BRAN: Modeling and Experimental Results at ATLAS and CMS

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BRAN Chamber Design

- 4 quadrant hi-pressure Ar-N\(_2\) ionization chamber
- Located in the TAN on both sides of IP1 and IP5
- Designed to measure
  - the relative bunch × bunch luminosity
  - collisions at 25 ns bunch spacing
- Quadrant nature allows measurement of crossing angle

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Overview of Simulations

- Using FLUKA with IR1 and IR5 geometry done by CERN
- We have added a detailed model of the TAN including forward detectors and BRAN
FLUKA model of ATLAS IP1

IP model developed at CERN

TAN Model developed by LBNL

ZDC Detector

BRAN

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Two methods of readout

- All four quadrants read out for each bunch and turn
- Data is processed in two ways
  - **Counting Mode (currently recorded for left side of each IP)**
    - Each bunch is counted as a “1” if exceeds a certain threshold
    - Software integrates over a specific number of turns
    - At lower luminosity this is linear as BRAN has a low acceptance
    - At higher luminosity can saturate
  - **Pulse Height Mode (currently recorded for right side of each IP)**
    - The signal voltage for each bunch is collected and summed for a number of turns
    - This higher statistical fluctuations but linear up to maximum digitization of the ADC (There are several ways to reduce the signal)
Simulated Counting Mode with Pileup

- Counting mode with thresholds of 10, 15, 20, 25 mV (number 2011 includes attenuators and cable lengths)
- Counting mode is linear but starts to saturate as rate increases
- One can reach a linear region by increasing threshold
Average Energy Collected/pp interaction

- Difference of energy between ATLAS and CMS due to different absorbers
- Total energy deposited decreases with increasing crossing angle
- Mapped energy response from 3.5 to 7.0 TeV beam energy with varying crossing angle
Correlation between BRAN and ATLAS

![Graph showing the correlation between BRAN and ATLAS. The x-axis represents ATLAS Lumi in units of $10^{30} \text{ cm}^{-2}\text{s}^{-1}$, and the y-axis represents the relative difference in percentages. Two lines are depicted: 1L (Count) and 1R (Pulse). The graph is labeled Fill 2006.](image_url)
Crossing Angle: Data and Simulation

- Crossing Angle ratio defined as:
  \[
  \frac{(Q_1+Q_2)(Q_3+Q_4)}{(Q_1+Q_2+Q_3+Q_4)}
  \]

- 0.259 ± 0.006 (vertical) for ATLAS at 240 µrad
- 0.261 ± 0.005 (horizontal) for CMS

**Graphs:**
- Data
- Simulation

**Reference:**
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New GUI for use in the CCC

System Parameters

Luminosity
Atlas and CMS

B x B Lumi @ ATLAS

Emittance
Atlas and CMS

B x B Emitt. @ ATLAS

Bad Batch

B x B Lumi @ CMS

B x B Emitt. @ CMS

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Beam Size Evolution– IP5

The plot of the Specific Luminosity is part of the operator display.

\[ A = 4\pi \sigma_x \sigma_y = f_{rev} \frac{N_1 N_2}{L_b} \]
Tool providing data to experts

Counting Mode

- Records both counting mode and pulse height mode at the same time for each quadrant of all detectors
- Useful tool to diagnose health and setup of detector

Provided by E. Bravin
Summary

• Timber Data is different in Left and Right for 2011 data

• BRAN is in LHC control system and being used to optimize collisions

• Fully integrated detailed FLUKA model of TAN with CERN’s model of both IPs

• Detectors at the TAN are sensitive to crossing angle
  • As energy and or crossing angle increases, center of shower becomes more asymmetric

• BRAN is an excellent tool to cross check experiments

Timber Plot for PbPb

x axis: time
y axis: bunch #
z axis: Luminosity
Backup
Ionization Chamber Fabrication

Electrodes and ground plane
- OFHC copper
- Wire Electrical Discharge Machining (Wire-EDM)
- High precision
- Ground plane center element is e-beam welded

Sensor body
- Macor
- Several fine features with high precision
- Fasteners for assembly
- Over-constrained assembly requires some craftsmanship for precise alignment

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Case Hardware
Ar-N2 Ionization Chamber Design

- 4 quadrant gas ionization chamber (4 quadrant electrodes)
- 6x1 mm gaps
- Ar + N₂
- Central ground structure
- 3m coax between chamber and electronics

2 mm Cu
λ_R=14.4 mm
How to get Luminosity

\[ \tau = \frac{x_{\text{GAP}}}{\nu} \]

\[ Q = \int_0^\tau I(t)dt = \frac{1}{2}I_0\tau \]

- Signal is proportional to the # of parallel gaps
- Capacitance increases with # of gaps + slows down the signal
- Optimized for 6 gaps
- Must live in a radiation environment 10× worse than accelerator instruments have ever seen
  - \( \sim 10 \text{ GGy/yr}, \sim 10^{18} \text{ N/cm}^2 \) over lifetime (20 yrs), \( \sim 10^{16} \text{ p/cm}^2 \) over lifetime
Correlations between BRAN and CMS and ATLAS

![Graph showing correlations between IC rate and ATLAS/CMS lumi. The graph includes lines for 1L, 1R, 5L, and 5R.]
Can see subtle shift in Crossing Angle
PbPb Data in Timber
(Can average longer in Pulse Height Mode to lower error bars)
Program by Enrico Bravin

**Counting Mode**

**Pulse Height Mode**

Bucket Number

Bucket Number

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