A Measurement of π^0 A_{LL} with the STAR 2013 Endcap Calorimeter Data

Supported in part by

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Valparaiso University
On behalf of the STAR Collaboration
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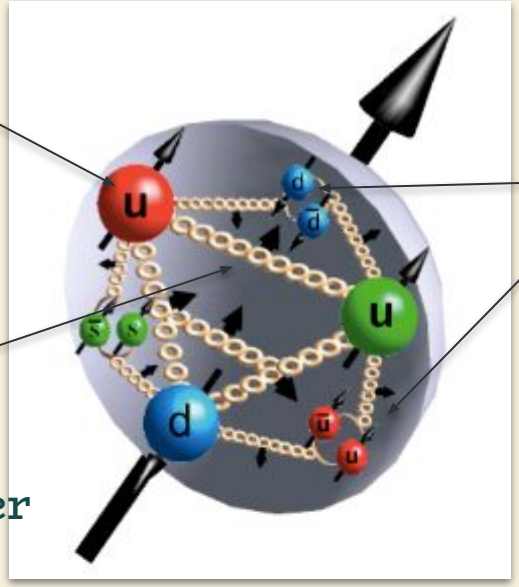
Protons, Quarks, and Gluons

Valence Quarks:

- Up, Up, Down
- Always present



Sea quarks: virtual particles

- Additional quark pairs - particle and antiparticle
- Pop in and out of existence in the proton

Gluons:

- Strong force carrier

Contributions to Proton Spin

- Proton spin: ½ ħ
- Quark spin: ~30% of proton spin
- Gluon spin: ~35% of proton spin

$$\frac{1}{2}\hbar = \underbrace{\frac{1}{2}\Delta\Sigma}_{\text{Quark intrinsic spin}} + \overbrace{\Delta G}^{\text{Gluon intrinsic spin}} + \underbrace{L_q}_{\text{Quark angular momentum}} + \overbrace{L_g}^{\text{Gluon angular momentum}}$$

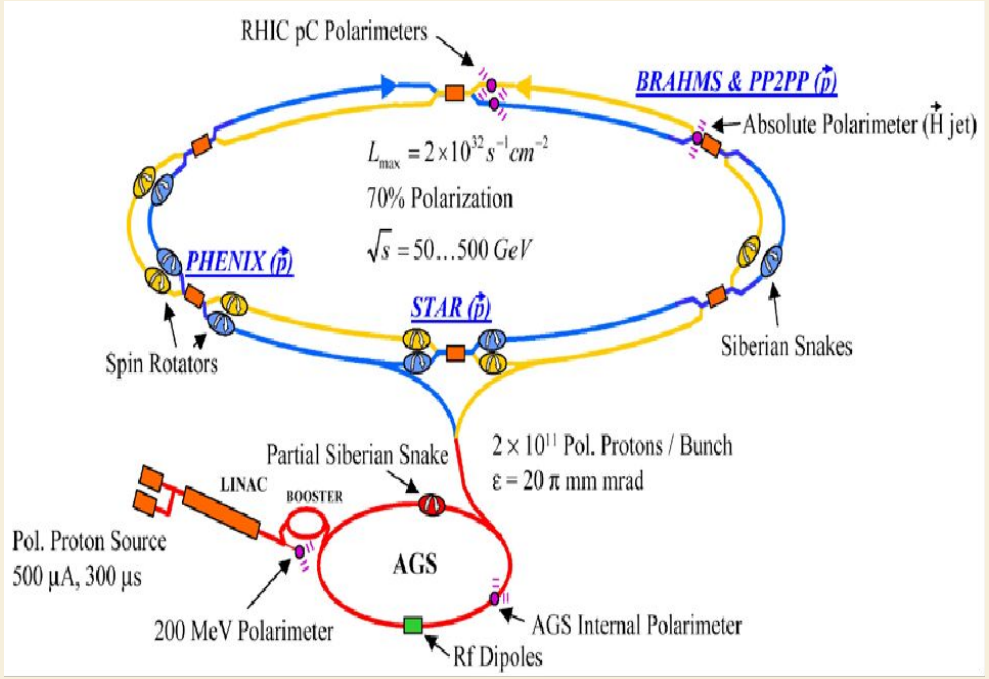
RHIC Ring

Relativistic

Heavy

Ion

Collider



Solenoidal

Tracker

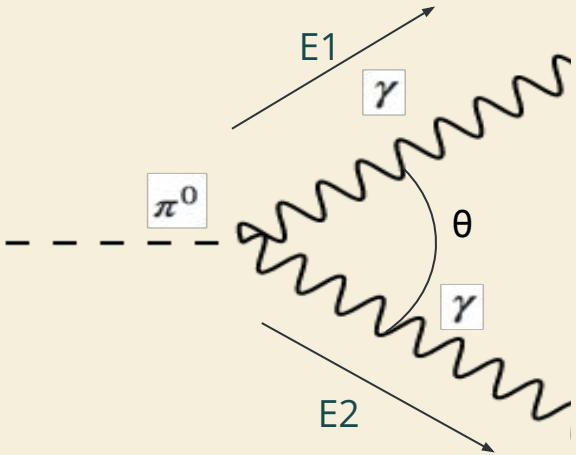
At

RHIC

RHIC Location

Particle Reconstruction

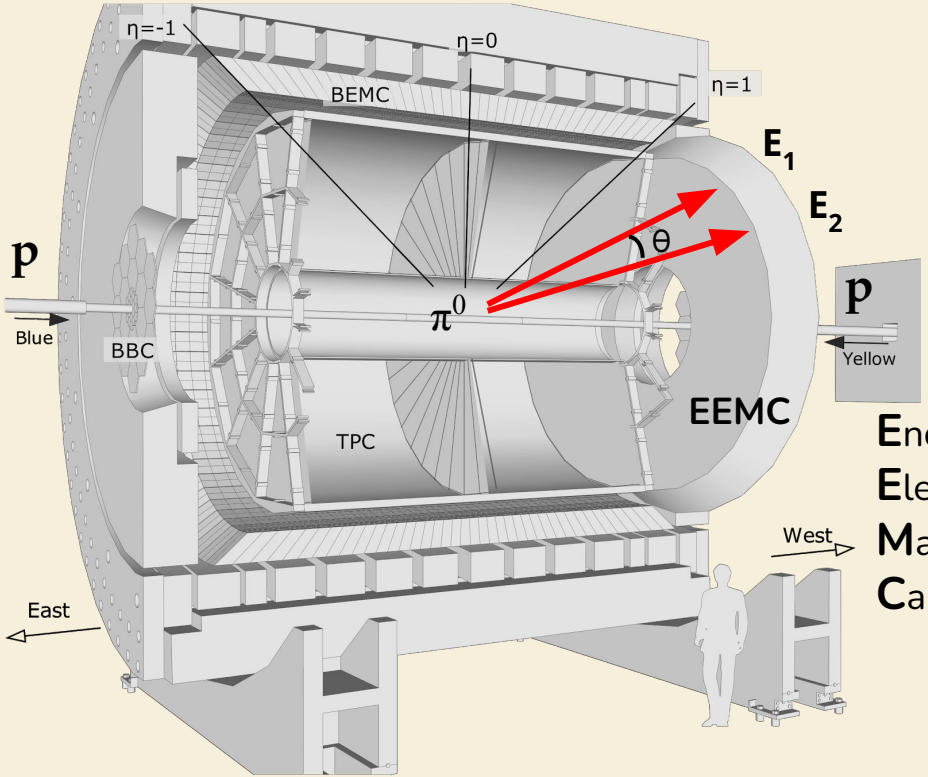
- π^0 (neutral pion) particles decay into two photons
- Position and energy of each photon can be measured by Endcap EMC (EEMC)
- Equation used to calculate $M_{\gamma\gamma}$ of the two photons
- If the two photons come from a π^0, the invariant mass will equal the mass of the π^0 particle
- **Known π^0 mass:** 0.135 GeV/c^2



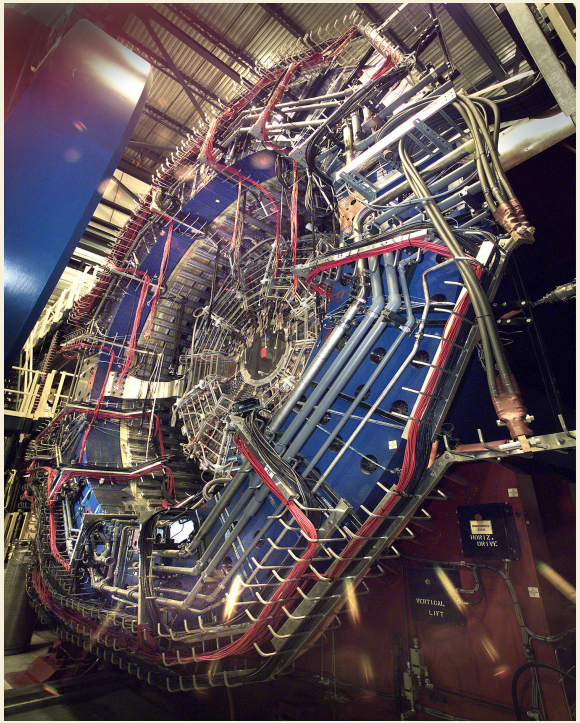
Invariant Mass

$$M_{\gamma\gamma} = (E_1 + E_2)\sqrt{1 - \left(\frac{E_1 - E_2}{E_1 + E_2}\right)^2} \sin\left(\frac{\theta}{2}\right)$$

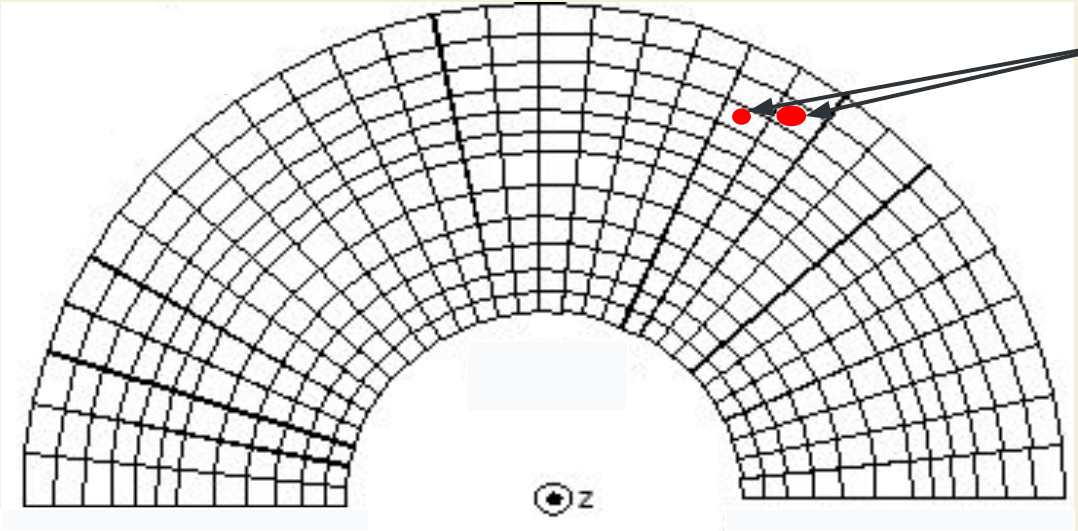
STAR Detector



Endcap
Electro-
Magnetic
Calorimeter



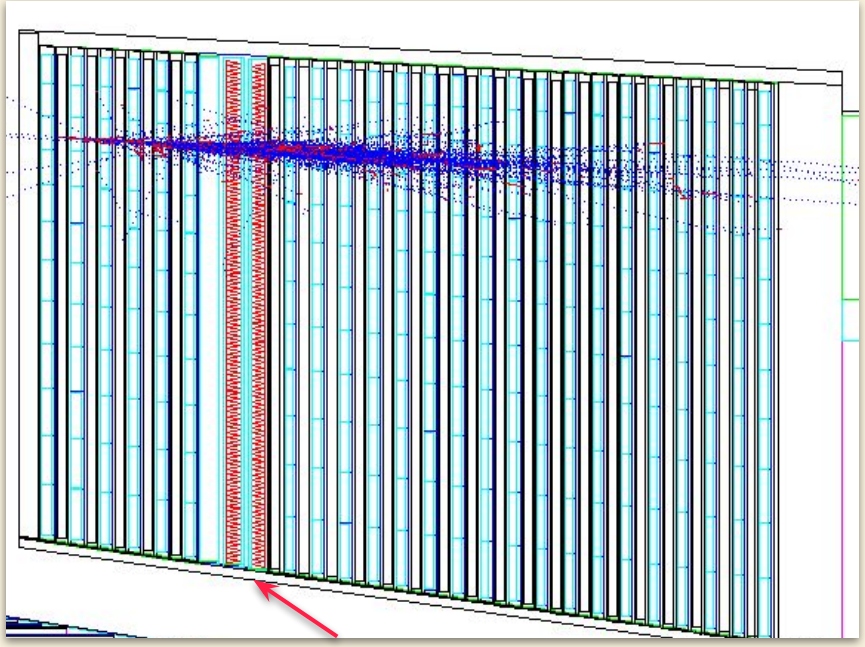
STAR Endcap Calorimeter



- Towers go “into the page”
  - Energies detected via the electromagnetic (EM) shower

EM Shower in EEMC

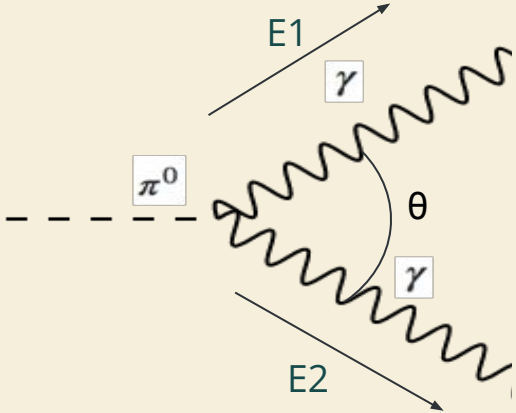
photon

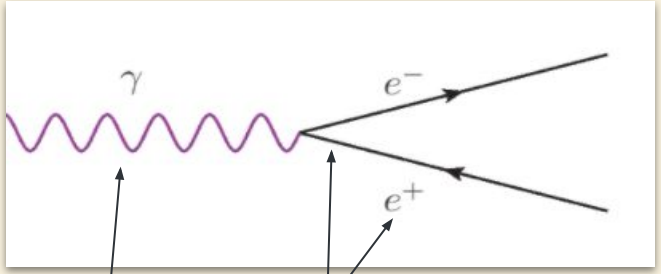


SMD

Shower Max Detector

Measures positions of photons



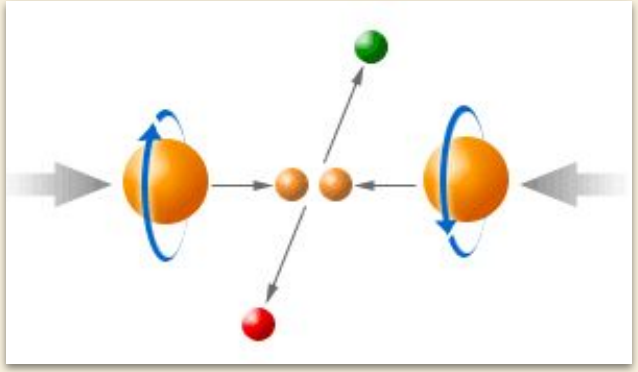


Uncharged Charged

Asymmetry and Proton Spin

- A_{LL} is sensitive to the gluon helicity distribution (equation used to determine A_{LL})

$$A_{LL} = \frac{1}{P_Y P_B} \frac{(N^{++} - RN^{+-})}{(N^{++} + RN^{+-})}$$



- N = Number of particles (pions)
- P = Beam polarization
- R = Luminosity ratio

Polarization - a measure of the alignment of the proton spin and momentum

Fills and Runs

- Fill: Given set of protons in the accelerator ring
  - Polarization and number of protons decrease → dump the current fill, start new fill
  - New fill means different set of protons
- Run: Snapshot of a fill that contains a certain number of proton-proton collisions
  - One fill has many runs

Data Quality Assurance

- Gather all runs from a given fill
  - ~10 runs per fill
  - Analyze data
  - Generate π^0 invariant mass histograms
- QA on the runs ensures quality data
- QA on the fills takes place after run QA
  - Because of more events it provides a more stringent test of data quality

Fill QA

- Background is fit using the Chebyshev polynomial (blue)

$$B = c_0 T_0 + c_1 T_1 + c_2 T_2 + c_3 T_3 + c_4 T_4$$

$$T_0(x) = 1$$
$$T_1(x) = x$$
$$T_2(x) = 2x^2 - 1$$
$$T_3(x) = 4x^3 - 3x$$
$$T_4(x) = 8x^4 - 8x^2 + 1$$

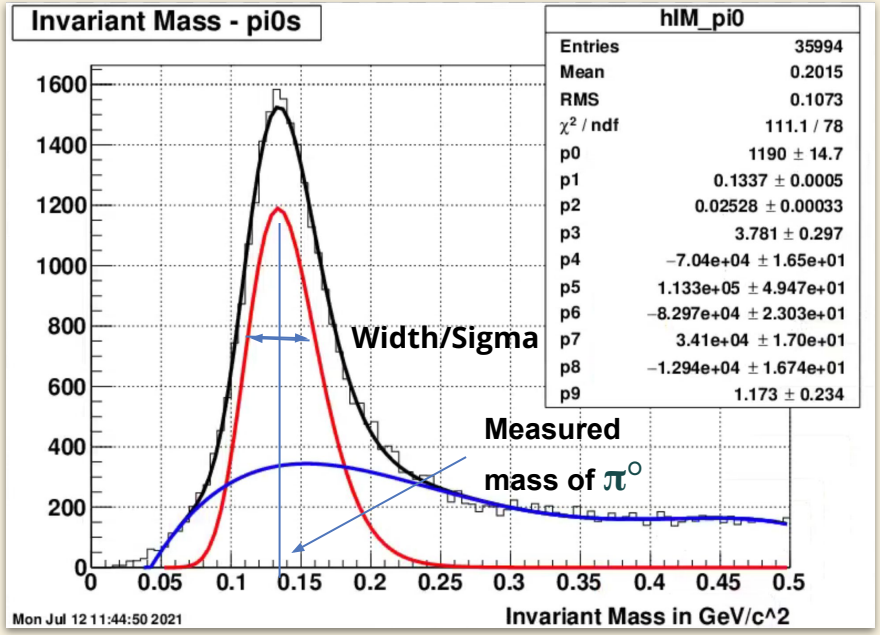
Known π^o mass: 0.135 GeV/c^2

Measured π^o mass: 0.1337 ± 0.0005 GeV/c^2

- Signal (π^0 s) is fit using a skewed Gaussian function (red)

$$f(x) = a \cdot exp\left(-0.5\left(\frac{x-b}{c(1+d(x-b))}\right)^2\right)$$

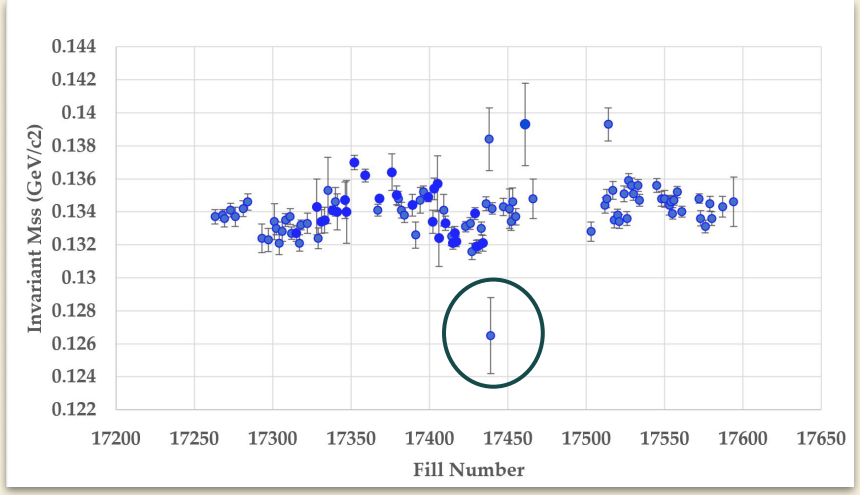
- b = mean
- c = sigma
- d = 'skewing' parameter



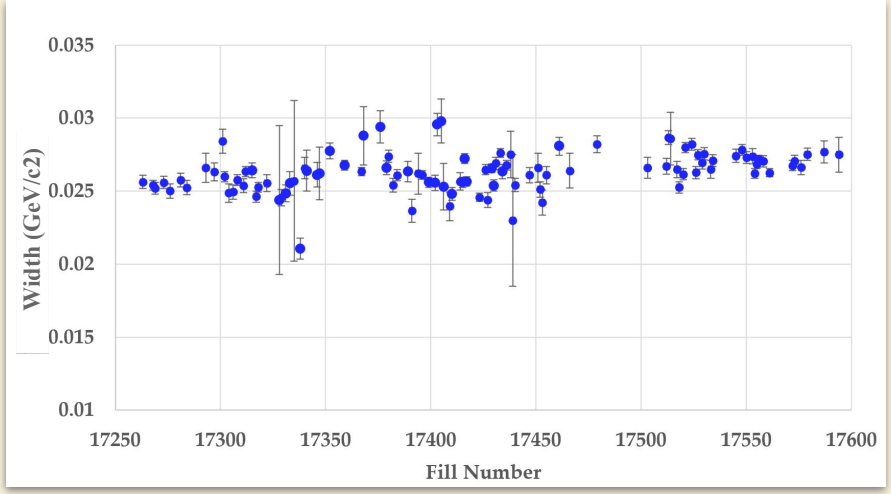
π^0 Reconstruction

- Plot important information such as π^0 mass, width, number of π^0s, etc.
- Look for outliers

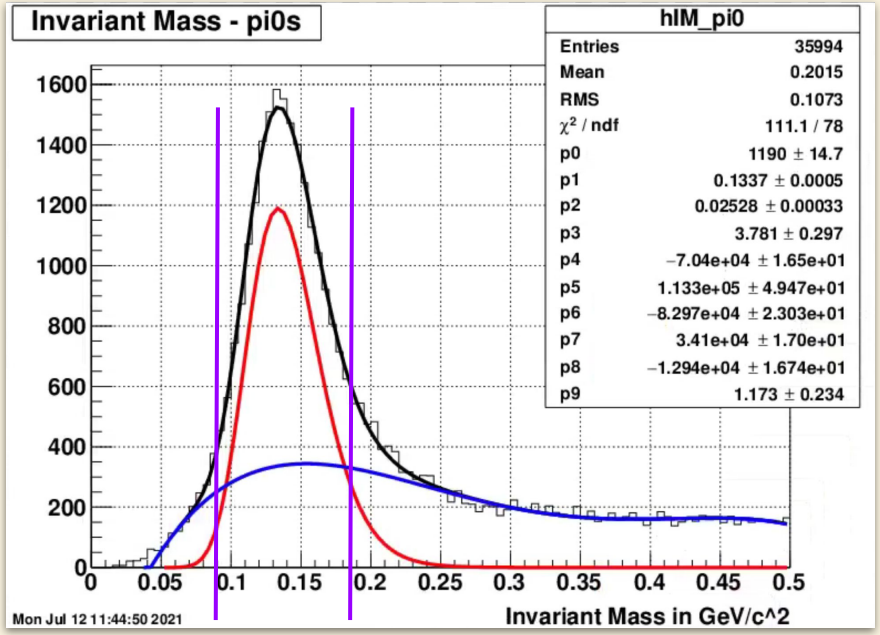
π^0 Mass vs. Fill

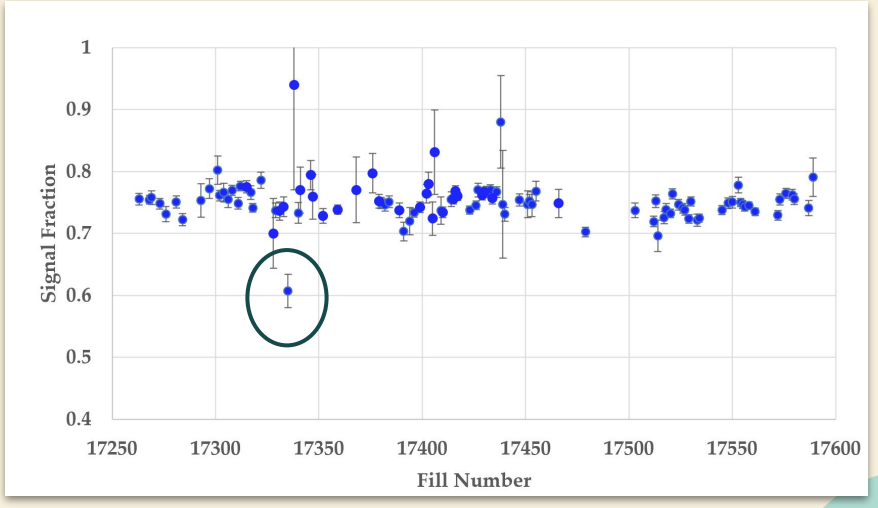


Width vs. Fill



Signal Fraction vs. Fill





Signal Fraction: number of π^0s within 2σ (purple) of the π^0 peak (red) divided by total counts (black).

Mass range: 0.08 - 0.18 GeV/c^2

Summary

- Fill-by-Fill quality assurance for ⅓ of 2013 data set completed
  - Evaluating outliers: work in progress
  - Remaining fills to be analyzed summer 2022
- Next Step: measure A_{LL} to constrain gluon contribution to proton spin
  - To be completed in 2022

Acknowledgements

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Data Processing