# Coulomb Sum Rule Experiment

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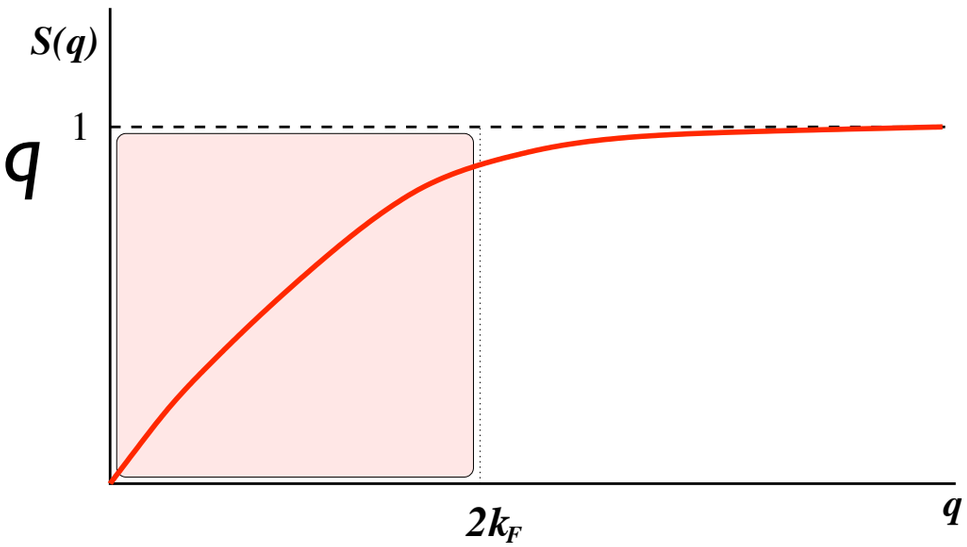
# In Short

- Measurement of response functions $R_L$ and $R_T$ from quasi-elastic electron scattering
- Integral of $R_L$ = Coulomb Sum ($S_L$)
- Study Saturation/Quenching of Coulomb Sum on various nuclei: $^{4}$He, $^{12}$C, $^{56}$Fe, $^{208}$Pb
- Probing nucleons inside the nucleus

# Coulomb Sum Rule in a Nutshell

- Coulomb Sum Rule
  - $S_L(q) \rightarrow 1$ at sufficiently large $q$
- Deviation from unity
  - at small $q$
    - Pauli blocking
    - NN long range correlations
  - at large $q(>>2k_F)$
    - Short range correlations
    - Nucleon properties in the nuclear medium



# Experiment

- Beam: 16 energies from 0.4 to 4.0 GeV
- Scattering angles: 15°, 60°, 90°, 120°
- Targets: $^{4}$He, $^{12}$C, $^{27}$Al, $^{56}$Fe, $^{208}$Pb
- Spectrometer momenta range from 4 GeV down to 100 MeV
- Covers $q$ from 550 to 1000 MeV/c

# People

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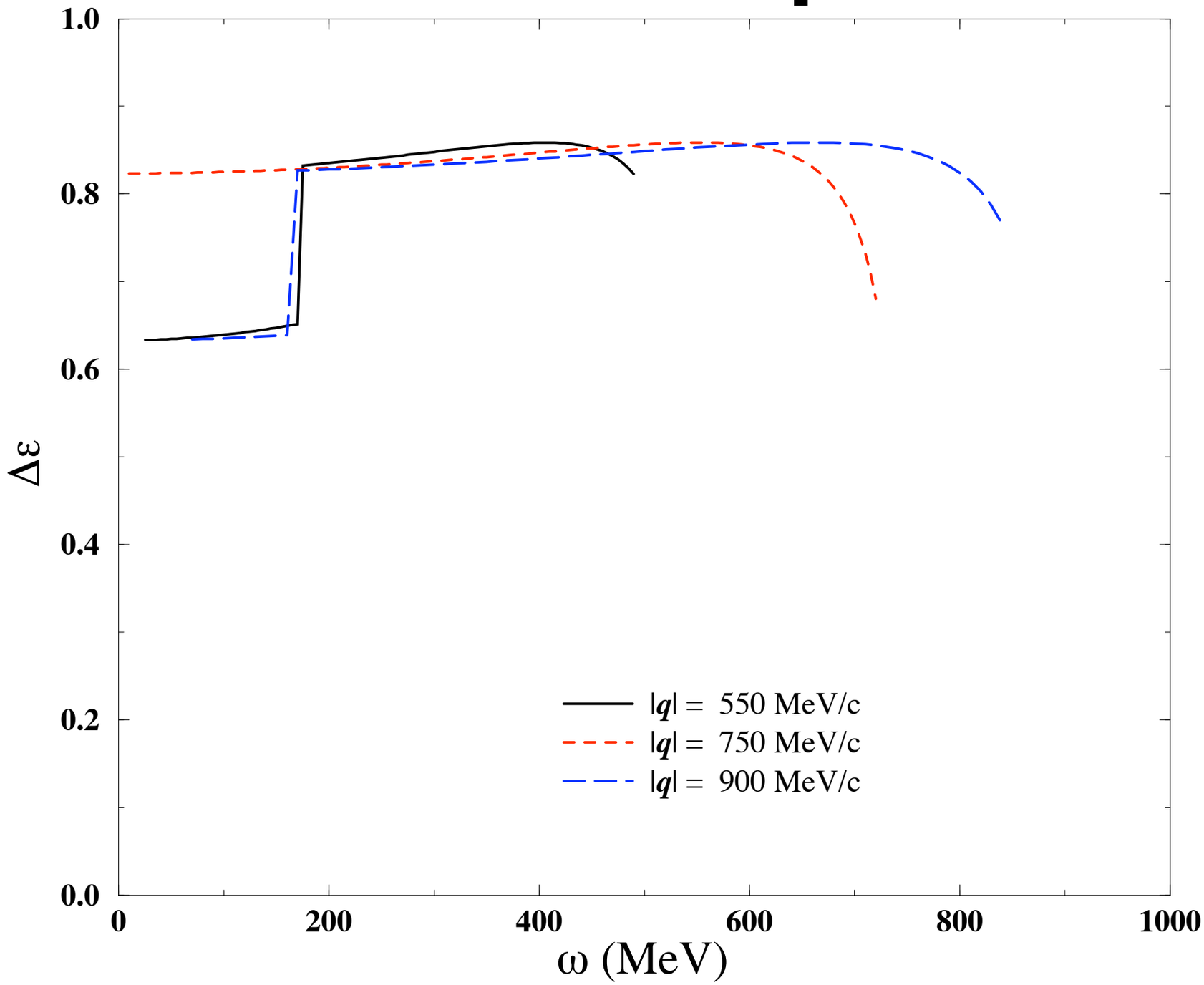
and

*Hall-A Collaboration*

# What's New?

- Comfortable high values of $q$
  - From 550 MeV/$c$ to 1000 MeV/$c$
  - High enough for clean observation of CSR
  - Previously unexplored region
- Comprehensive single experiment
  - Largest lever arm
  - Measurement at 4 angles
- Better control of background with NaI detector

# Lever arm for Rosenbluth Separation

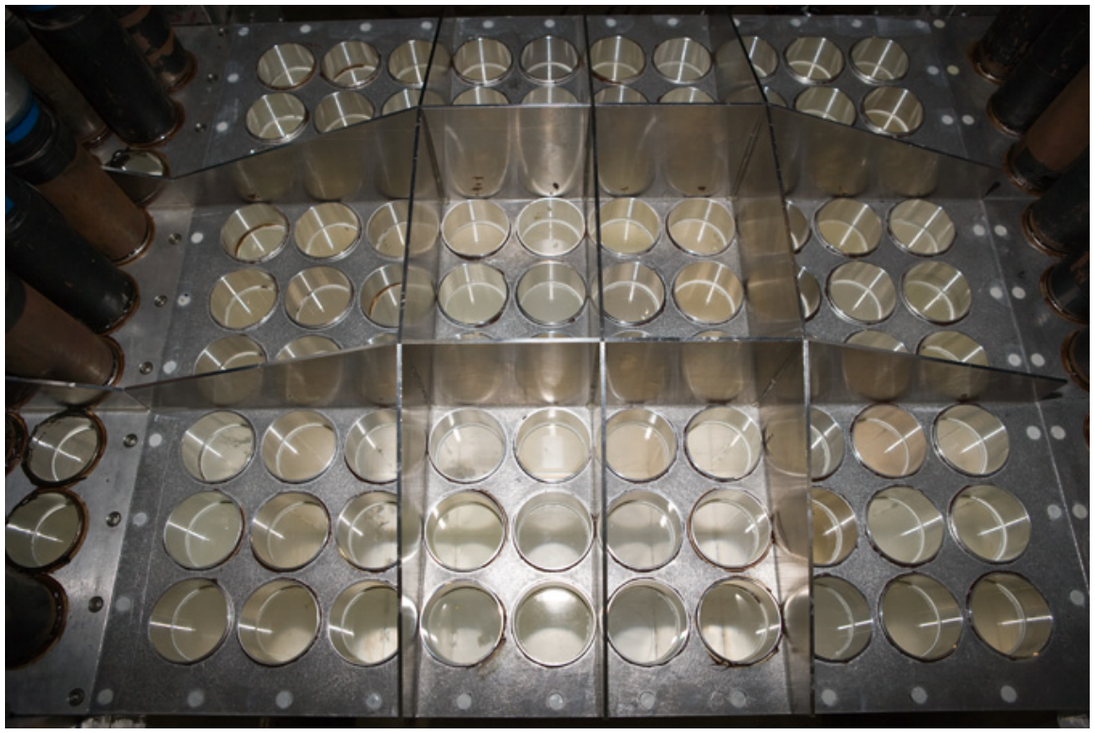


# NaI Detector

- NaI Crystal borrowed from BNL
- About 400 crystals of 2.5”x2.5”x12”
- Refurbished at JLab: polishing, assembly in new boxes, sealing
- Final product: 3 boxes of 90 crystals (9x10 arrangement) each
- Covers whole focal plane of L-HRS

# Installation of NaI detector

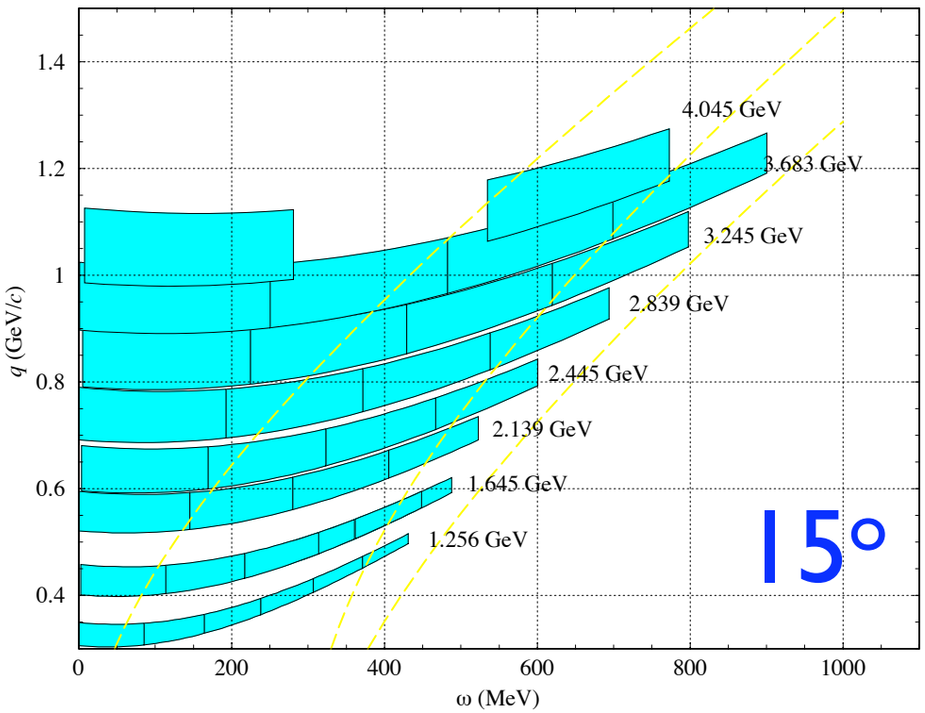


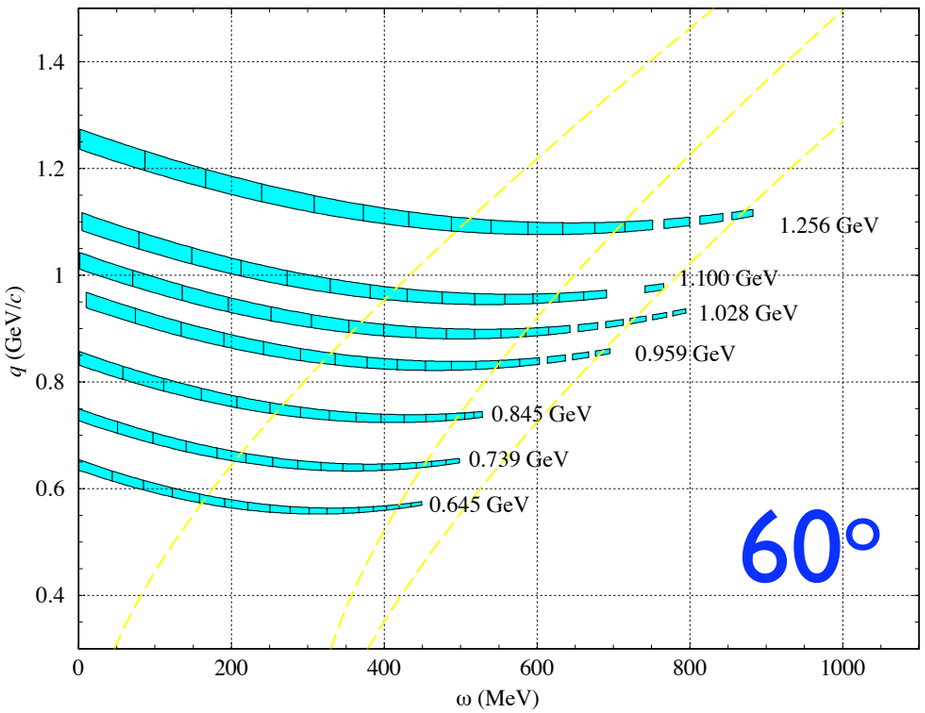


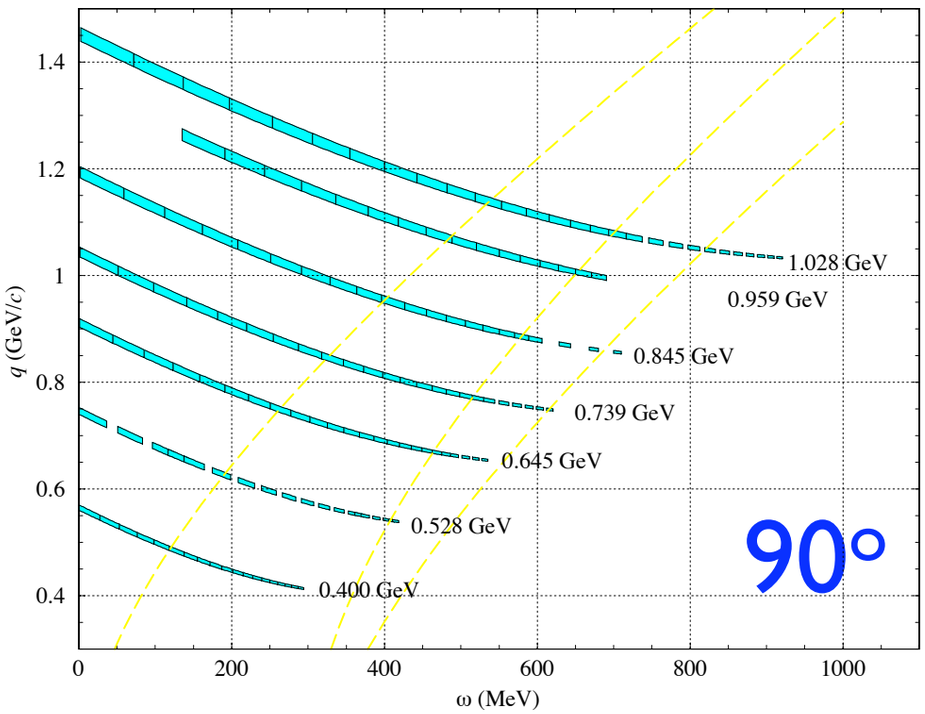
# Data Taking

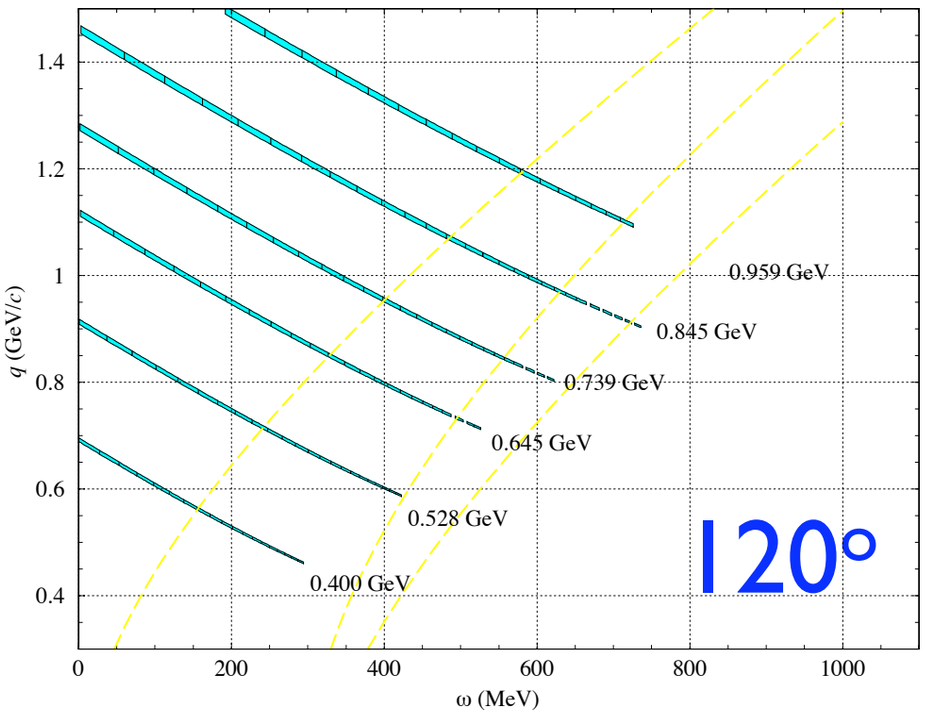
- Dates: Oct. 23, 2007 - Jan. 16, 2008
  86 calendar days - 2 holiday shutdowns
- Data taken: about 3TB over 7000 runs
- Most of the runs are 5 minutes long
  - Frequent changes of target and spectrometer momentum

# Kinematic Coverage



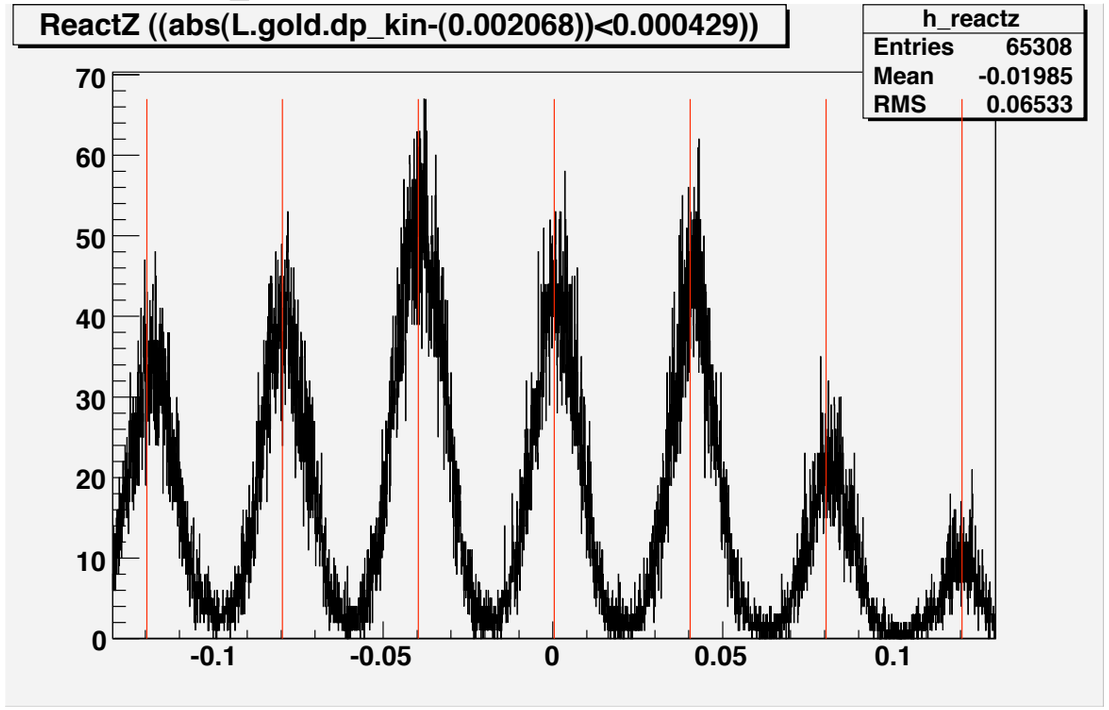



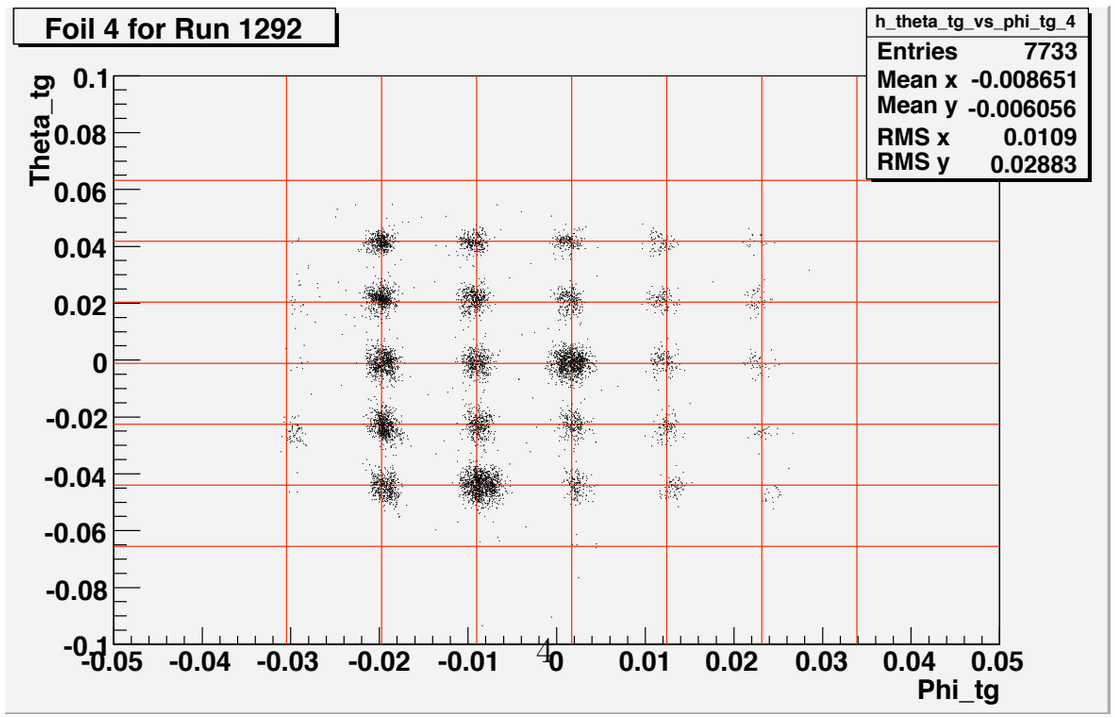



# Analysis in Progress

- Spectrometer optics at low energies (Huan Yao)
- NaI detector calibration (Xinhu Yan)
- Boiling effect of liquid targets (Yoomin Oh)
- Beam energy calibration (Jeongseog Song)

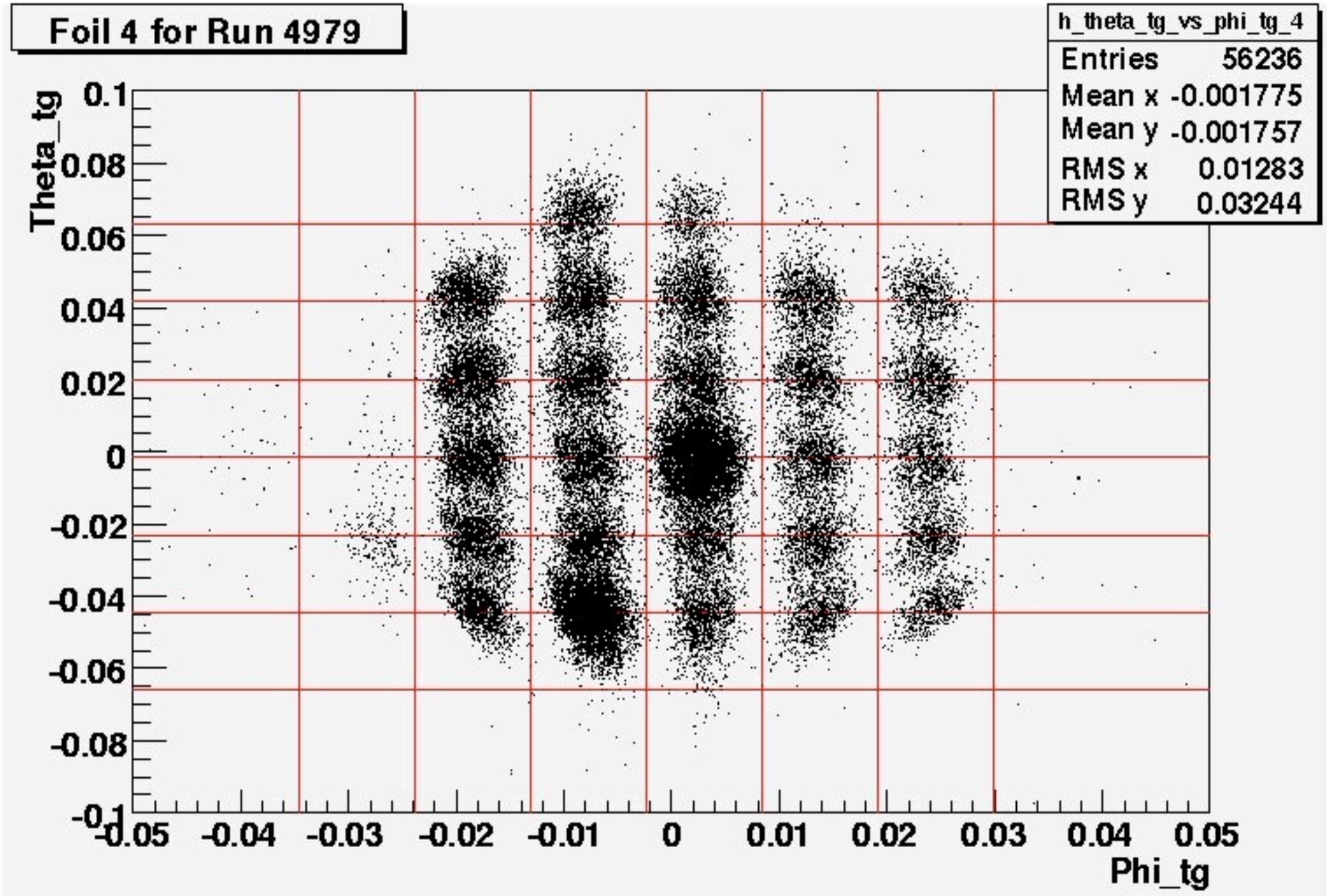
# Spectrometer Optics




- Optics analysis at higher energies as the first step
- New challenges for spectrometer optics at lower energies

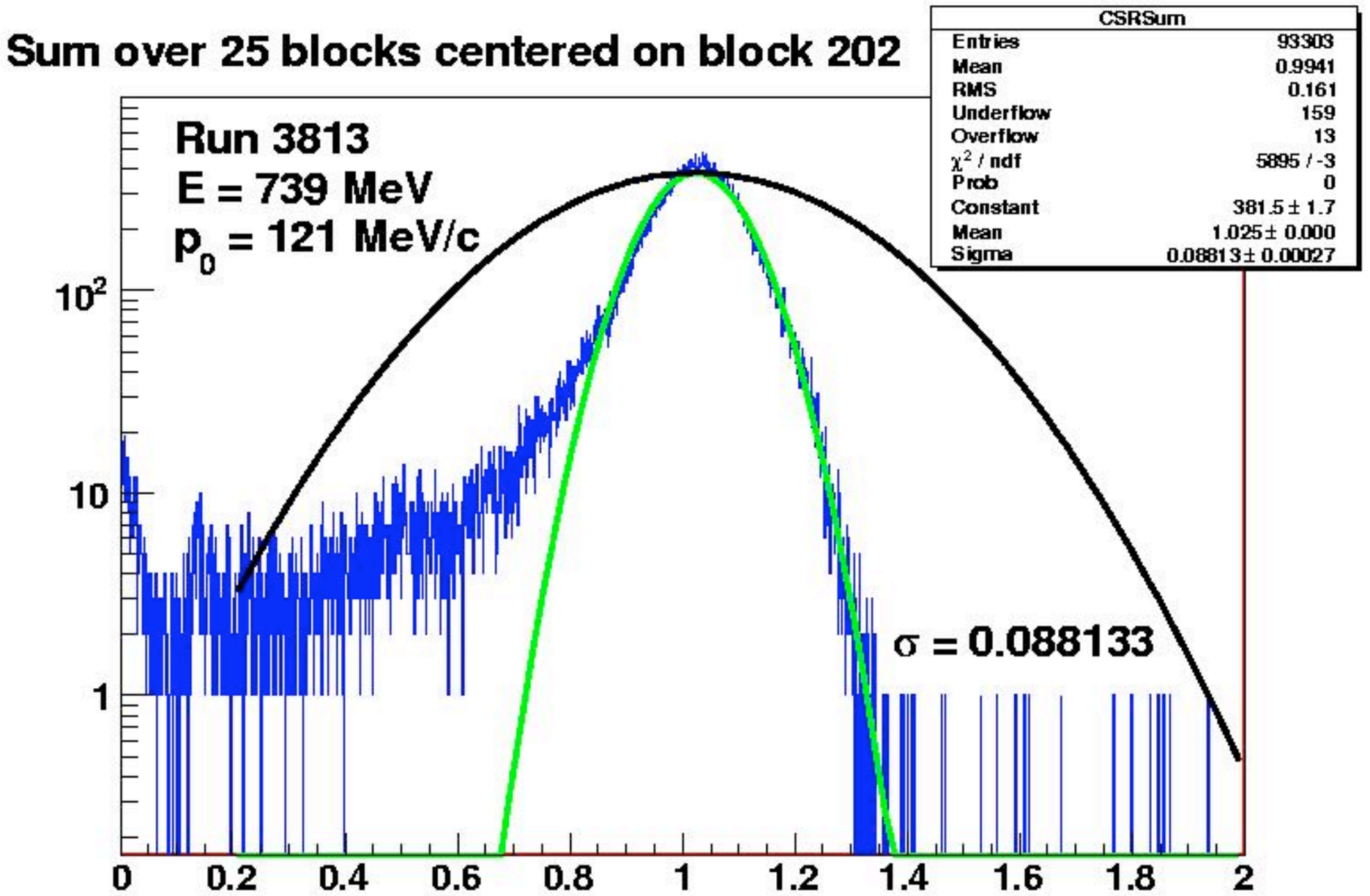
# Optics at 400 MeV



# NaI Detector Calibration

- Overall gain calibration for each HV settings
- Recovery of non-working blocks
- Fine tuning of the background simulation

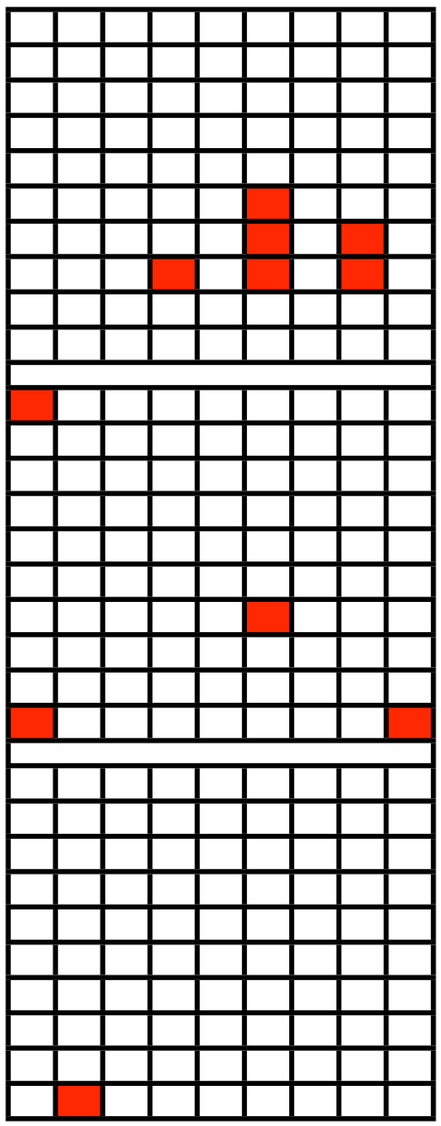
# Performance



# Performance

- Resolution: 8.8% at 121 MeV/c
- Reduction of background by a factor 2 from 8% to 4%
- Fine tuning of the simulation to reach 0.5% systematic from the background contamination

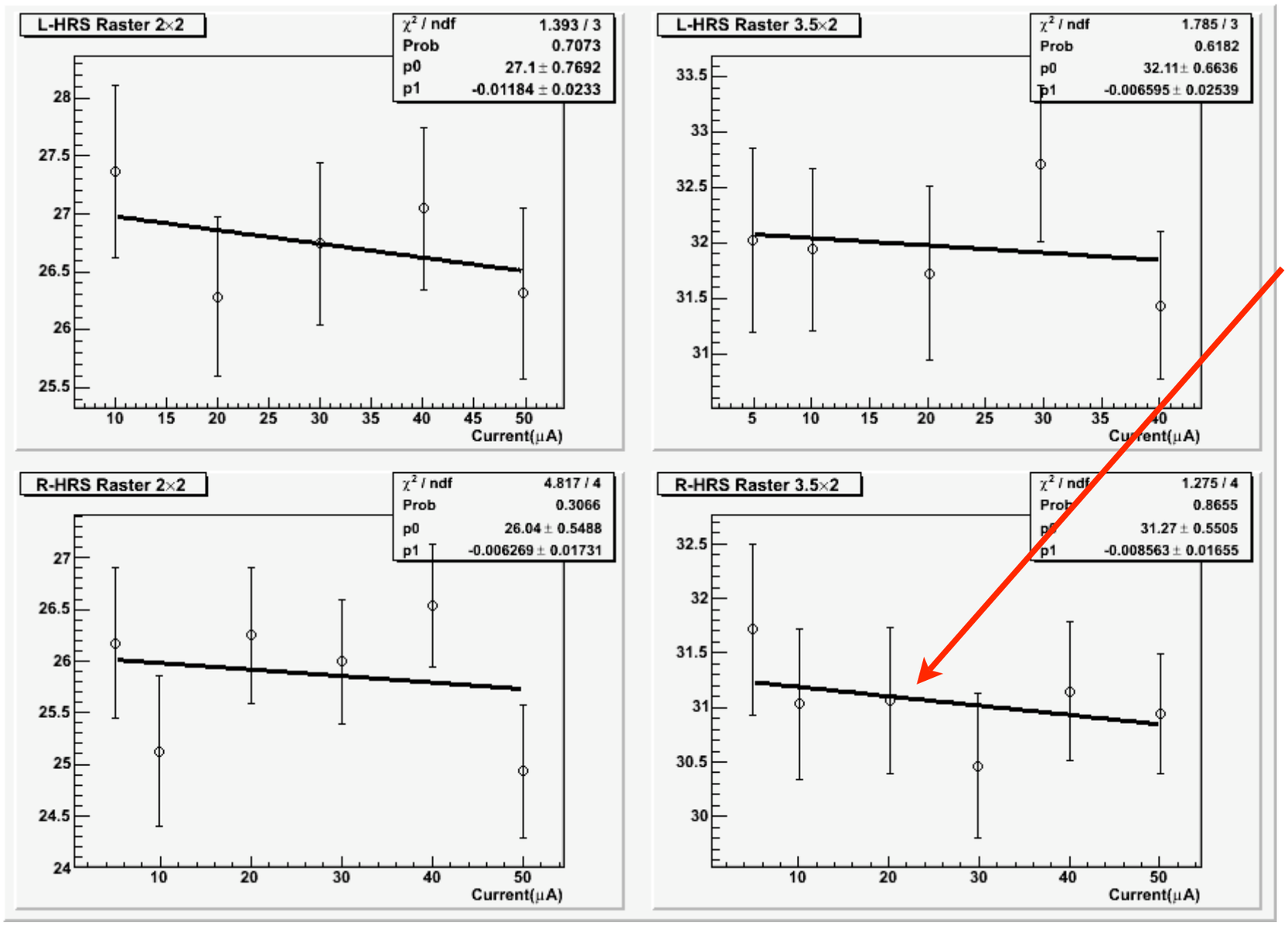
# Non-working blocks



- Sporadic spots of non-working blocks
- Boundaries between each boxes
- Energy deposit on these dead zones need to be accounted for
- Determine the energy deposit fraction from working blocks
- Apply the corrections depending on the proximity to the dead zones

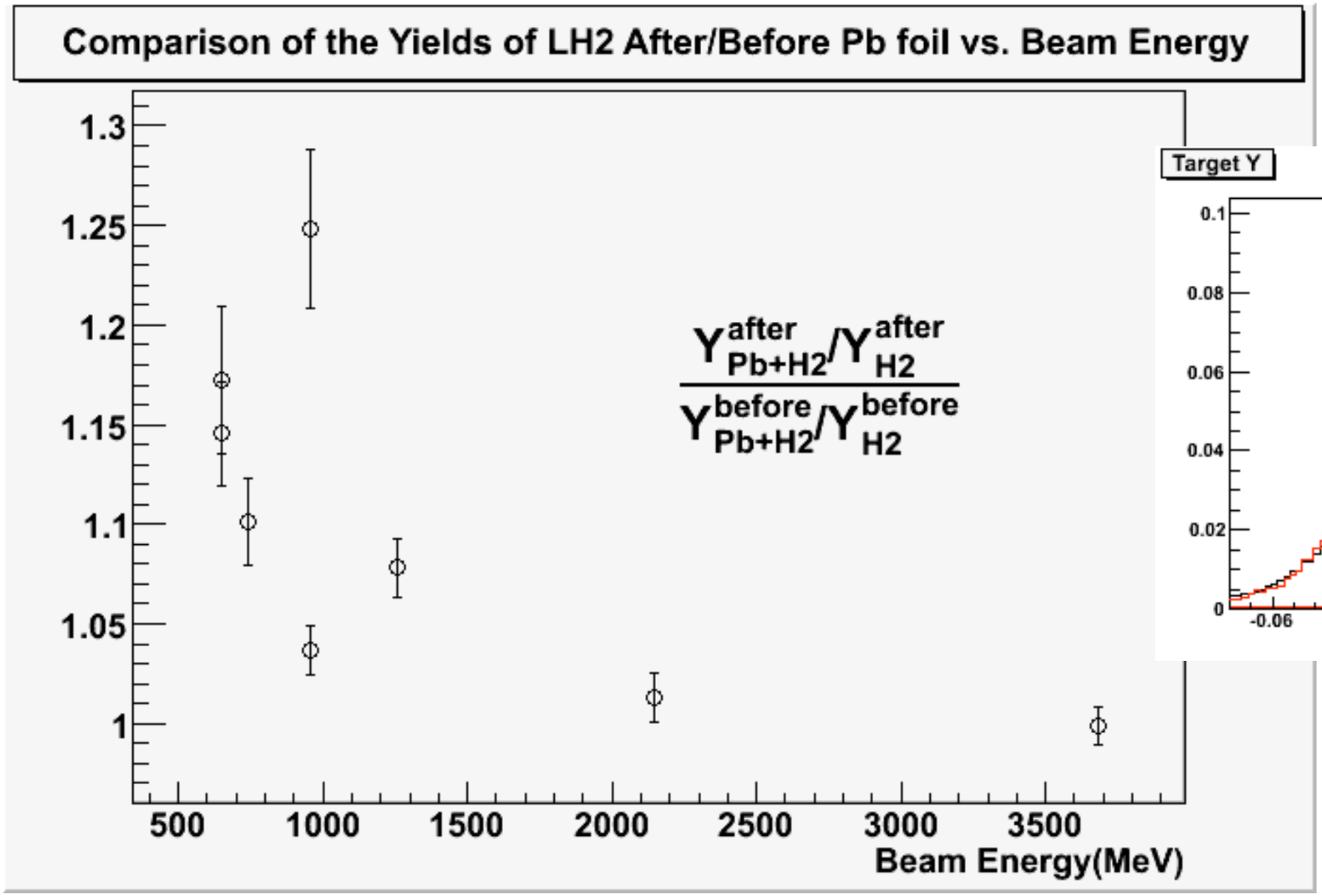
# Boiling Effect on Target Density

- Pb target cooled by $LH_2$
- Making sure of the correct $LH_2$ yield subtraction

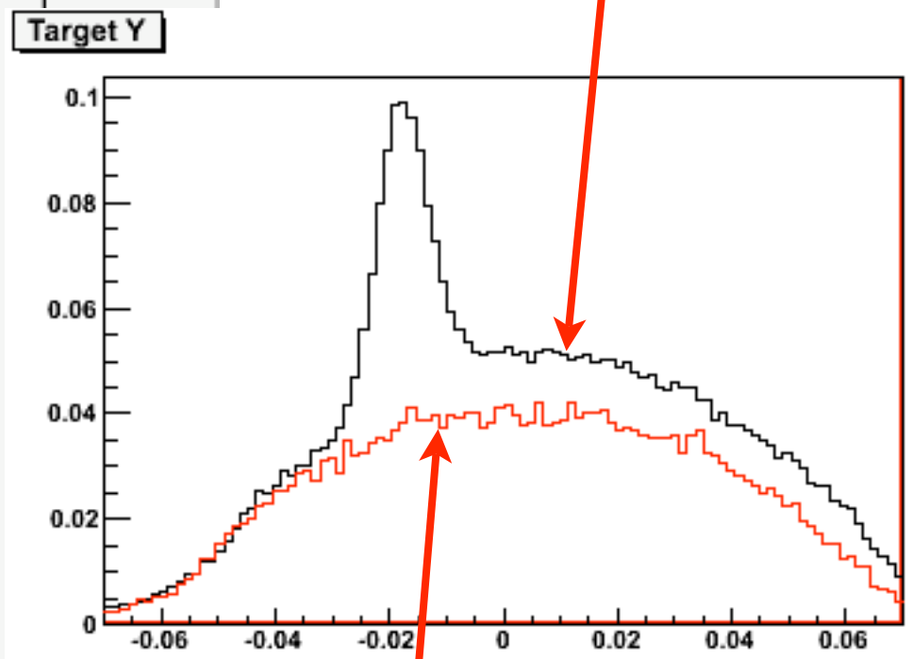



Constant normalized yield within error

# Effect of Energy Loss through Pb foil




After the Pb foil. Scattering at lower incident energy

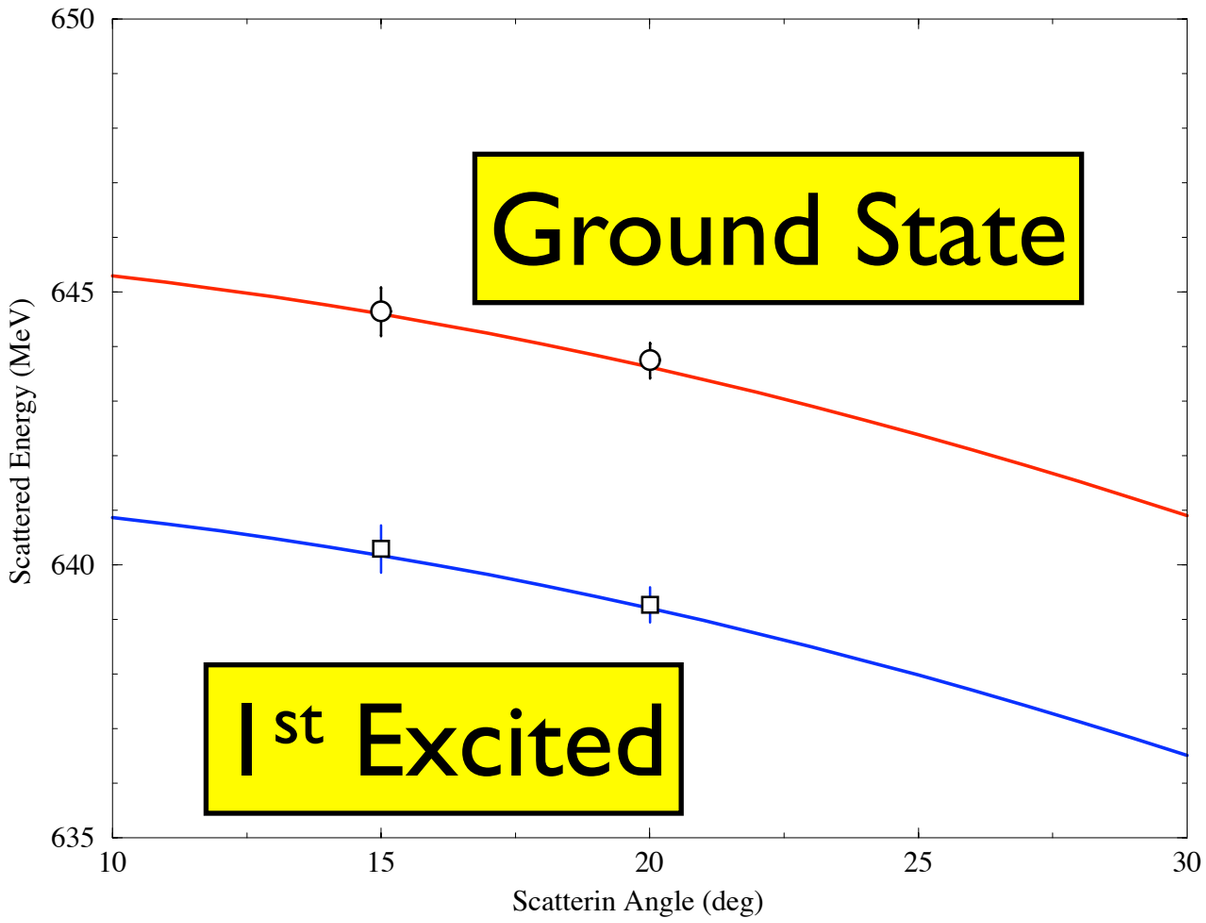


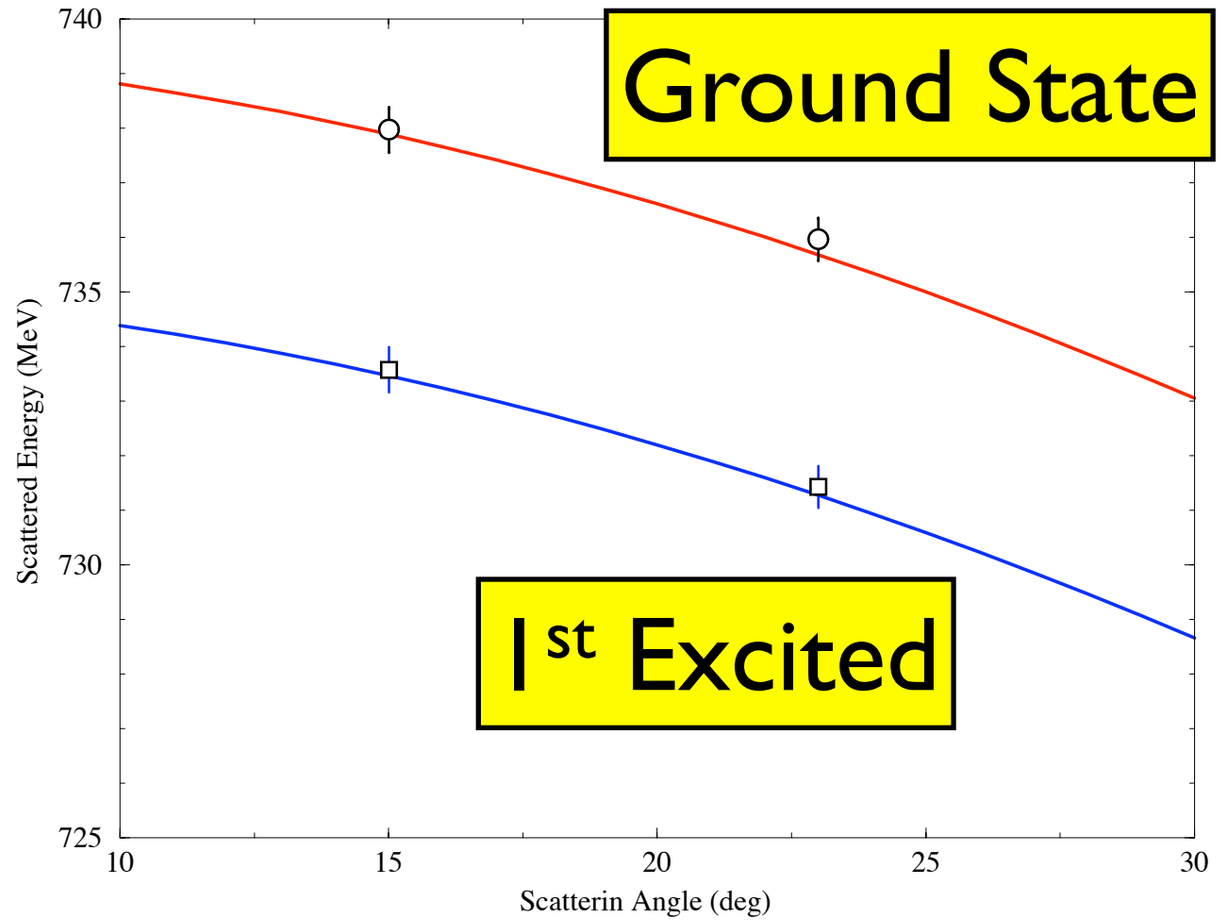

$LH_2$ Yield

# Beam Energy Calibration

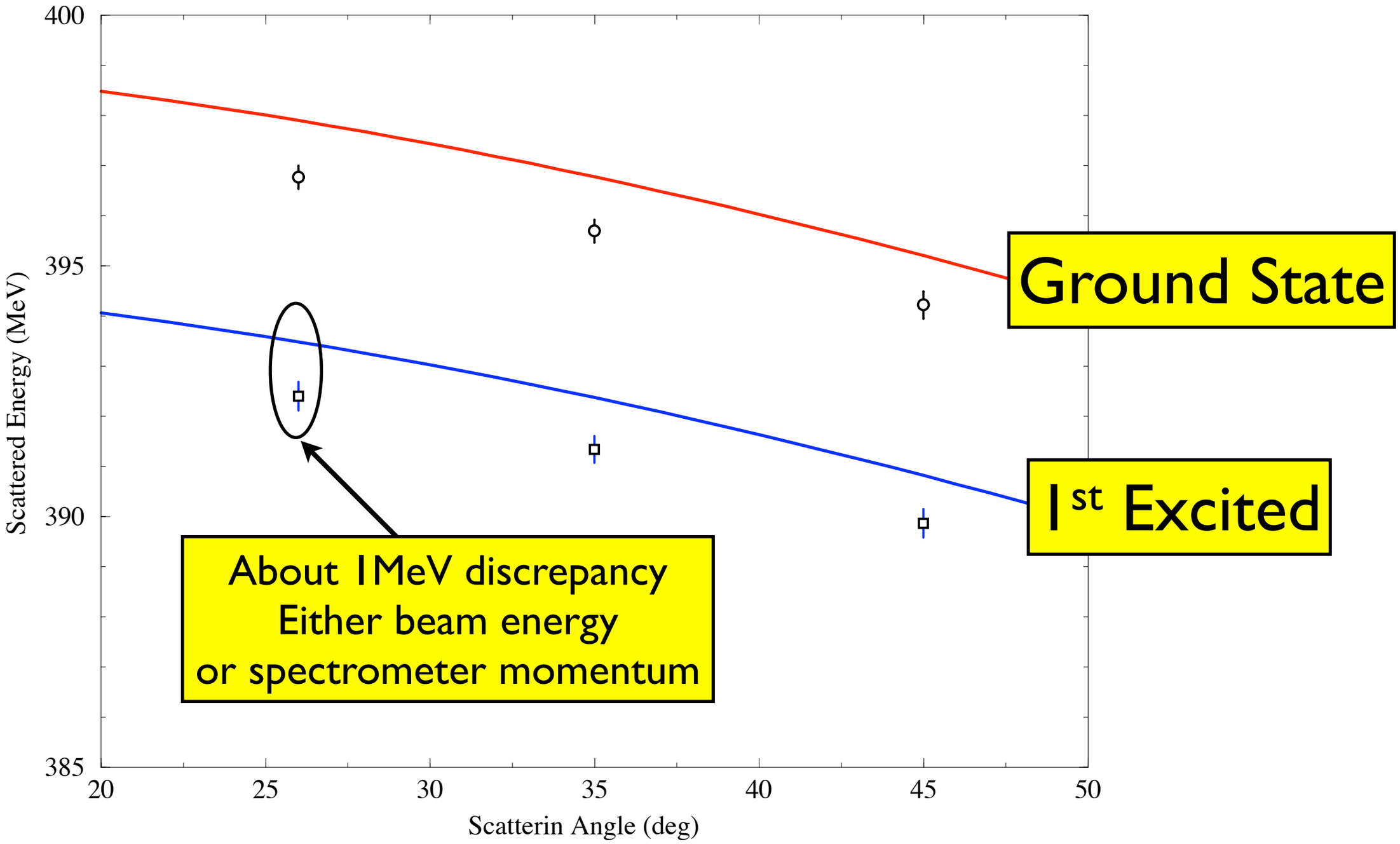
- At low beam energies, ARC energy measurement is not available.
- Calibration run taken using C elastic at several angles.
- Elastic scattering from hydrogen can also be used.

# High Energies

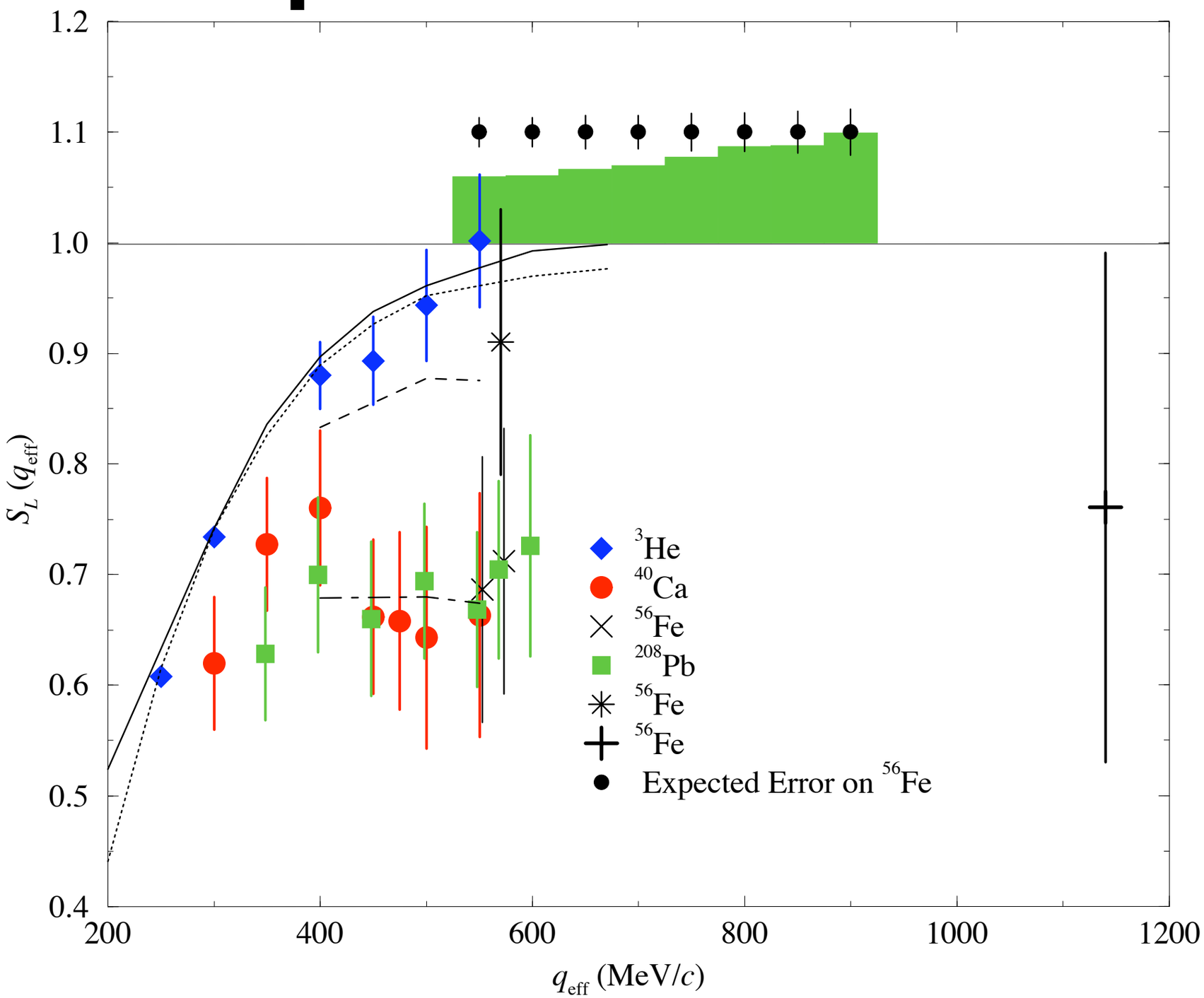


# Low Energy


400
395
390
385
Scattered Energy (MeV)
20
25
30
35
40
45
50
Scatterin Angle (deg)
Ground State
1st Excited
About 1MeV discrepancy
Either beam energy
or spectrometer momentum

# Expected Error



# Summary

- Experiment completed in Jan 2008, analysis in progress.
- A few new features
  - High enough momentum transfer, previously unexplored.
  - Comprehensive single experiment
  - Independent energy measurement for background reduction
- Hope to answer the question on the CSR in 2-3 years