G4SBS Beamline and HCal Calibration

Sebastian Seeds - SBS Collaboration Meeting Feb. 2021

G4SBS Beamline Overview

G4SBS is an interactive simulation software that uses Geant4 to simulate beam conditions for various SBS hardware configurations in Hall A. It can:

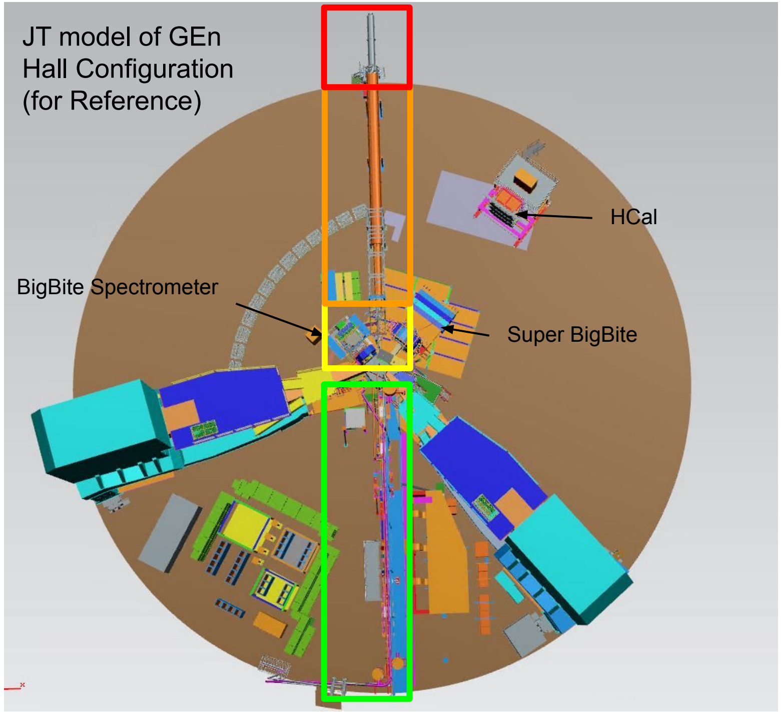
- Track the kinematics and interactions of simulated particles
- Simulate/calculate event rates for processes of interest in sbs program
- Calculate detector performance/acceptance/resolution
- Estimate background rates and detector occupancies

G4SBS requires simulated geometry. The beamline, in particular, consists of:

- Upstream beampipe and components
- Target-Proximal downstream beampipe
- Target-to-midpipe section
- Beam dump section

All builds hosted on git

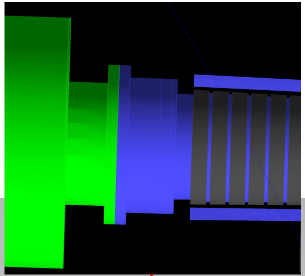
- github.com/JeffersonLab/g4sbs



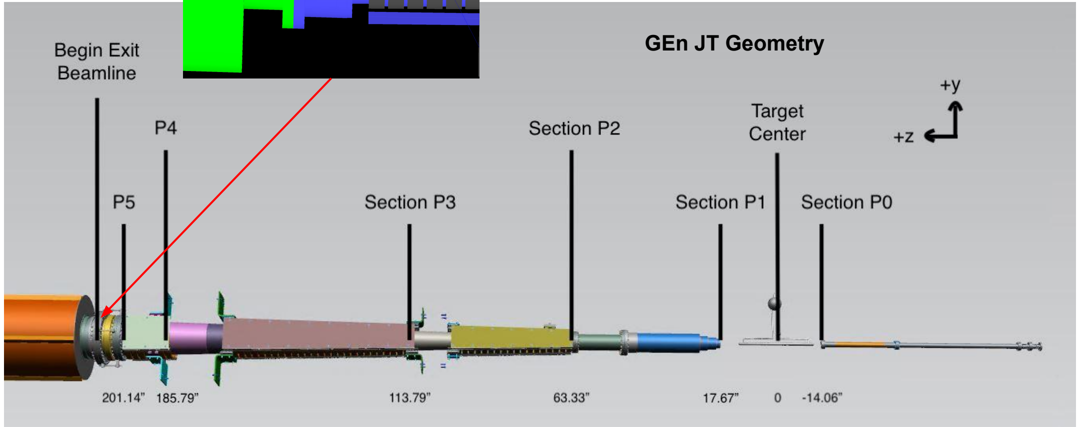
G4SBS GEn Beamline

- All sections constructed to match engineering plans (primary JT file)
  - Geometry and materials
- Insignificant elements ignored
  - Brackets, screws, rivets, etc.
- Target to midpipe, beam dump, and active upstream components implemented by David Flay

- Interface to experiment-common target-to-midpipe section accurate

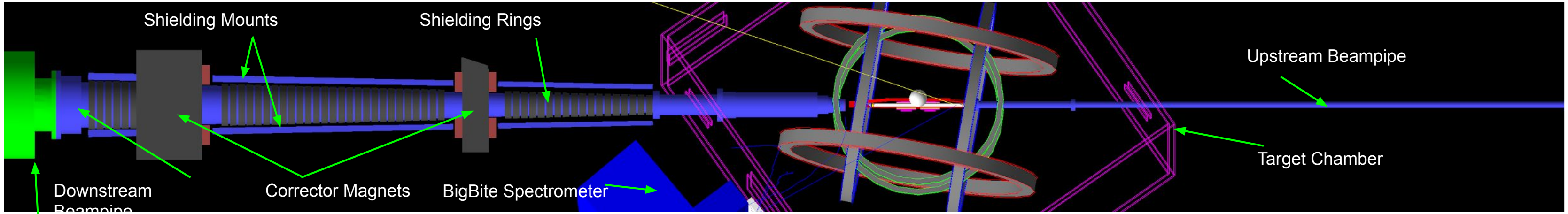


Interface between target-proximal beamline and common target-to-midpipe sections.



Corrector magnets removed for perspective

Current G4SBS geometry



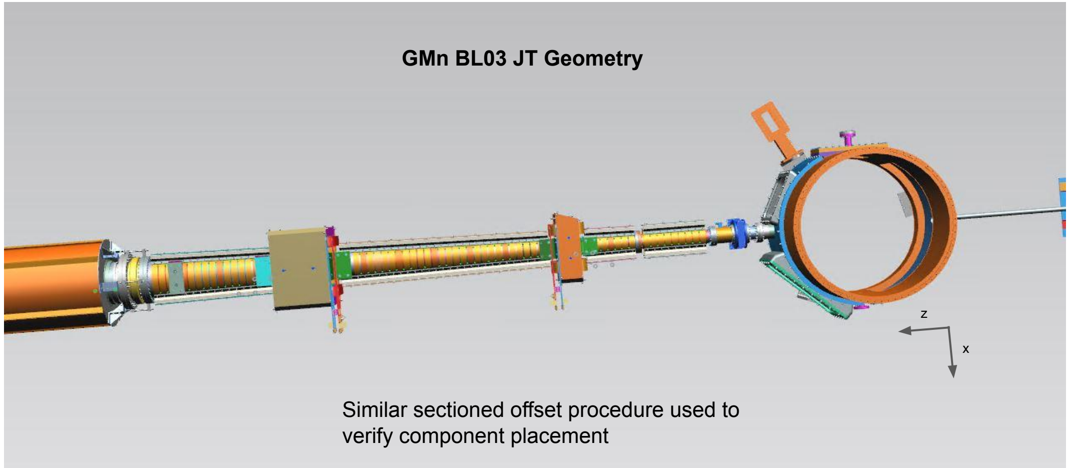
Common target-to-midpipe section in green, large O/D

48D48 magnet moved for perspective

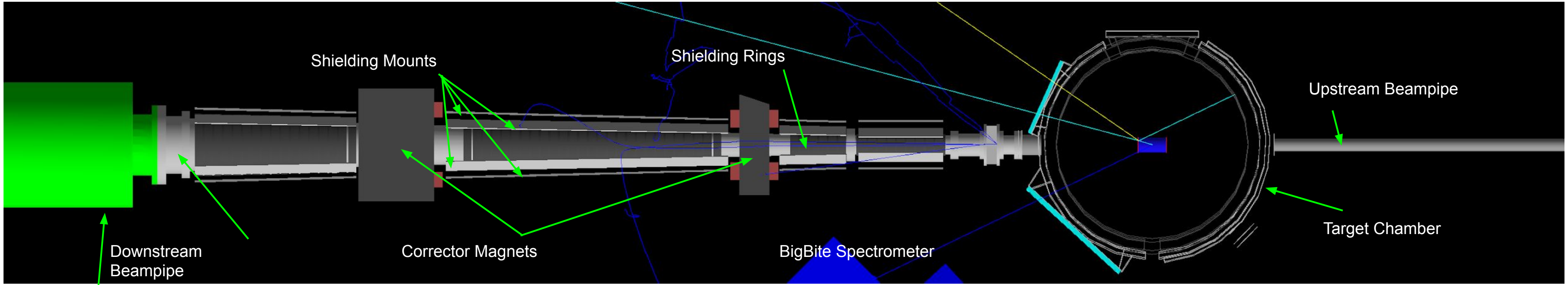
G4SBS GMn Beamline

- Beamline geometry now constrained to previous BL03 configuration
  - No others expected for GMn
- Conical beamline section (including corrector magnets and shielding) shifted and checked.
- Additional components can be added as needed including lead shielding.

- All experiment common downstream beamline elements are consistent with GEn.



Current G4SBS geometry



Common target-to-midpipe section in green, large O/D

48D48 magnet moved for perspective

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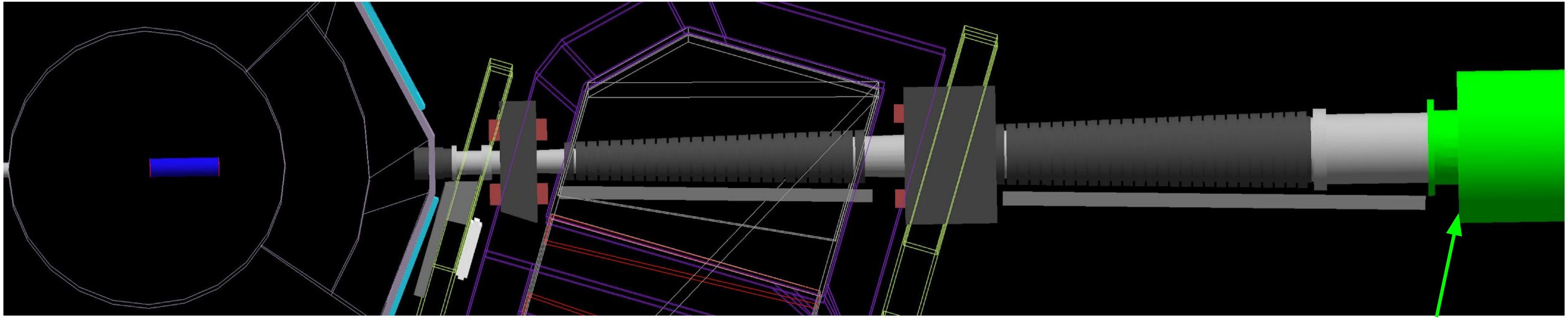
G4SBS GEp Temporary Beamline Status

- Similar G4SBS geometry retooled as stand-in
  - Pending determination of final GEp configuration
- All overlaps and air gaps eliminated with simple assumptions about configuration of shielding and target-proximal bellows.
  - Similar magnetic shielding structure
  - SBS side lead shielding
  - Bellows and flange extensions interface with common elements at similar radial dimensions



Target to midpipe section in green, large O/D

48D48 magnet wireframe (in purple) located between corrector magnets

G4SBS Beamline Status and Further Work

SBS experiments with complete beamlines in simulation software:

- GEn/SIDIS
- GEn-rp
- GMn
- WAPP
- nTPE

Experiments with incomplete beamlines in simulation software pending work:

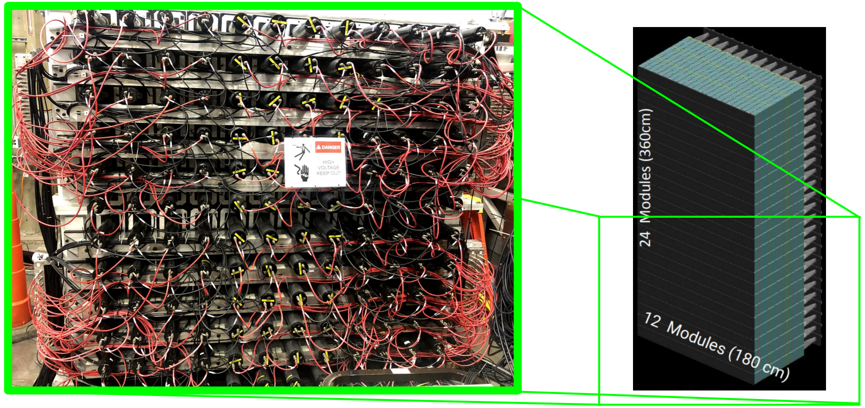
- GEp (in progress, pending final configuration)

..and any other configurations which require changes to the beamline.

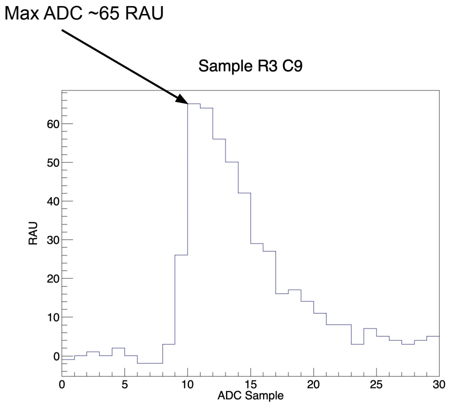
Along with all detectors (hadron arm and electron arm), the beamline in g4sbs is ready for simulation in support of the Fall 2021 run and up to date with all GMn run group hall configurations.

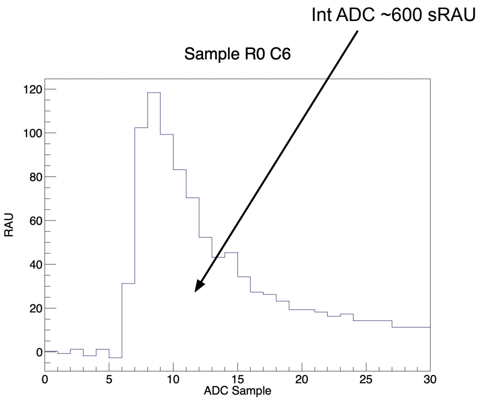
HCal Cosmic Configuration Fast Overview

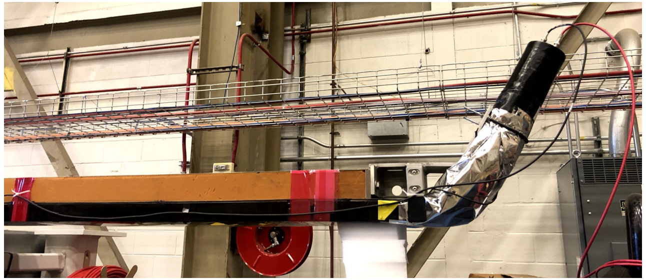
- Hadron Calorimeter will measure hadron (p/n) energy for all SBS experiments
  - 288 (12 x 24) channels
    - One pmt per module/channel
  - Cosmic paddle trigger
  - Typical signal pulses by channel
    - 4 ns bins on x-axis
    - fADC converts PMT analog signal to Raw ADC Units (RAU) (~0.5 mV = 1 RAU)
    - Summed RAU (sRAU)



Bottom half of HCal in Test Lab. 144 modules (channels) showing.







Cosmic scintillator over top half of HCal. One cosmic paddle for each 12 x 12 set of modules.

HCal Calibration Targets

- Target RAU by channel set to within electronics saturation
  - Average energy deposition by cosmic per pmt -> 14 MeV
  - Max energy deposited per pmt for highest Q^2 point in GMn -> 700 MeV
  - Saturation -> 4095 RAU (ADC limit) * 1.5 (dynamic range of amplifier/fADC) * 0.5 (cable attenuation)
  - Target signal maximum RAU per channel -> (4095 RAU * 0.75) * (14 MeV / 700 MeV) = **61 RAU**
- Gain and Target HV by pmt
  - Gain from data sheet
    - Alpha est. by pmt type

$$\frac{HV_{set}}{HV_{target}} = \left[\frac{RAU_{measured}}{RAU_{target}}\right]^{\frac{1}{\alpha}} \longrightarrow HV_{target} = \frac{HV_{set}}{\left[\frac{RAU_{measured}}{RAU_{target}}\right]^{\frac{1}{\alpha}}}$$

- Cosmic Calibration Plan
  - Set HV by channel using initial estimate from data sheet range. Take cosmic run with 500k to 1500k events.
  - Calculate target HV from measured RAU per channel.
  - Set HV for next iteration. Repeat calculation.
  - HV setting convergence (61 RAU) is reached and final HV setting by channel can be extracted for cosmic rays.
    - At these final HV settings the highest expected energy deposition during running will not saturate the amplifiers, but the signal gain is at the highest possible level.

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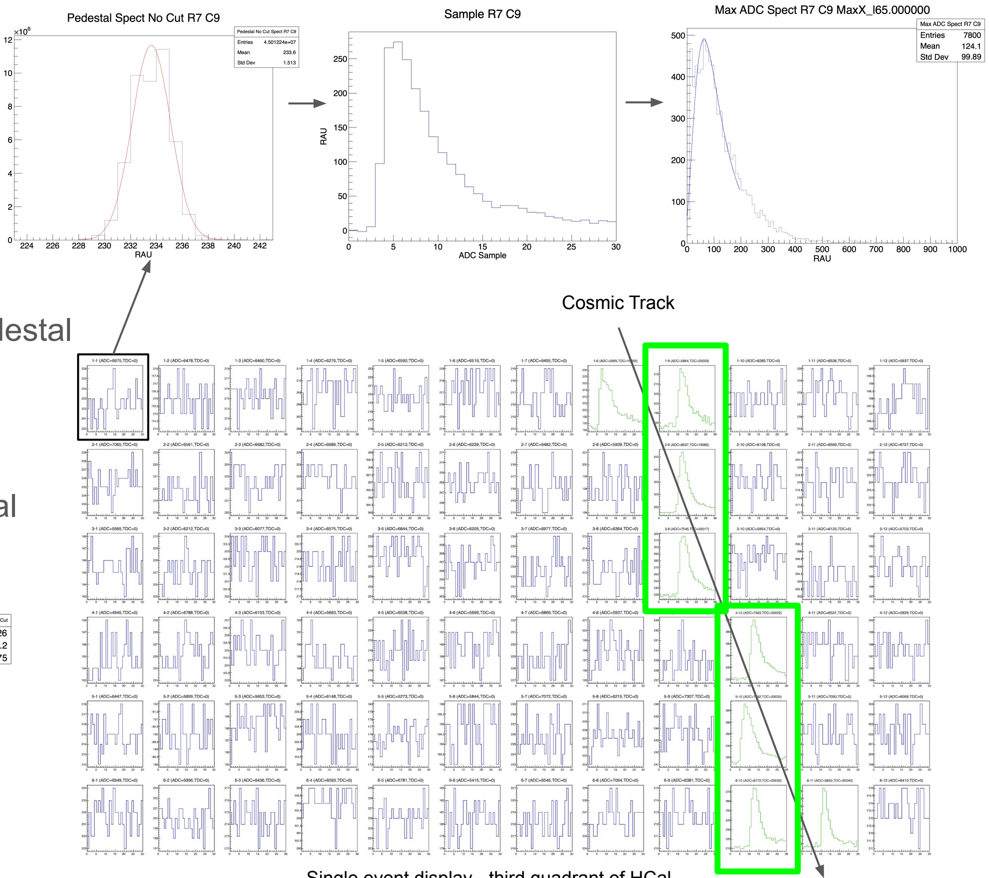
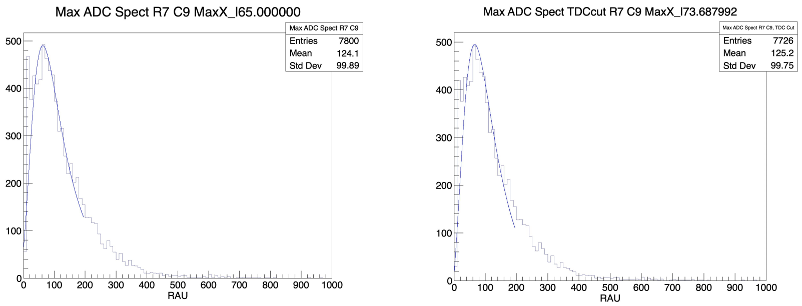
Cosmic Calibrations

- Trigger
  - Scintillation in cosmic paddle over threshold
- Event cuts
  - Pedestal from aggregate events by channel
  - ADC threshold set in software to 6 sigma pedestal
  - Pedestals subtracted from signal
  - Track cuts
    - Three in line, else rejected
  - TDC cut and final comparison with ADC signal without TDC cut



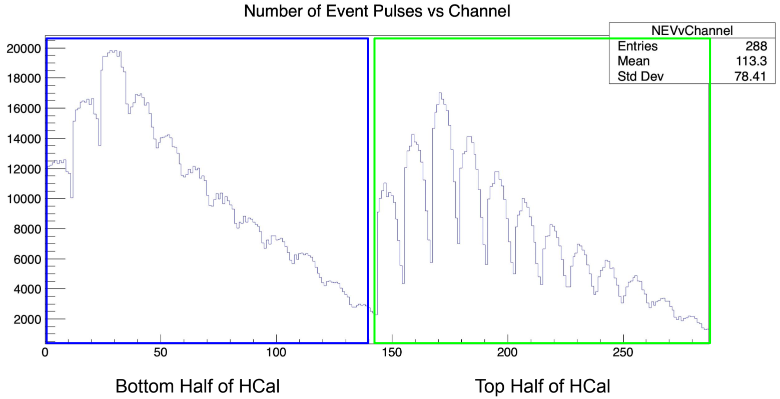
Single event display - third quadrant of HCal

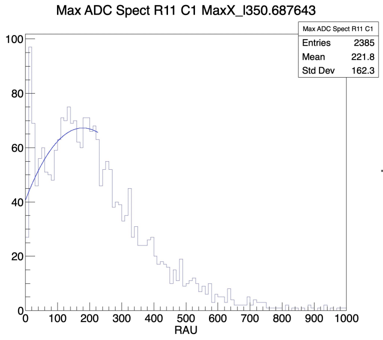


Similar results, some low amplitude noise rejected by TDC

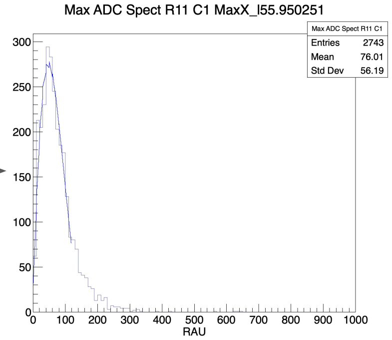
Cosmic Calibration Results

- Max ADC and Max TDC by channel
  - 1.5M events to obtain average value for measured RAU
    - ~2500 cosmic events that pass cuts per channel
- Fits
  - Landau distribution for cosmics - when fit fails default to mean in histogram
    - Effective for iterative calibration approach
    - Some manual fitting required
  - Average Max value (in RAU) extracted.
    - Recall: Target is 61 RAU from simulatec neutron events at highest Q^2 in GMn run group and associated energy deposition





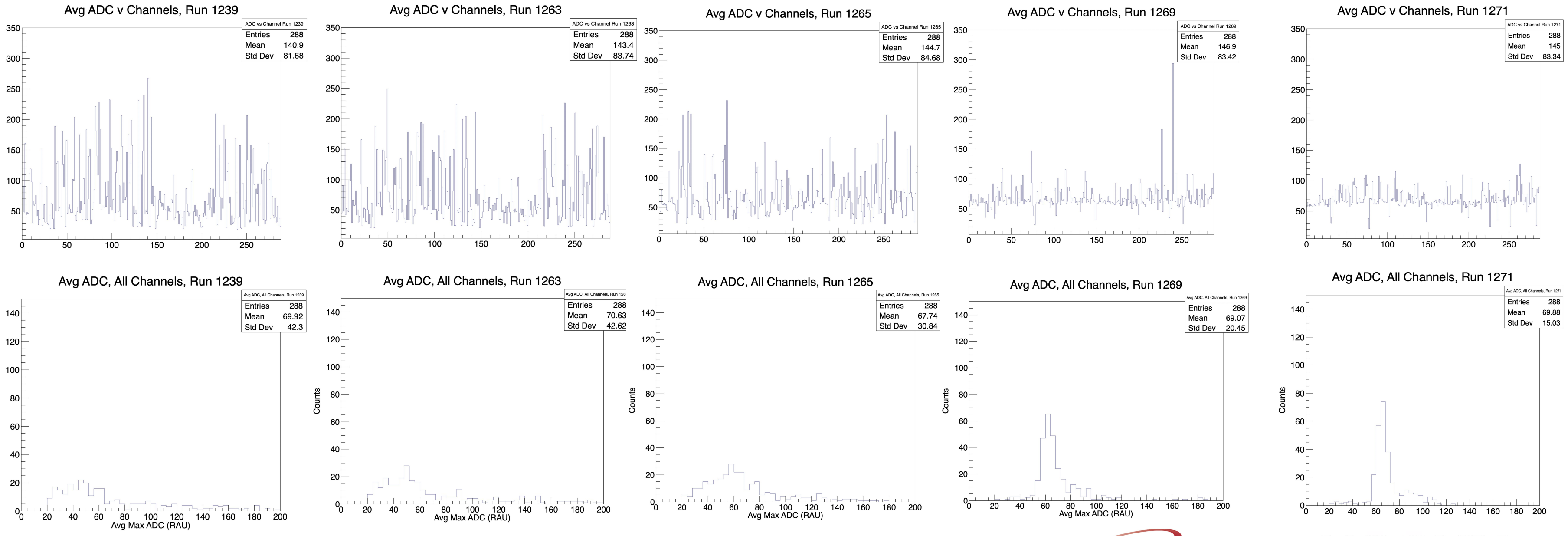
Several Iterations



Cosmic Calibration Results - continued

- Analysis Histograms
  - Over several iterations, all channels converging to 61 RAU Max ADC
- Output target HV settings per channel

```
#Target HV settings for run 1271.
#Row Col targetHV_landauFit targetHV_landauFit_TDCCut
0  0  1496.7  1493.14
0  1  1474.07  1472.61
0  2  1481.01  1482.01
0  3  1460.48  1458.66
0  4  2087.38  2087.34
0  5  1801.1  1800.26
0  6  1790.09  1788.82
0  7  1863.81  1862.41
0  8  1465.27  1465.69
0  9  1442.21  1441.66
0  10  1428.59  1425.91
0  11  1485.44  1435.89
1  0  1436.53  1436.3
1  1  1447.3  1447.31
1  2  1446.7  1448.4
1  3  1439.61  1423.84
1  4  1963.47  2037.2
1  5  1729.73  1729.73
1  6  1998.99  1992.88
1  7  2058.51  2343.7
1  8  1414.07  1402.57
1  9  1472.01  1473.43
```



Over several Iterations

Future HCal work

- Hardware
  - Can extract gain curves by pmt across various HV settings and compare with parallel LED analysis (see Vanessa Brio’s talk).
    - This will provide a means to calibrate by various kinematics in the hall via better estimation of alpha parameter.
  - Hardware checks
    - General calibration constants are being checked by channel to account for front end electronics and cable attenuation. These analyses consider an electronics attenuation factor of 0.75, but recent measurements will update this factor (closer to 0.6).
  - Software
    - Implement script to run when we have beam that sets HV by channel from signal via gain curve.

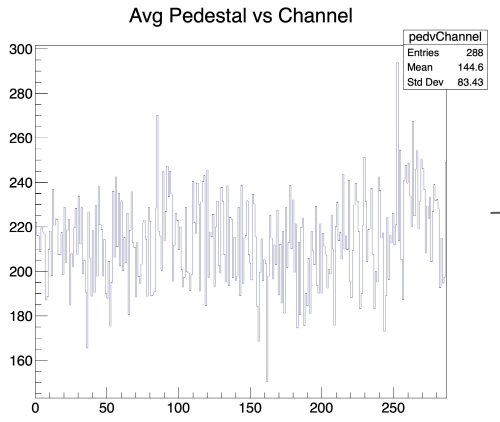
Acknowledgments

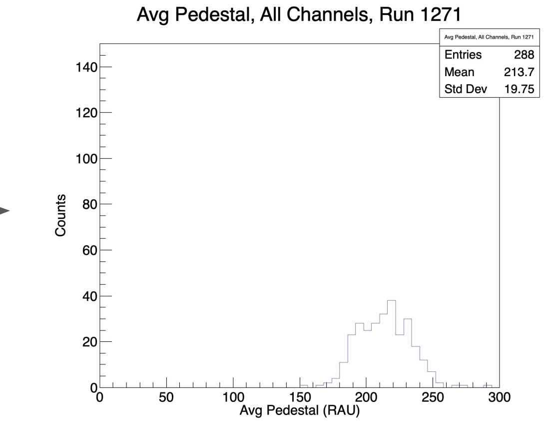
- David Flay and Eric Fuchey - beamline and geant4
- Juan Carlos Cornejo and Scott Barcus - HCal, g4sbs, hardware
- Andrew Puckett

Lots to do! Thank you for your time and attention!

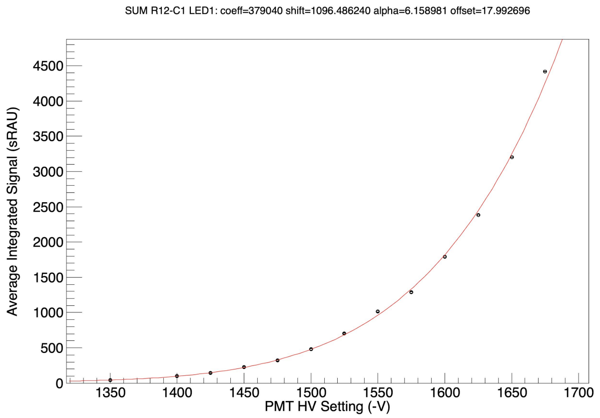
Backup

- Pedestals



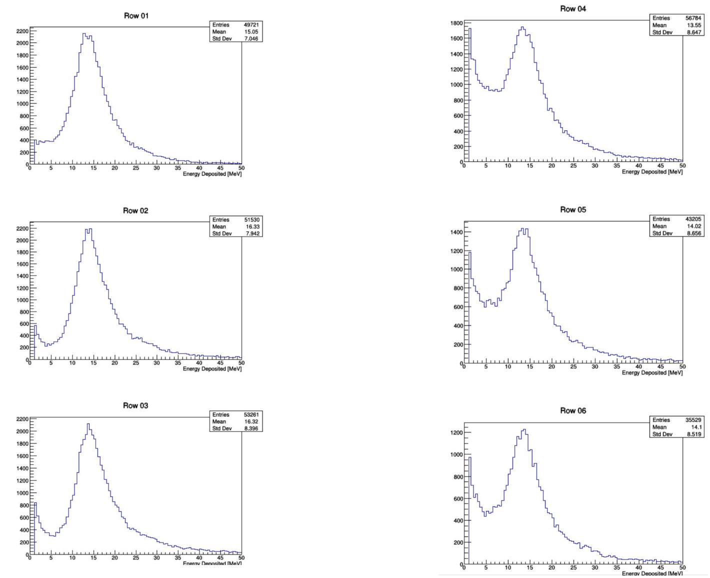


- Gain Curves

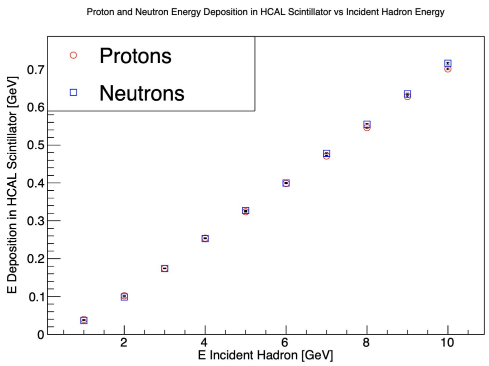


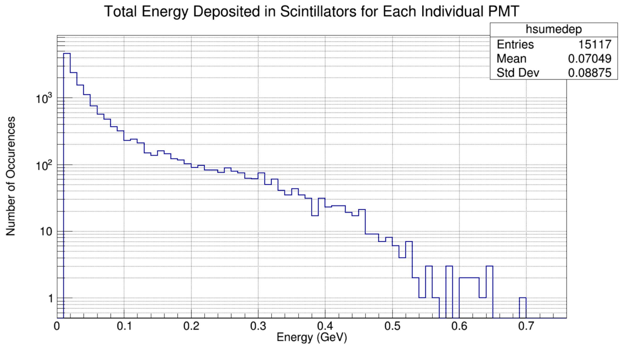
Backup

- Average cosmic E
  - Simulation plots via Juan Carlos Cornejo



- Total E dep per pmt
  - Simulation plots Sebastia Seeds and Scott Barcus





Backup

- Several max adc histograms