Prototype for a Radiation Hard Upgrade to the ATLAS ZDC

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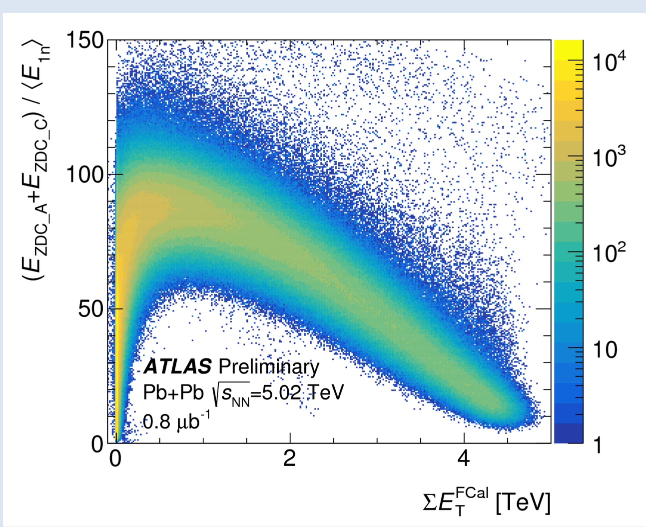
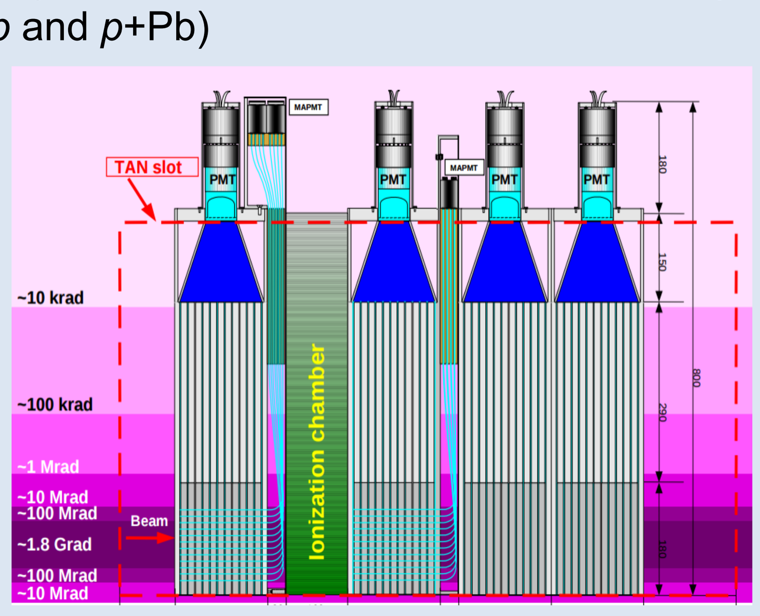
ATLAS ZDC



Event centrality correlation between the ZDC and FCAL. Ultra-peripheral events appear in the lower left corner and central collisions in the lower right. [1]

- **ZDC in heavy ion physics:**
  - Event centrality (shown above)
  - Ultra-peripheral triggers
- **ZDC in *pp* physics:**
  - Unused because of extreme radiation dosage
- **Upgraded ZDC is aimed at:**
  - Centrality measurements during HL-LHC era
  - Future UPC physics
  - Exploratory measurements of neutrons, π^0 and η at low x (*pp* and *p*+Pb)



Radiation dosage expected at the ZDC at a luminosity of 10^{33} cm^{-2}s^{-1}

Upgrade: Liquid Radiator Sampling Calorimeter

Radiation Hardness

- Liquid aromatic hydrocarbons will be used as a Cherenkov radiator and replaced at regular dosage intervals
- Vessels will be sealed, impurities minimized and electronegative molecules avoided

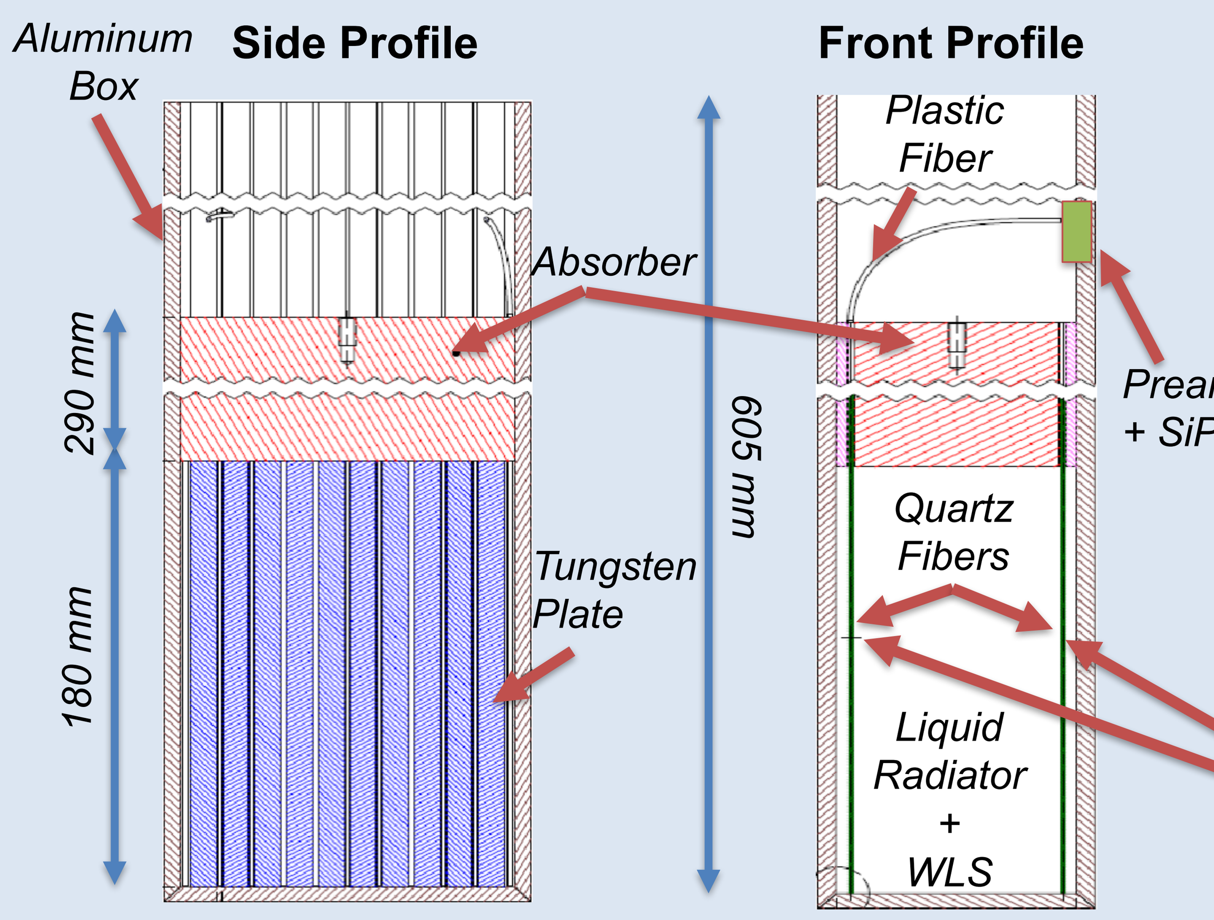
Light Transport (Dual Stage WLS)

Motivation:

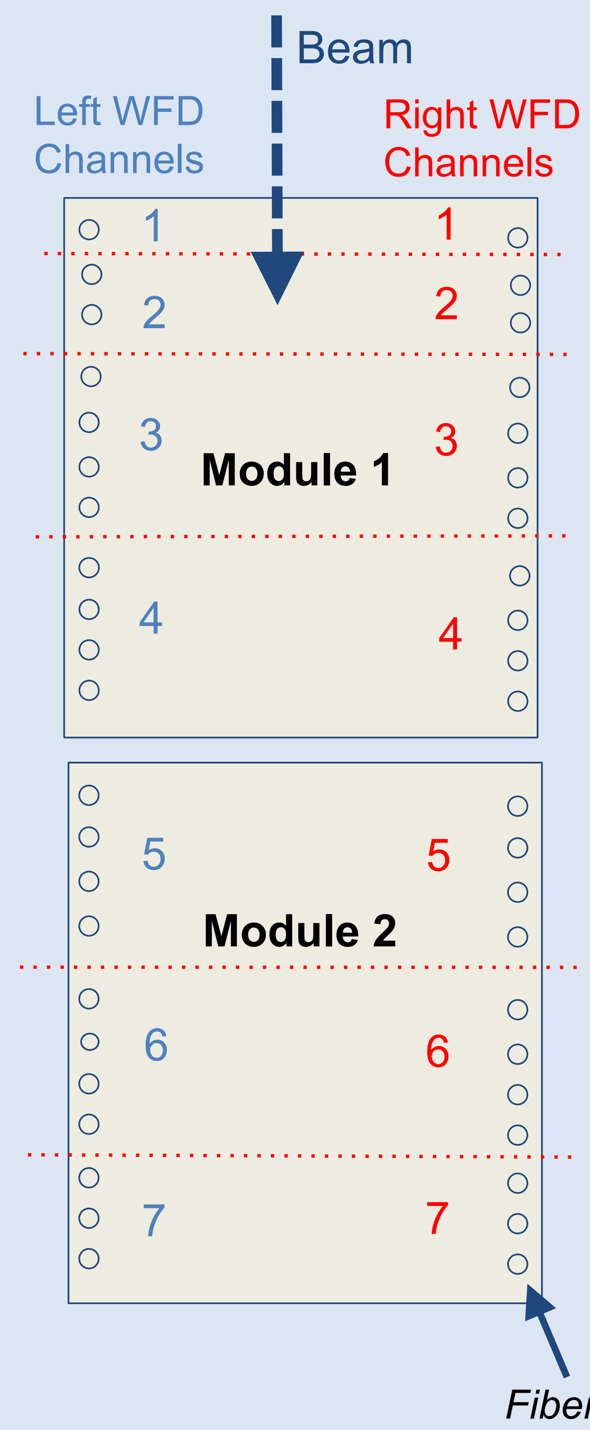
- Efficiency of light transport using reflectors along radiator surface is too low

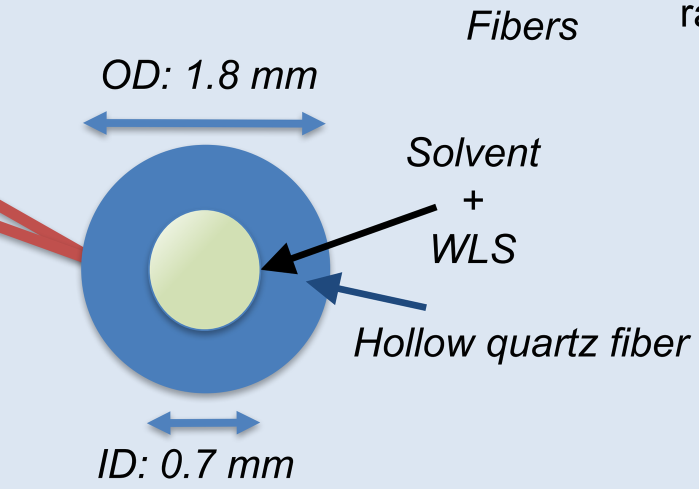
Solution:

1. Dope the radiator with wavelength shifter (WLS) to isotropically re-emit fraction of light to the sides of each radiator gap
2. Place hollow fibers filled with solvent + WLS at the sides of each gap, where they re-emit fraction of light toward the SiPMs



*** At Luminosity: 10^{33} cm^{-2} s^{-1} ***
Beam Spot: ~1.8 Grad/yr
Edges: ~1 Mrad/yr
SiPM: ~10 krad/yr

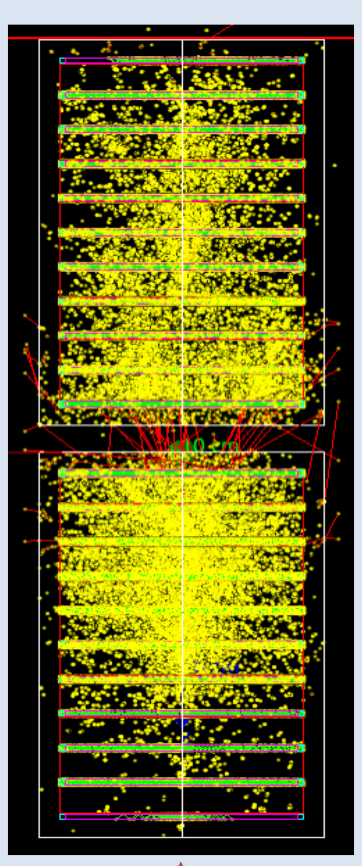




Readout scheme

- SiPMs used to increase quantum efficiency at longer wavelengths -- necessary for dual-stage WLS concept
- **Longitudinal segmentation:** SiPM readout allows for in depth study of shower development. Aiming for ***PID of e/gamma from charged hadrons*** in the upstream channels
- **Transverse sampling:** Light transport scheme allows the shower to be sampled at two transverse positions within each radiator gap. Aiming for ***coarse position resolution*** in the upstream channels by taking a calibrated ratio of the two signals

GEANT4 Simulation



150 GeV Proton

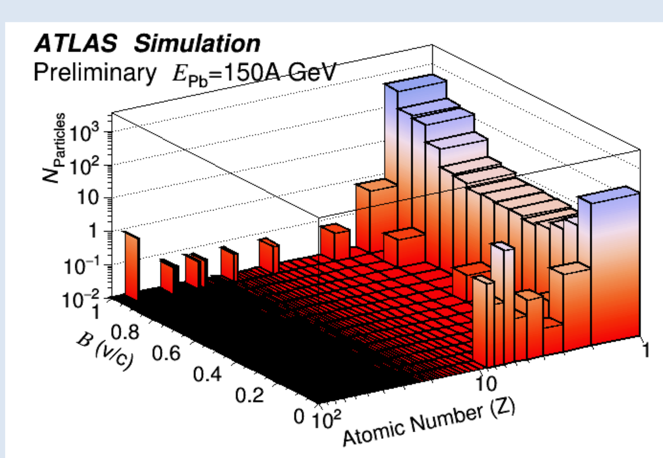
Shown: charged shower particles, Cherenkov photons and vertices

Energy and Charge Spectra

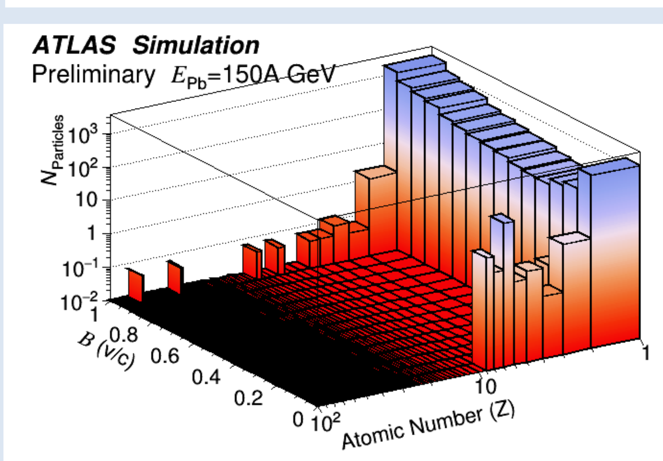
Radiator Gap: 1
L/λ_{int}: 0.02

Radiator Gap: 7
L/λ_{int}0.63

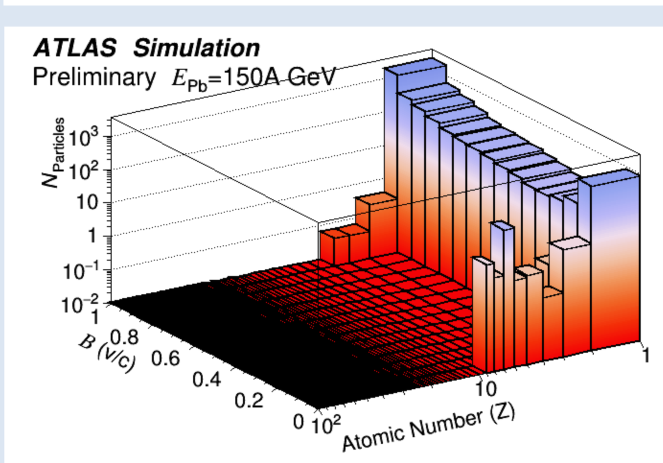
Radiator Gap: 22
L/λ_{int}: 2.11



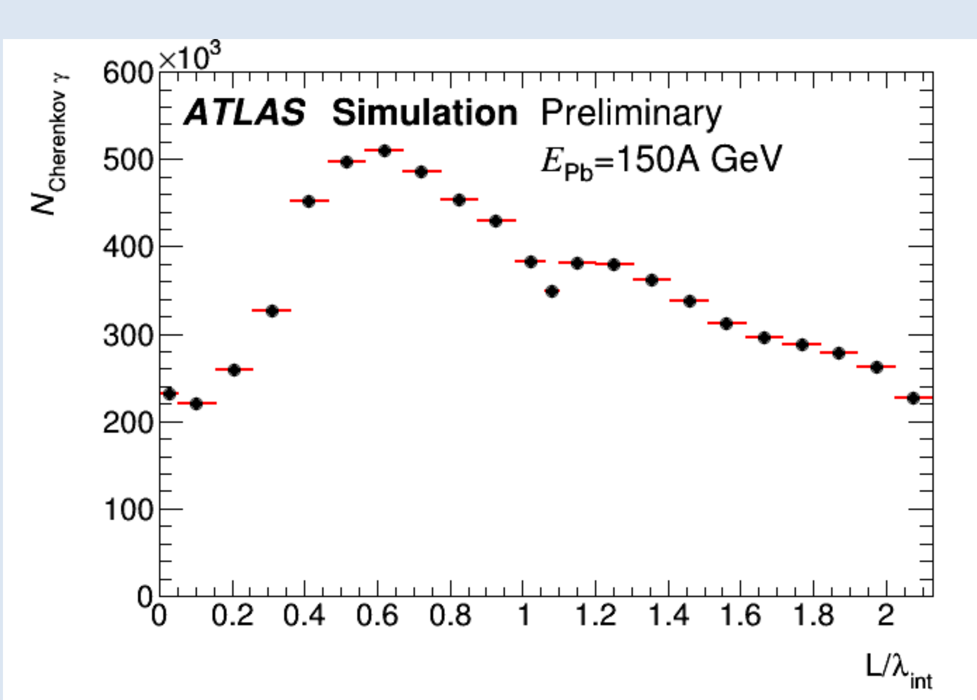
- *Cherenkov signal in first gaps dominated by primary Pb ion*



- *Cherenkov shower max occurs in Gap 7, where signal is dominated by high multiplicity in the low Z shower*



- *Each radiator gap has a soft, low Z spectra from material fragments inside the detector*

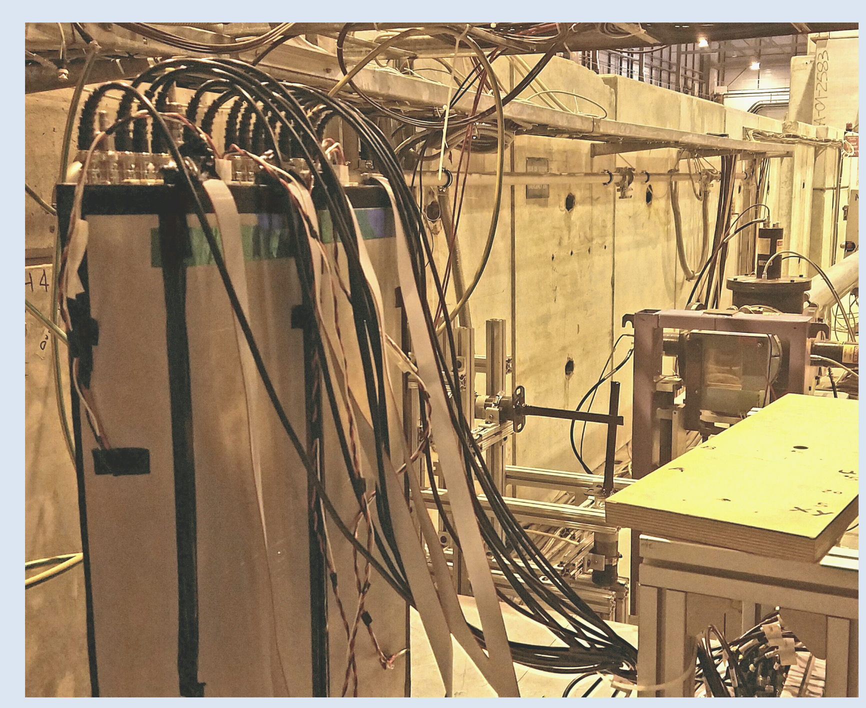


Simulated Cherenkov signal produced at each radiator gap

- Cherenkov signal peaks in the 7th radiator gap, which maps to the 3rd and 4th WFD gaps
- Test beam data should be sensitive to large Cherenkov signal from primary Pb ion in the first few gaps
- Test beam data should also be able to resolve shower max and spectral shape

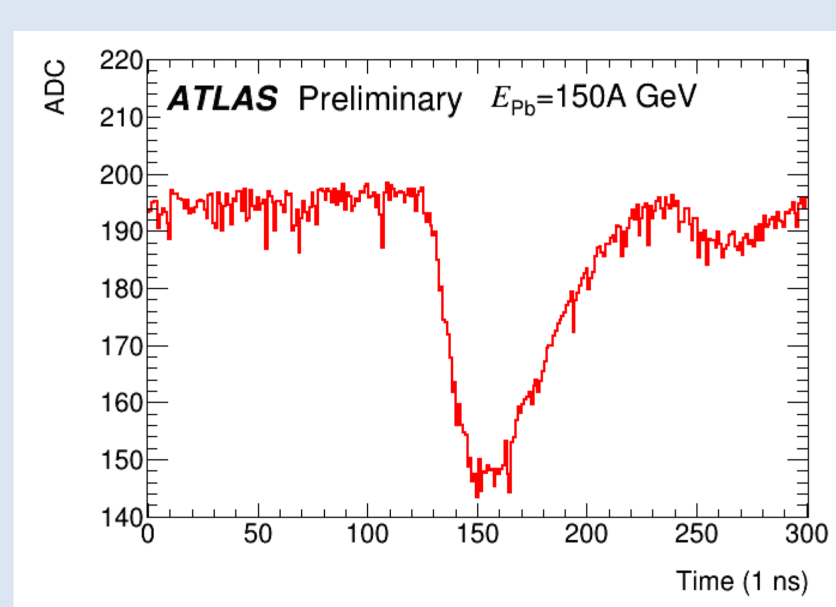
SPS Beamtest: 150A GeV Pb Ions

- Liquid ZDC (LqZDC) modules successfully assembled and read out at an SPS test hall in December 2016
- Shower development was observed across the detector
- Dual-wavelength shifting concept validated
- Test beam data analysis ongoing

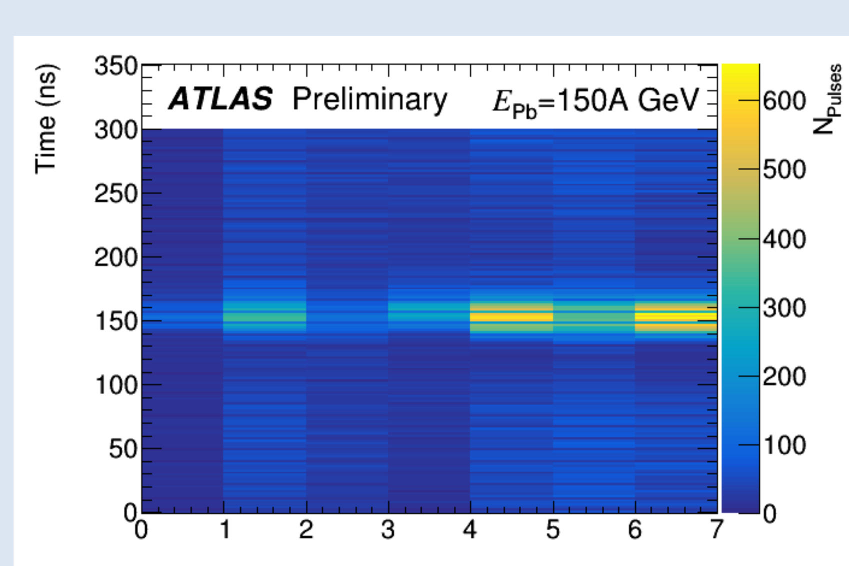


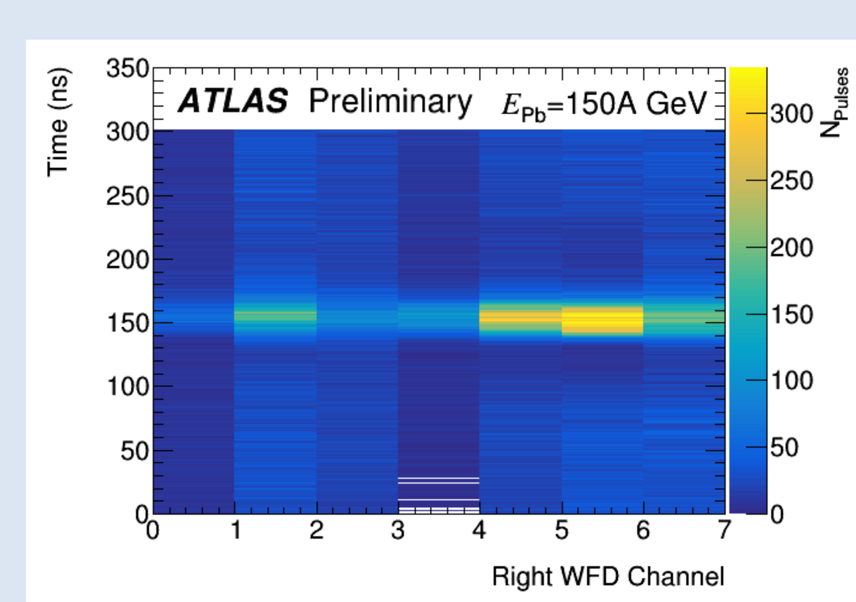
[Above] LqZDC modules are shown on the left-hand side of the image in aluminum casing. The modules are in place along the SPS H4A beamline, with a pair of scintillator paddles in front as Pb beam triggers. As pictured, beam comes from upper right of image.

Raw signal from a single channel



[Below] Timing distributions are shown from hits occurring in channels on both sides of the detector. There is a continuous background of dark current and electronic noise but also a ***clear correlated signal showing the shower development across all channels.***





References:
[1] ATLAS Collaboration, HION-2015-001
[2] ATLAS Collaboration, ATL-COM-FWD-2017-002