Calibration Techniques for the STAR Forward Electromagnetic Calorimeter

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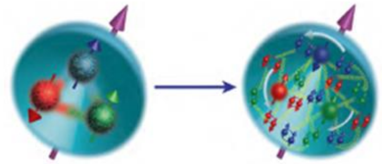
Motivation

At RHIC, energetic proton and ion collisions allow deeper investigation of standard model physics, notably QCD.

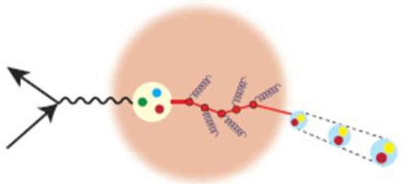
The STAR Upgrade Program is poised to address many existing questions in this field:

Hadron Properties
How parton spin and momentum are distributed within the hadron.



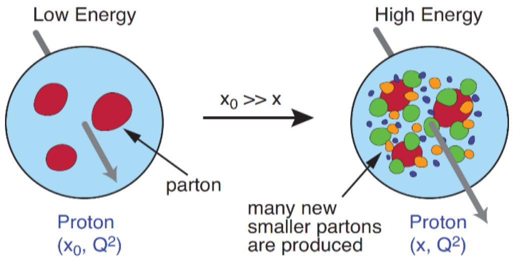
Channel: *Charged hadrons in jets and dijets*

Nuclear Medium Properties
How a nuclear environment affects gluon and quark distributions bound inside nucleons.



Channel: *Drell-Yan e^+e^- pairs*

Gluon Properties
How the gluon density changes with energy and momentum, and if any of these density states are more favorable in nature.



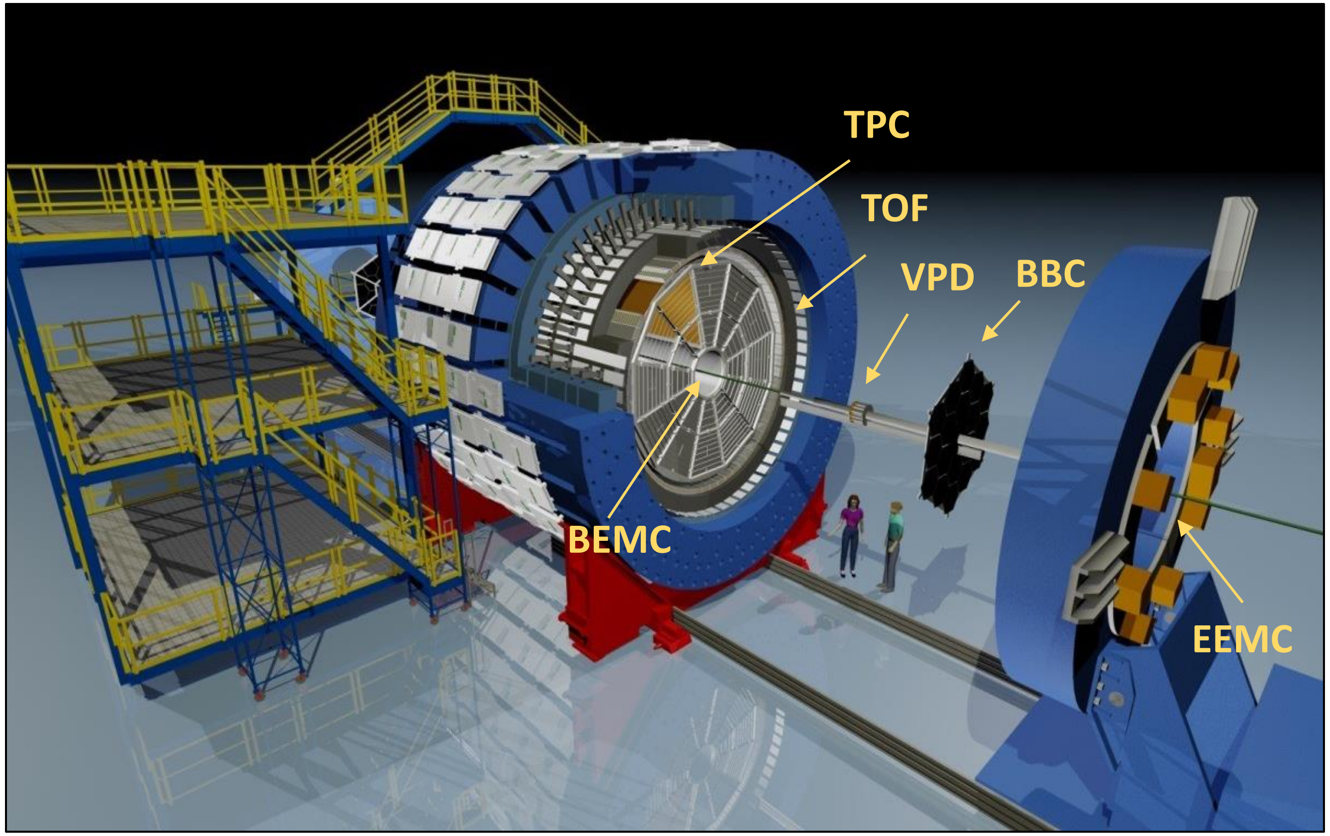
Channel: *Di-hadron pairs and h^+jets*

Further development of studies in these areas require access to the forward region, pushing sensitivity to high and low parton momentum fractions (*x*).

STAR Experiment

" **S**olenoidal **T**racker **A**t **R**hic "

TIME PROJECTION CHAMBER (TPC)	charged particle tracking
TPC + TOF	charged particle identification
BARREL EM CALORIMETERS (BEMC) ENDCAP EM CALORIMETER (EEMC) 5520 (PbSc) towers	EM particle detection high p_T triggering
BEAM BEAM COUNTERS (BBC) ZERO DEGREE COUNTERS (ZDC) VERTEX POSITION DETECTORS (VPD)	relative luminosity minimum bias triggering

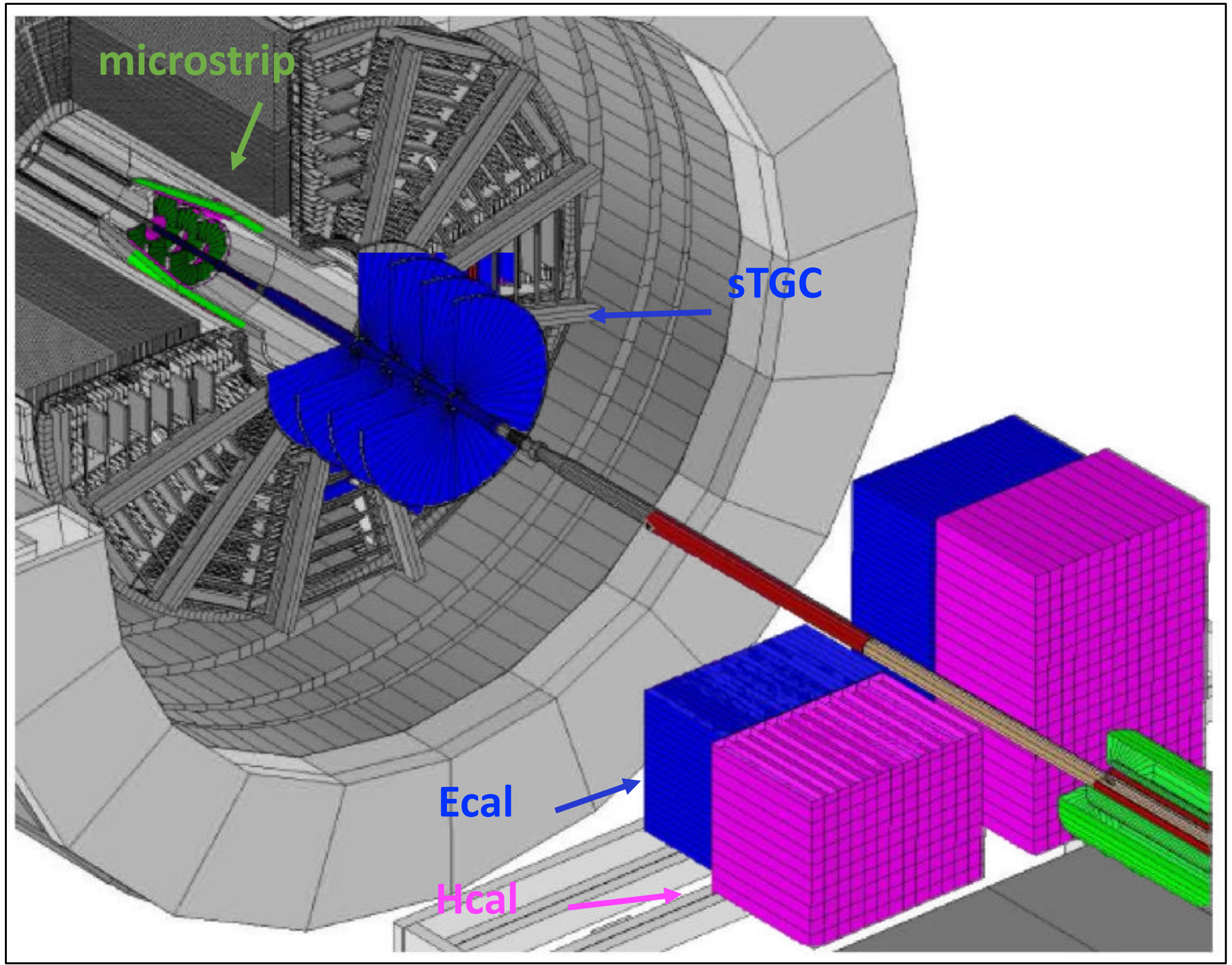


BNL.gov

STAR Forward Upgrade

- Provides access to low and high x

RANGE	
Current "Mid-rapidity"	Forward Upgrade "Forward rapidity"
$0.05 < x < 0.2$	$0.005 < x < 0.2$
$-1 < \eta < 2$	$2.5 < \eta < 4$



- Trackers
  - 3-layer silicon microstrip
  - 4-layer small-strip thin gap chamber (sTGC)
- Calorimetry
  - Pb/Sc Electromagnetic Calorimeter (Ecal)
    - 1496 towers
    - Repurposed from PHENIX
  - Fe/Sc Hadronic Calorimeter (Hcal)
    - 520 towers
- Scheduled start operations in Fall 2021
  - Polarized 510GeV pp run

STAR Forward Upgrade

Calorimetry Prototyes

first successful run, 2019

AuAu at $\sqrt{s}$= 200 GeV

Electromagnetic Calorimeter ("Ecal")

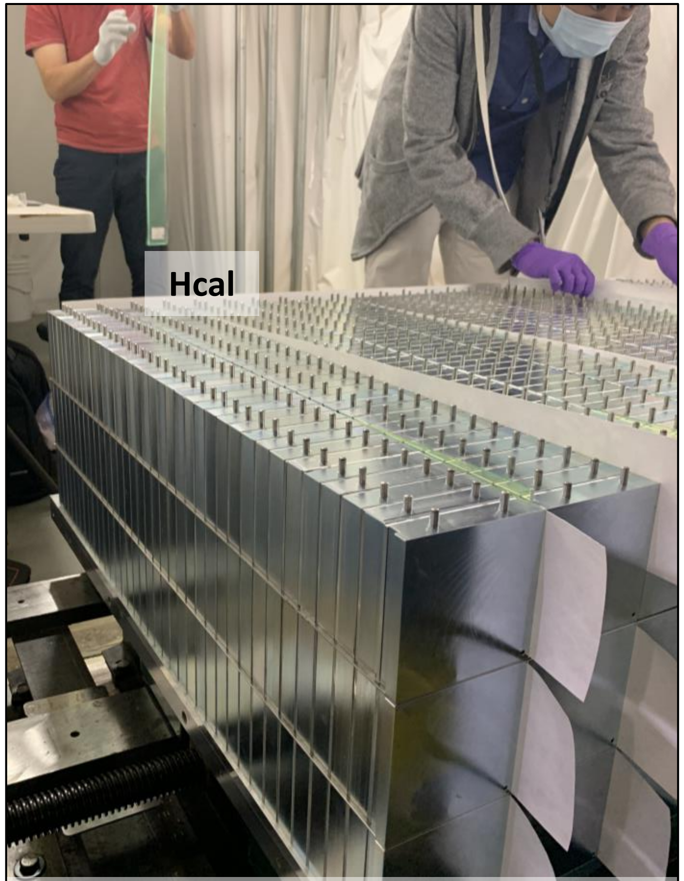
- Pb/Sc , alternating layers

Prototype: 64 towers

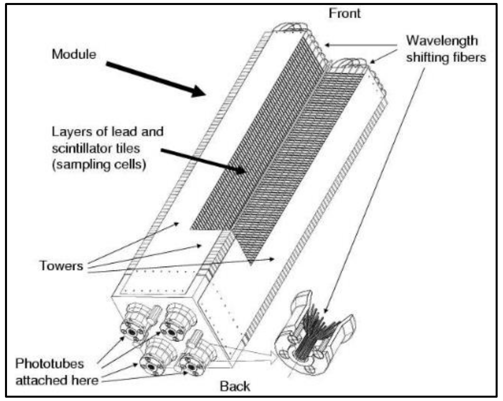
Hadronic Calorimeters ("Hcal")

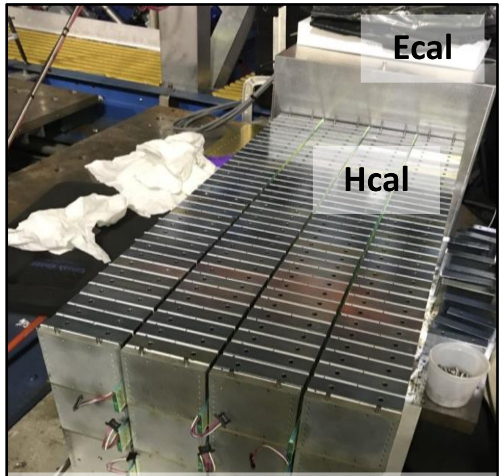
- Fe/Sc , alternating layers
- STAR's first Hcal to-date

Prototype: 16 towers



Forward Upgrade Installation





Prototype

Relative Calibration of Ecal

- Like all detectors in particle experiments, Ecal and Hcal must be calibrated
  - Determine relative detector gain of Ecal

$$detector\ gain = \frac{ADC\ value}{energy\ deposited}$$

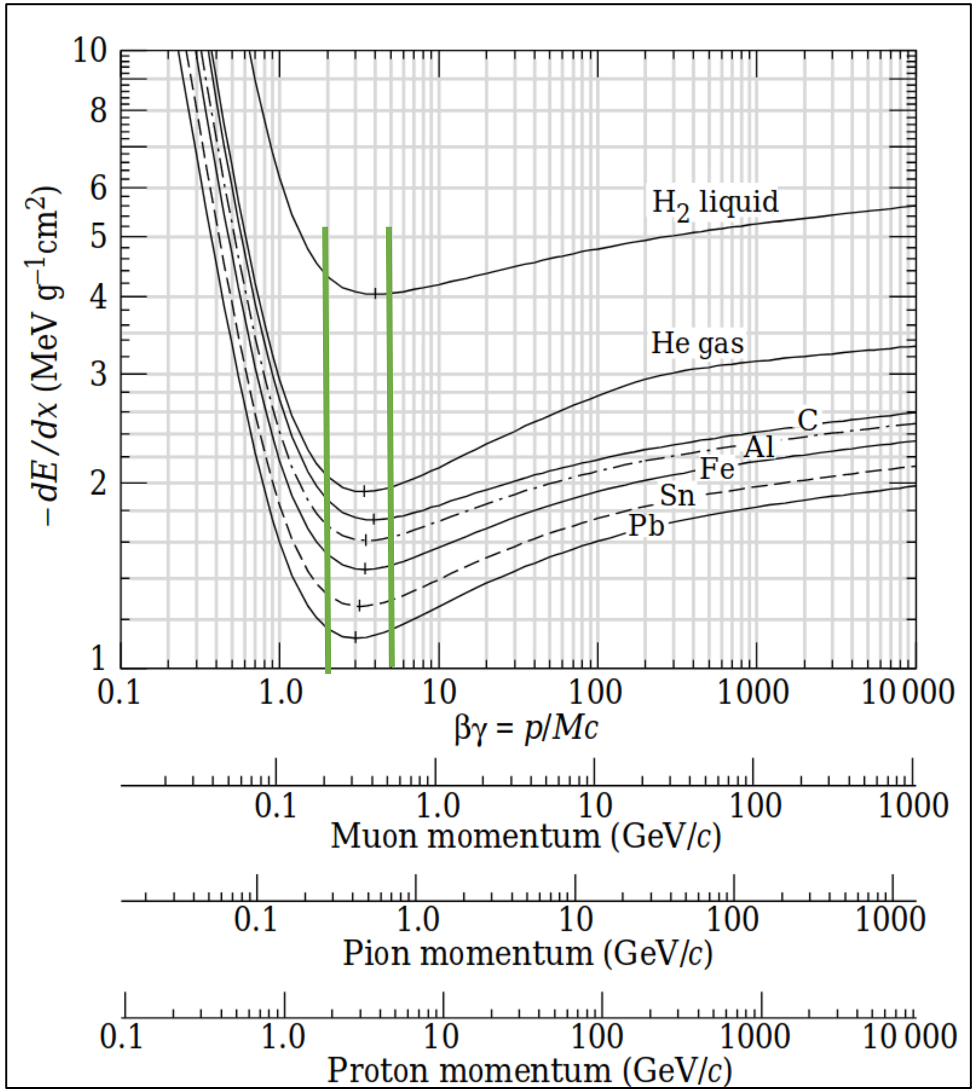
- ADC spectra are unitless until calibrated to some energy
  - Must be calibrated to source of known energy
  - One way to calibrate Ecal is with MIPs

- " **M**inimum **I**onizing **P**article "
  - Particle that deposits same energy in Ecal each time
    - Charged hadron, doesn't produce energy-dep. EM shower

$$\frac{1}{\rho}\frac{dE}{dx} \approx \frac{-4\pi\hbar^2 c^2 \alpha^2}{m_e v^2 m_u}\frac{Z}{A}\left\{ln\left[\frac{2\beta^2 m_e c^2}{I_e}\right] - \beta^2\right\}$$

Bethe – Blocke Eq.

  - Most relativistic particles have mean energy loss rates close to the minimum, so they're called MIP's



Particle Data Group

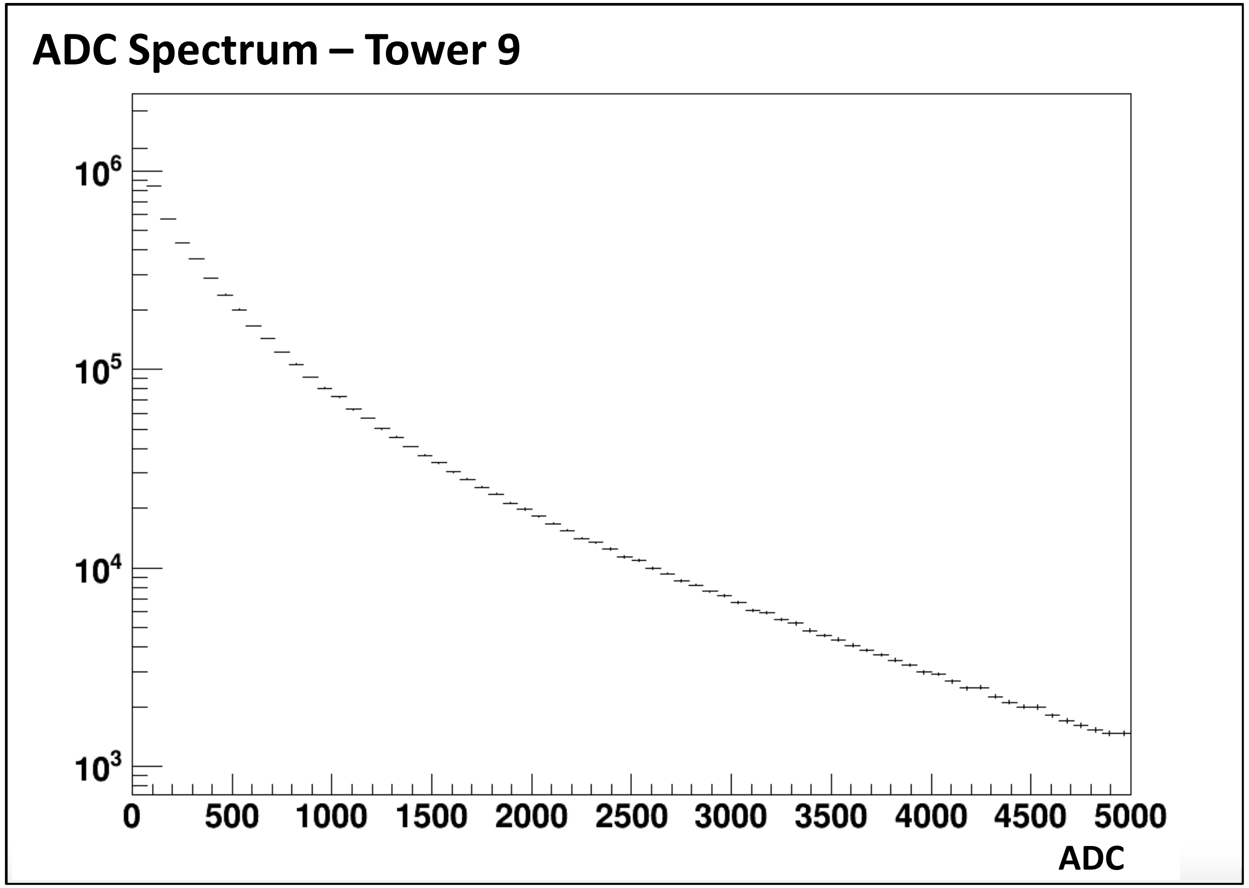
Relative Calibration of Ecal

Goal: Isolate and Fit Ecal MIPs

Run 19

AuAu at $\sqrt{s}$= 200 GeV

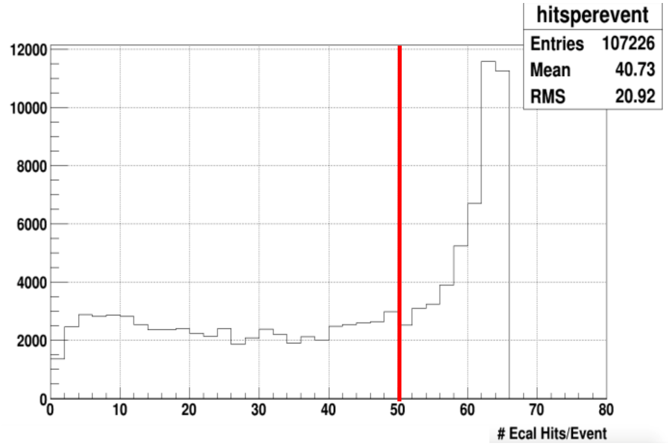
- Plot 1D energy distributions
  - each Ecal
  - Isolate MIP
- Fit MIP slopes
- Use slopes to gain match detectors

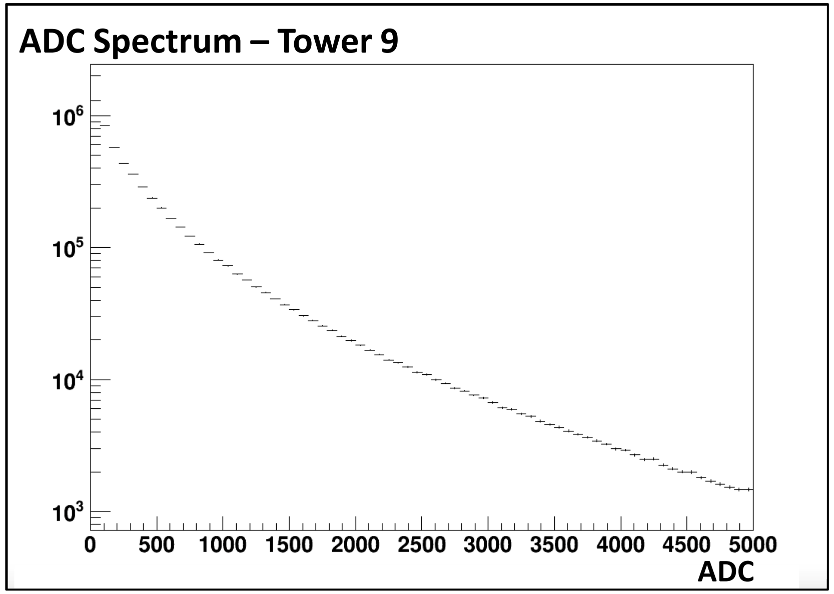


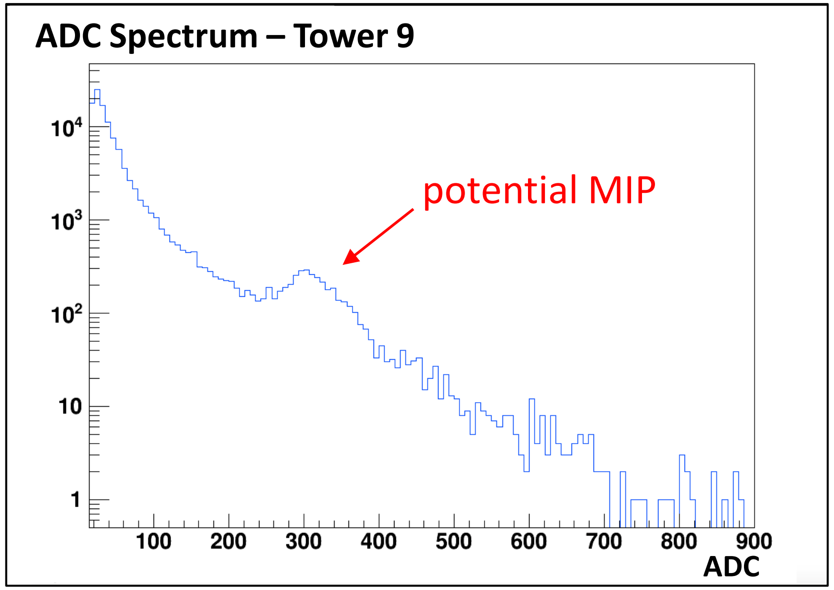
Relative Calibration of Ecal

Ecal Cuts

- Select Single Data Set
  - “Minimum bias” trigger data set
- Isolate Peripheral Events
  - Number of Hits/Event < 50
- Ensure We’re Looking at Individual Events
  - Number of Nearest Neighbors/Cluster =0
  - Number of Towers /Cluster = 1



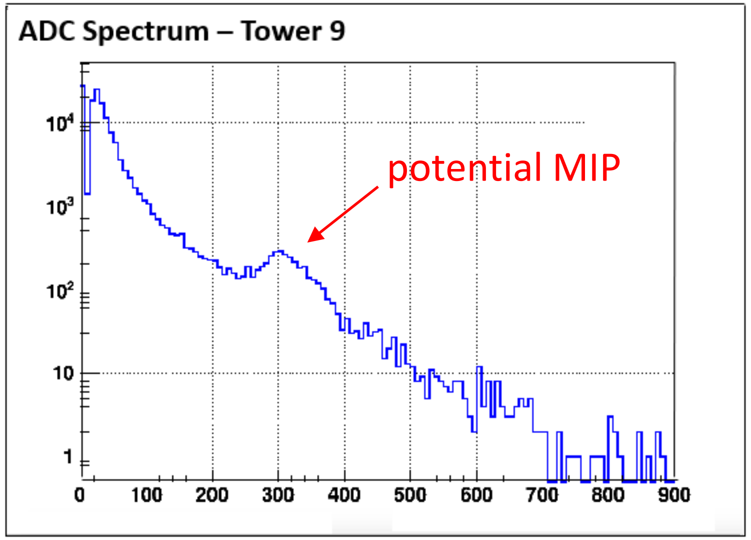




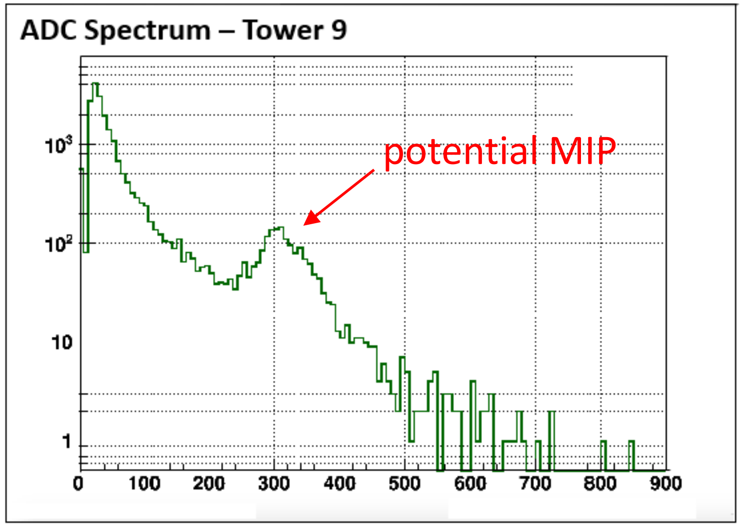
Relative Calibration of Ecal

Hcal Cuts

- Ensure that we have a hadron
- Maximize signal-to-noise ratio
    - E_{Hcal} > 6 GeV



No Hcal Cuts



With E_{Hcal} > 6 GeV Cut

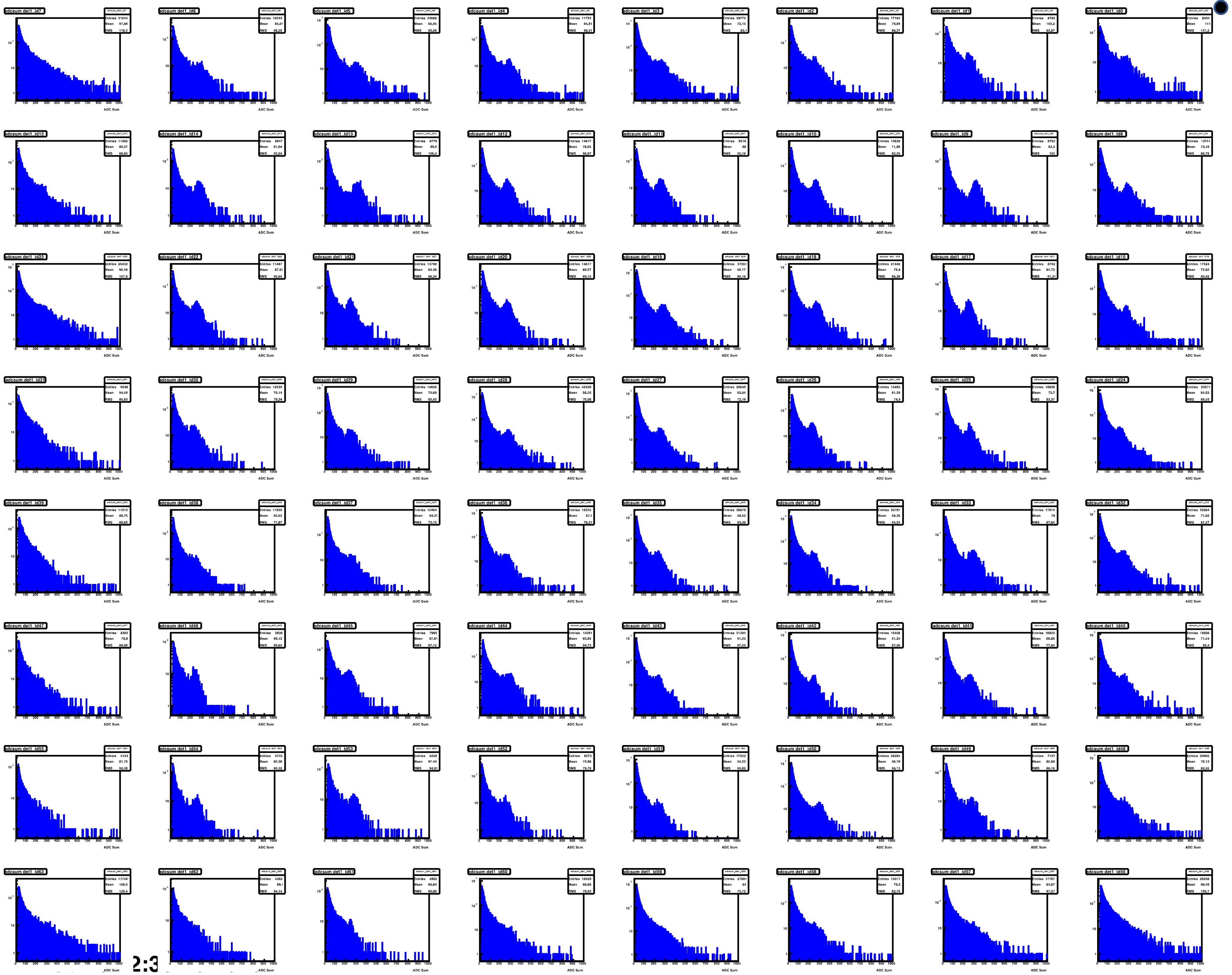
Cuts Applied

Ecal

- single trigger data set
- Nearest Neighbors =0
- Towers per Cluster = 1
- Number of Hits < 50

Hcal

- E_{Hcal} > 6 GeV



STAR Coord. {0, 0}

Cuts Applied

Ecal

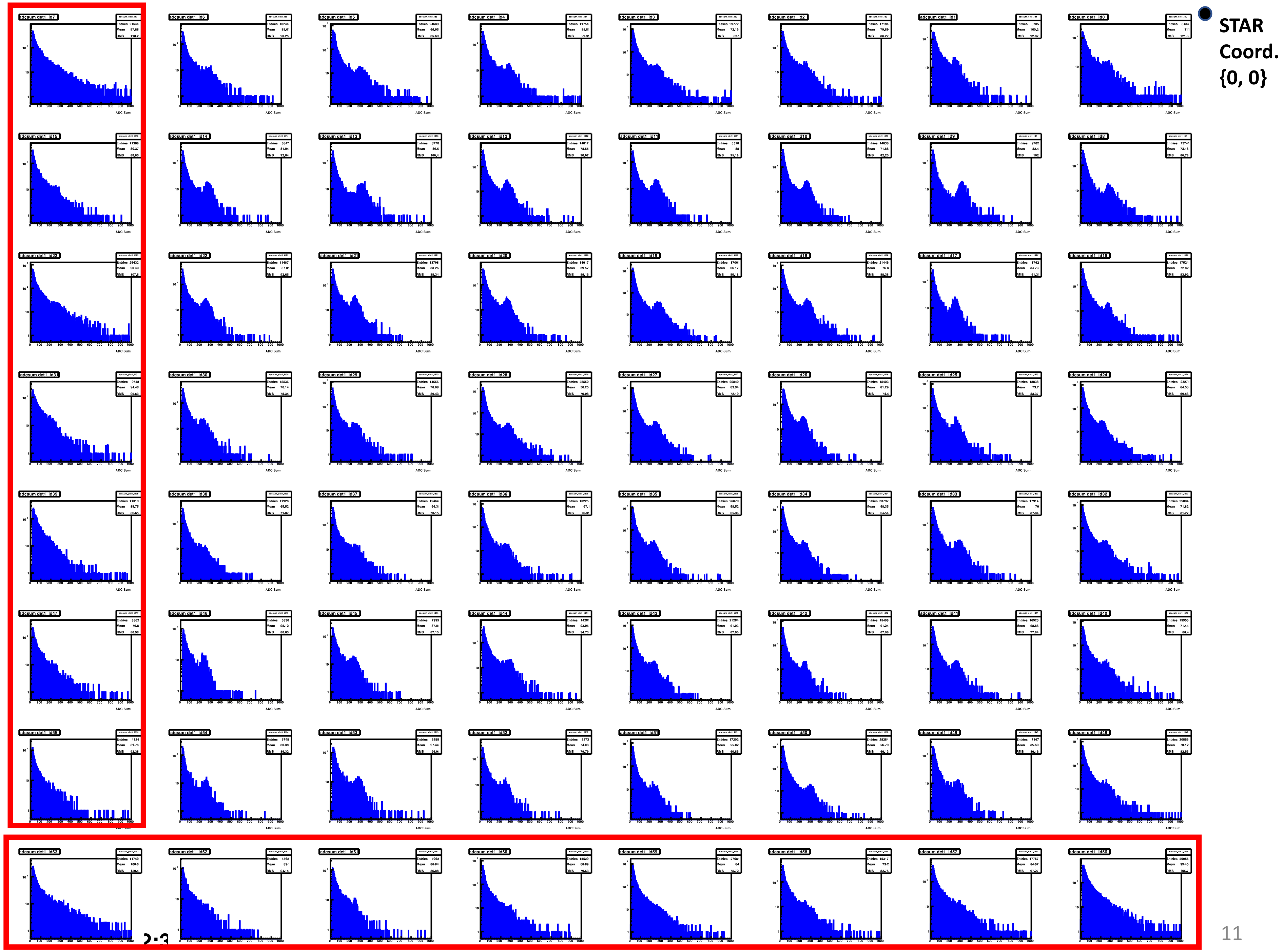
- single trigger data set
- Nearest Neighbors =0
- Towers per Cluster = 1
- Number of Hits < 50

Hcal

- $E_{Hcal} > 6$ GeV

(1) Edge towers

(2) Non-edge towers



Relative Calibration of Ecal

Background

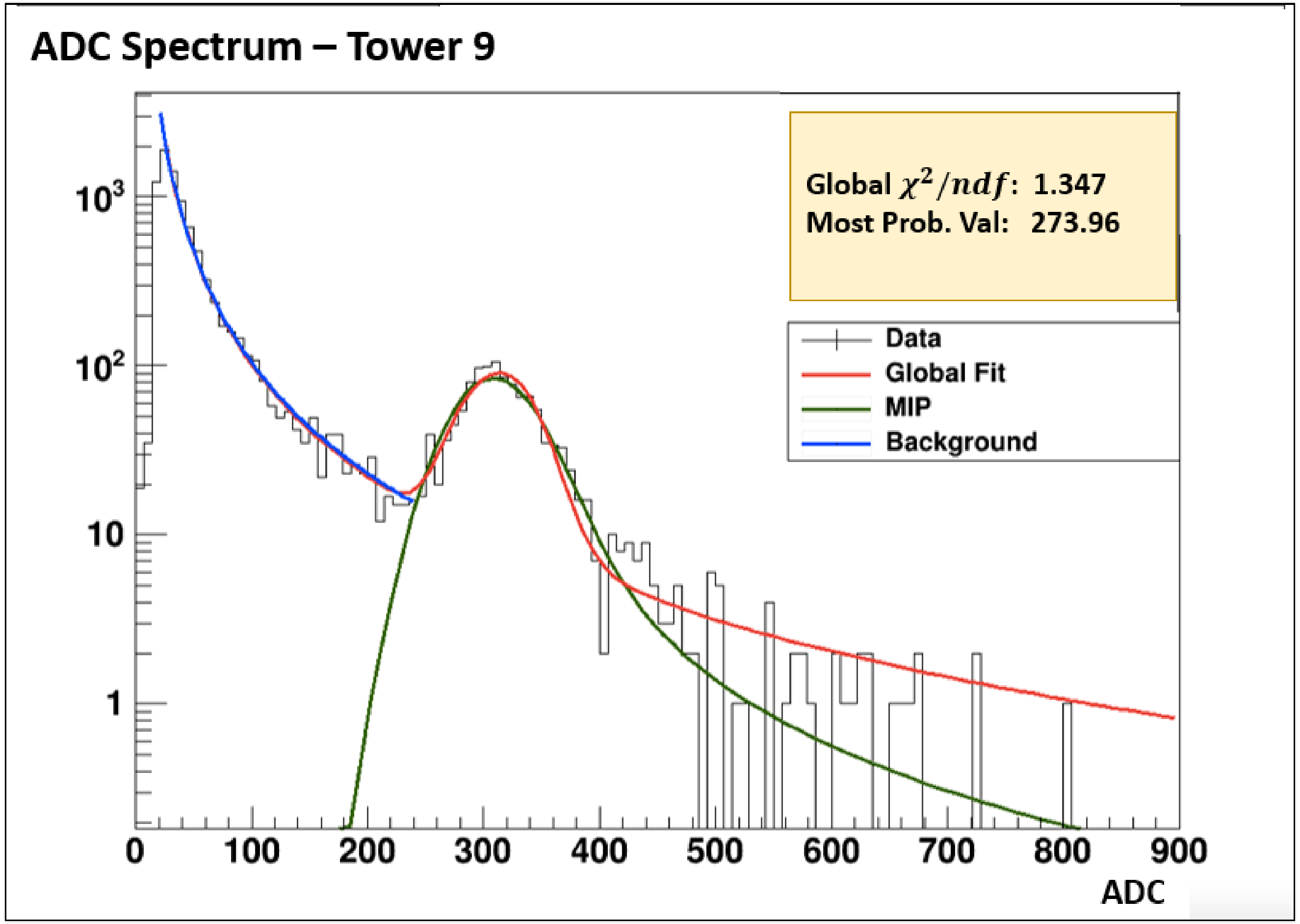
- Ax^n (EM shower)

'MIP' Convolution

- Gaussian (SiPM Response)
- Landau (MIP)

Global Fit

- Parameters extracted from background & convolution



Next step:

subtract background to isolate MIP

Relative Calibration of Ecal

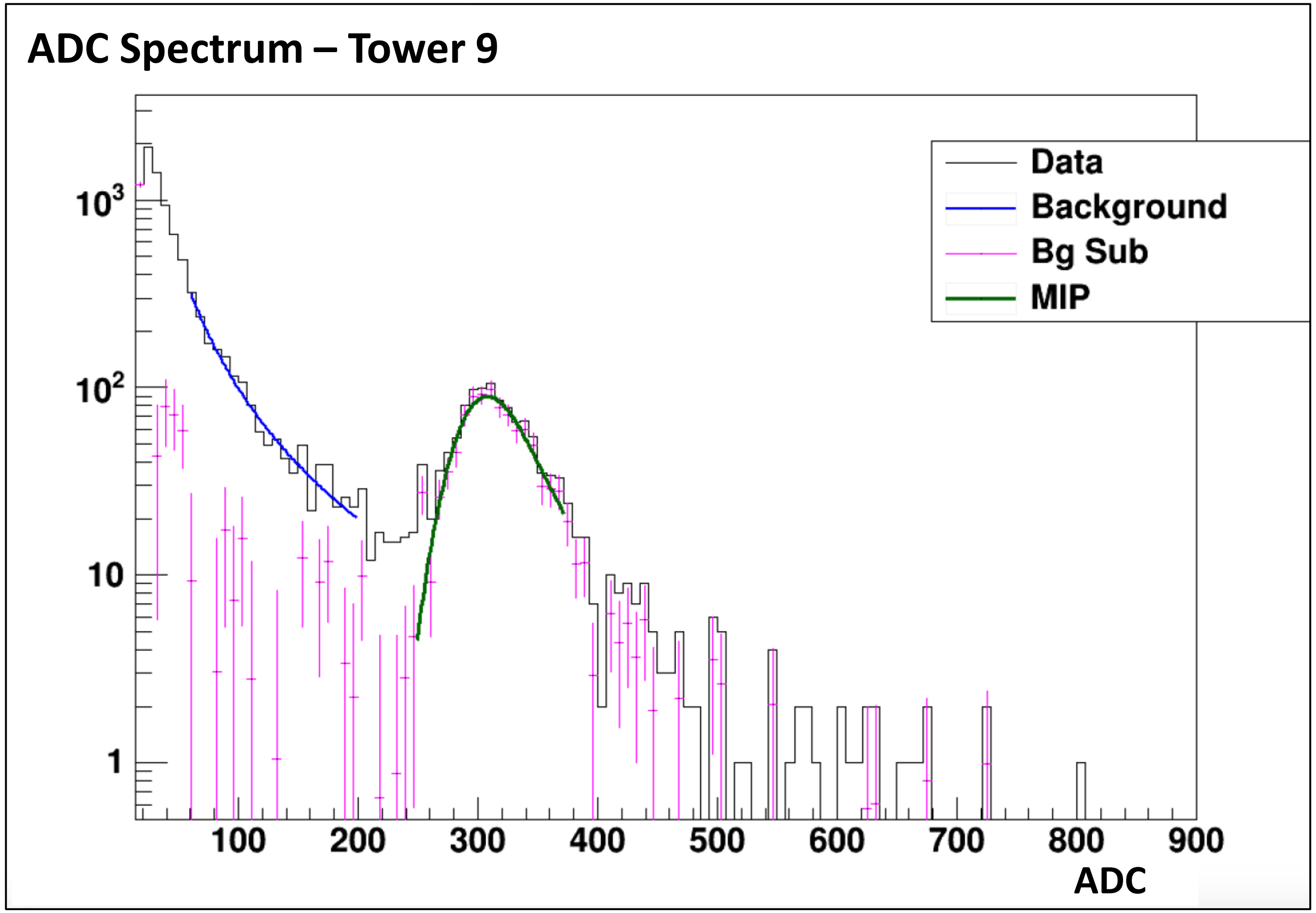
Background Subtraction

- Fit background

$$bg(x) = Ax^n$$

- Subtract background fit from data

$$bgsub(x) = data(x) - bg(x)$$



Conclusions

- The STAR Collaboration at RHIC is installing a forward upgrade to study quarks and gluons in nuclear matter at high and low x.
- Installation of the calorimeters has commenced. First data with tracking and calorimeters will be in run 22 with *p+p* at 500 GeV.
- It will be important to have a fast and robust calibration method to provide "online" calibration for ECAL.
- A method for MIP identification has been developed using data collected in 2019 Au+Au data.
- Run 21 will provide a first opportunity to commission and calibrate the ECAL.

Backup Slides

STAR Forward Upgrade

Calorimetry		
	Prototype	Forward Upgrade
Ecals	64	1496
Hcals	16	520