosity algorithm)
- The lower plot shows the ratio between the integrated luminosity measured in each LumiBlock by LUCID BiHitOR and each BMA configuration as a function of LumiBlock. The ratios are normalized to 1 for each BMA configuration in the first LumiBlock
 - The maximum deviation for BMA CTP is around 1.2%
 - The maximum deviation for BMA DAQ is around 2.7%
 - The maximum deviation for BMA DAQ (gain-correction) is around 1%



Calibration Strategy

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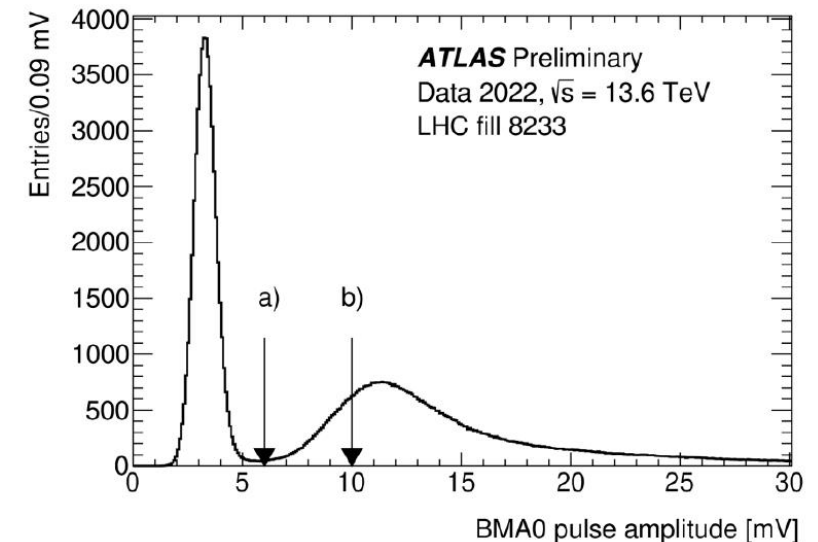
It is of utmost importance to monitor the detector response and gain stability

1. Calibration using a standard RP ^{90}Sr

- The present BMA box foresees already the possibility to place a source to regularly calibrate the detector
- This method has been used during the installation phase of the detector
- A final RP validation is needed for the installed detector
- **This solution will conflict with the plan to place BMA close to LUCID**

2. Self-calibration using P.H. spectra

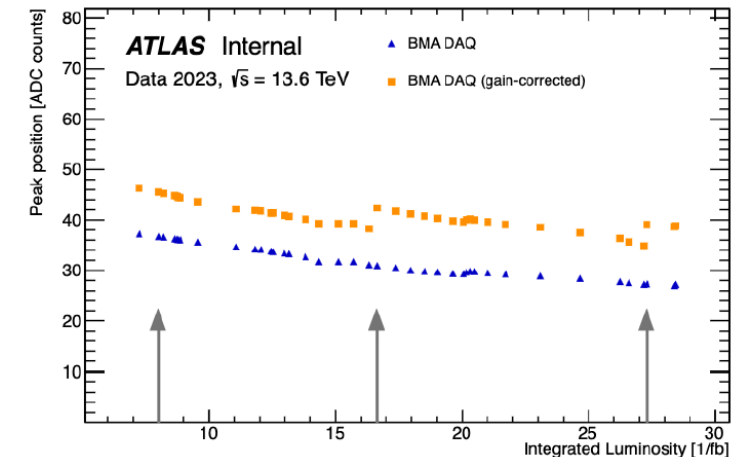
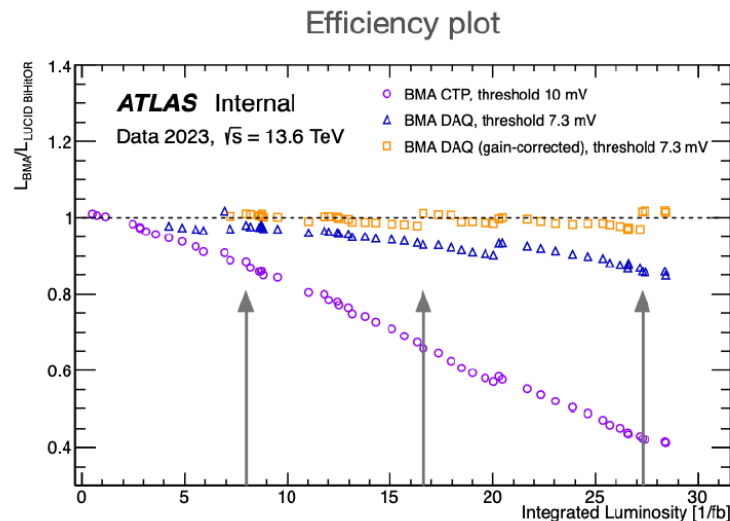
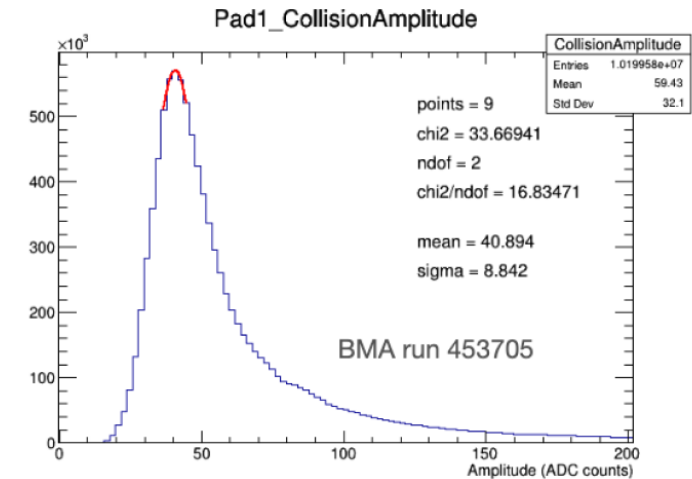
- The pad acceptance is very small, BMA is recording **single track spectra (MIP)**
- The efficiency variation can be hence be evaluated by the LUCROD amplitude spectra
- A promising method based on keeping the MIP peak position fixed by adjusting the LUCROD amplification factor is under study



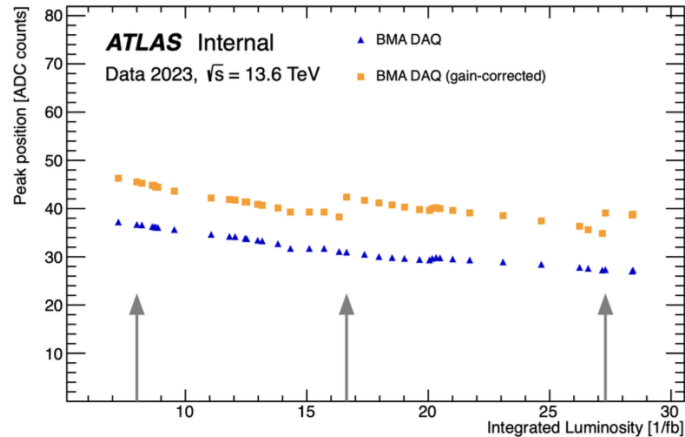
Self calibration using the pulse height spectra

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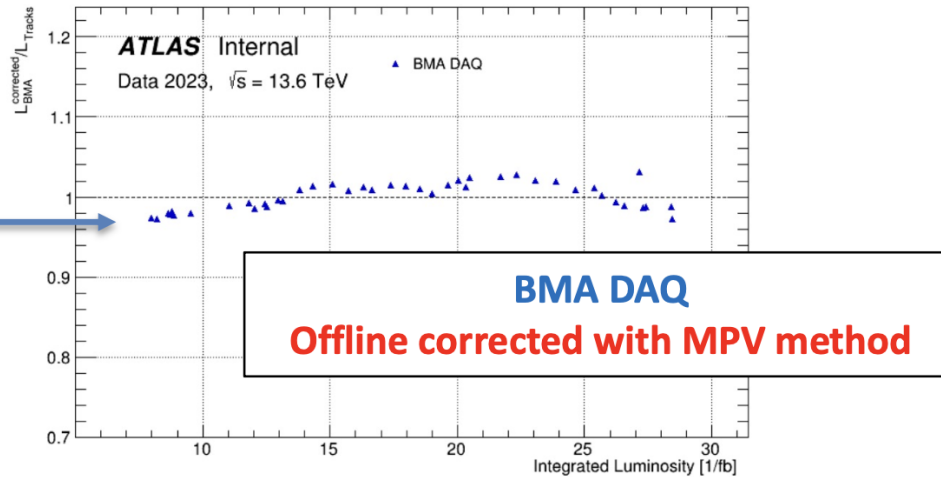
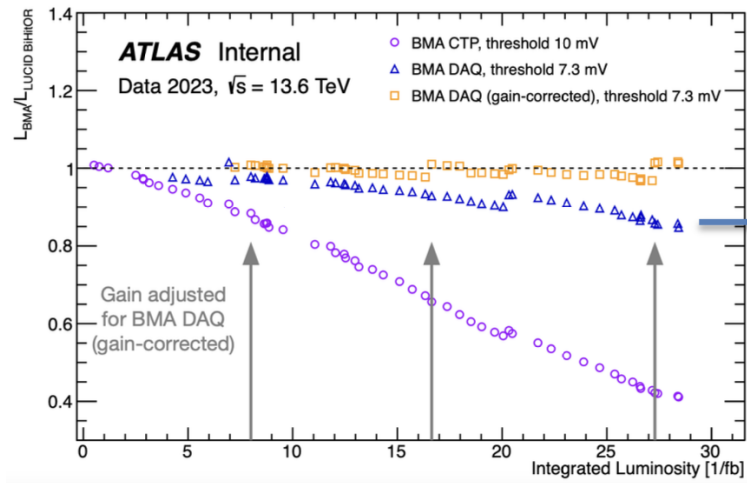
- The pulse height spectra peak is fitted with a parabola (upper plot) and the peak position is plotted as a function of the integrated luminosity (lower right plot) for the BMA DAQ and DAQ (G.C.) channels
- The peak positions trends are very similar to the ones reported in the Efficiency plot (lower left plot) already shown in slide 5
- It looks like the peak position can be used as a monitor of the detector efficiency
- **Next (crucial) step**
 - Prove that the peak position does not depend on the μ -value
 - Work in progress



Detector calibration based on MPV



- The change of electronic gain during 2023 data-taking was done to bring back the **Most Probable Value (MPV)** back to the value measured at the start of data-taking.
- Based on the MPV, it is possible to apply offline corrections on data (as one would do online).



Promising results with **BMA DAQ**. Analysis on-going with **BMA DAQ gain-corrected**.

Carbonated LGAD Performance at room temperature

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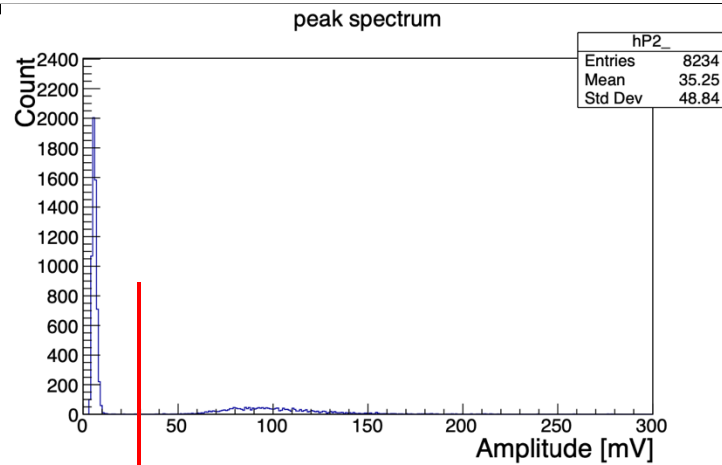


Fig. 1: Running time 0-2h

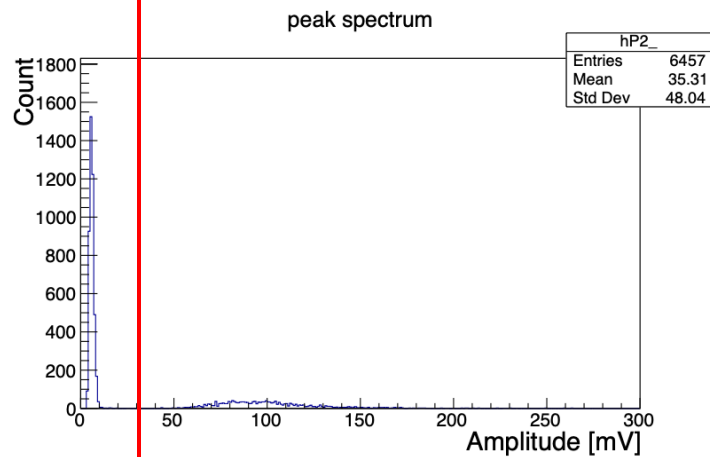
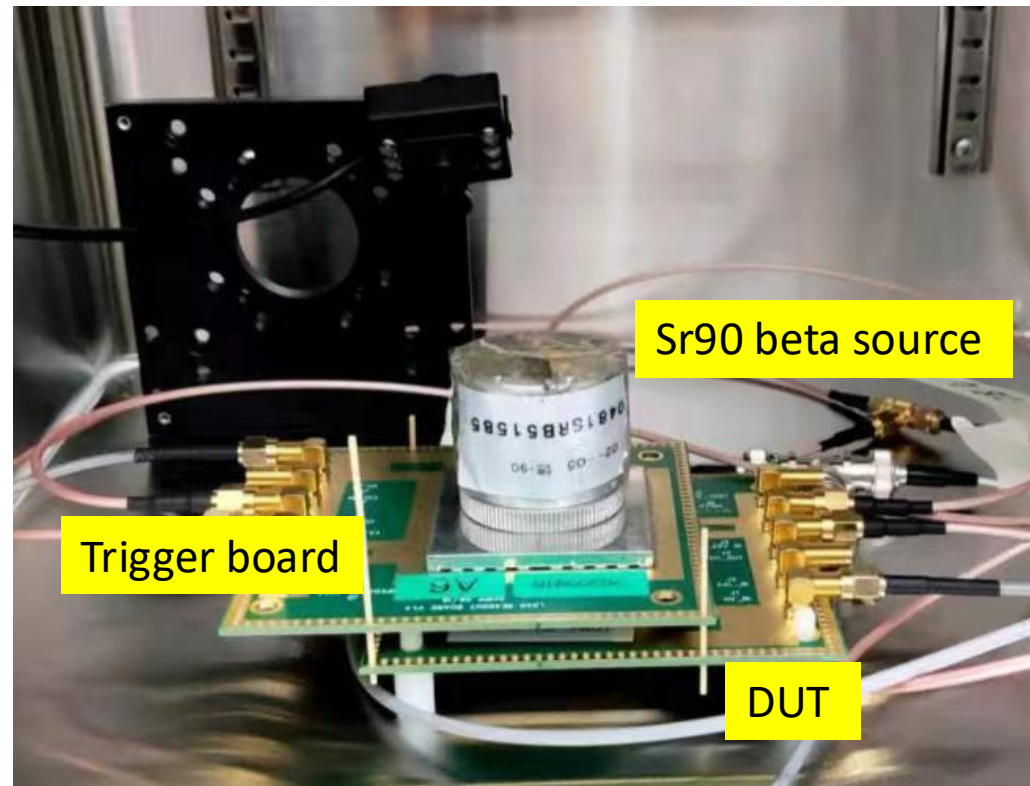


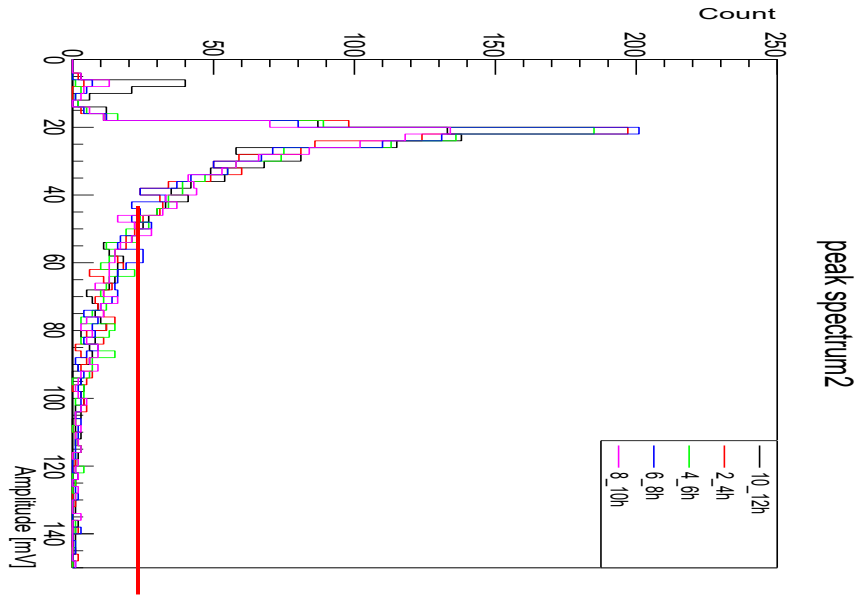
Fig. 8: Running time 14-16h

- Carbonated LGAD before irradiation
- Trigger only on both trigger board
- No significant performance decrease after long time operation

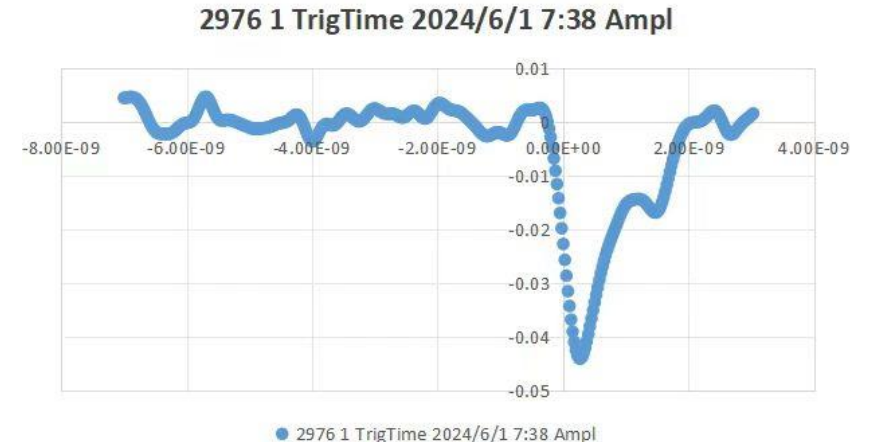
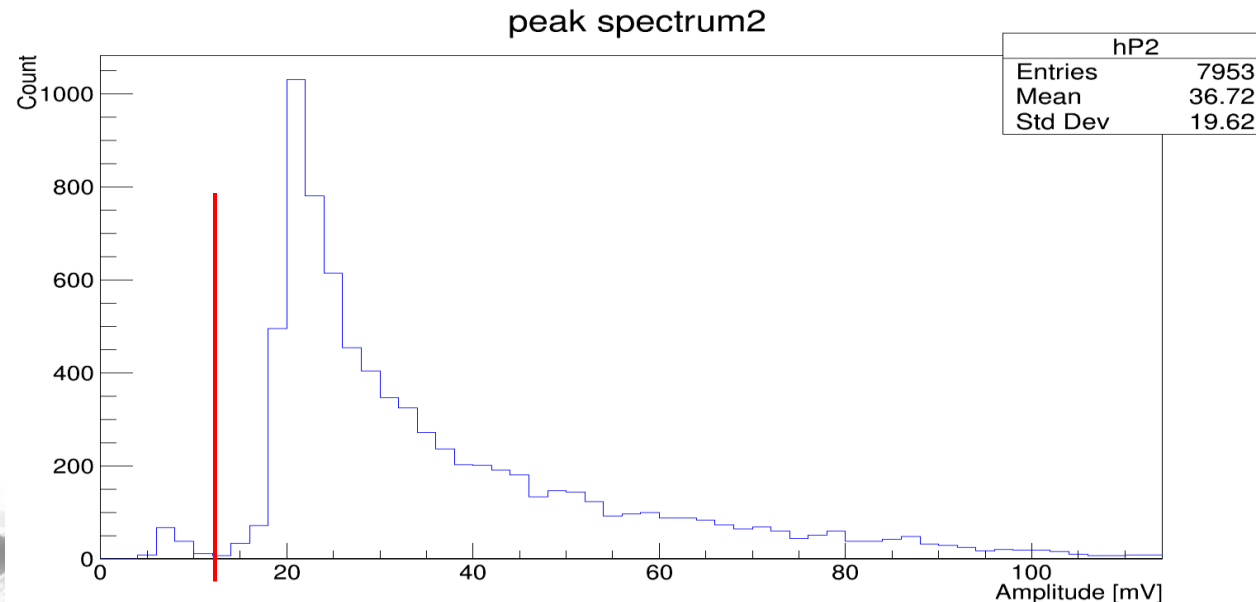


Carbonated LGAD Performance

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- Carbonated LGAD after irradiation
 - $8e14$ neq/cm²
- Tested at room temperature (according to BMA requirement)
- Trigger on both trigger board and DUT
 - Baseline noise reduced
 - Still can see a separation between baseline and MIP
- No significant performance decrease after long time operation



Summary

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- **BMA with LGAD shows promising ability of the luminosity measurement at ATLAS**
 - Almost no μ dependence (**good linearity**)
 - High S/N ratio
 - Promising self calibration with the bias voltage adjustment
 - **Run-3 showed that BMA with LGAD is a good candidate as an online and offline luminosity monitor @ HL-LHC, in addition to LUCID-3.**

**Thank you for your
attention□**

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- **Back up**

Luminosity test System with the LGAD

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- **Fast electronics**
- **Long distance of the signal transfer**
 - Radiation hardness and low signal loss cable
- **Detector HV power supply et al.**

