Field Off Scattering Studies: Current Status

John Nugent

University of Glasgow

john.nugent@glasgow.ac.uk

11/10/2018

- All referee's comment from CM51 completed
- Deconvolution
  - worked through Bayesian optimisation
  - added Gold Deconvolution algorithm

Gold Algorithm

- Looking to extract true scattering distributions from raw distributions. Remove effects of interstitial scattering, tracker resolution.
- Technique employed in nuclear γ-ray spectroscopy and image restoration.
- Does not rely on MC Truth or scattering models, purely data driven technique The scattering distribution that is measured by MICE can be stated as:

$$x'(\theta) = \int_{-\infty}^{t} x(\Theta)h(\theta - \Theta)d\Theta + n(\theta) = x(\theta) * h(\theta) + n(\theta), \quad (1)$$

where $x'(t)$ is the raw LiH scattering distribution measured. $h(t)$ is empty channel data includes the interstitial material + tracker resolution. $x(t)$ is scattering distribution due only to the absorber material. $n(t)$ is additive noise and the $*$ denotes the convolution operator.

Gold Algorithm

- For discrete systems, this statement can be expressed as:

$$x'(i) = \sum_{k=0}^{i} x(k)h(i-k) + n(i) = x(i) * h(i) + n(i), \tag{2}$$

an expression which represents a general system of linear equations that can be written in matrix form as:

$$x' = Hx + n \tag{3}$$

where the matrix H has dimension $N \times M$, the vectors x' and n have N elements and the vector x has M elements, while $N \geq M$. To find a least squares solution of the system of linear equations given in 3

$$||Hx - x'||^2 \tag{4}$$

must be minimised.

Gold Algorithm

$$x' = H'x \tag{5}$$

- where $H' = H^{\boldsymbol{T}} H H^{\boldsymbol{T}}$ and $H^{\boldsymbol{T}}$ is a Toeplitz matrix[1]. x' is known from data, and the method iterates over:

$$x_i^{(k+1)} = \frac{x_i'}{\sum_{m=0}^{N-1} H'_{im} x_m^{(k)}} x_i(K) \tag{6}$$

where

$$\begin{aligned} i &= 0, 1, ..., N-1, \\ k &= 1, 2, 3, ..., L, \\ x^0 &= [1, 1..., 1]^T \end{aligned} \tag{7}$$

where L is the number of iterations.

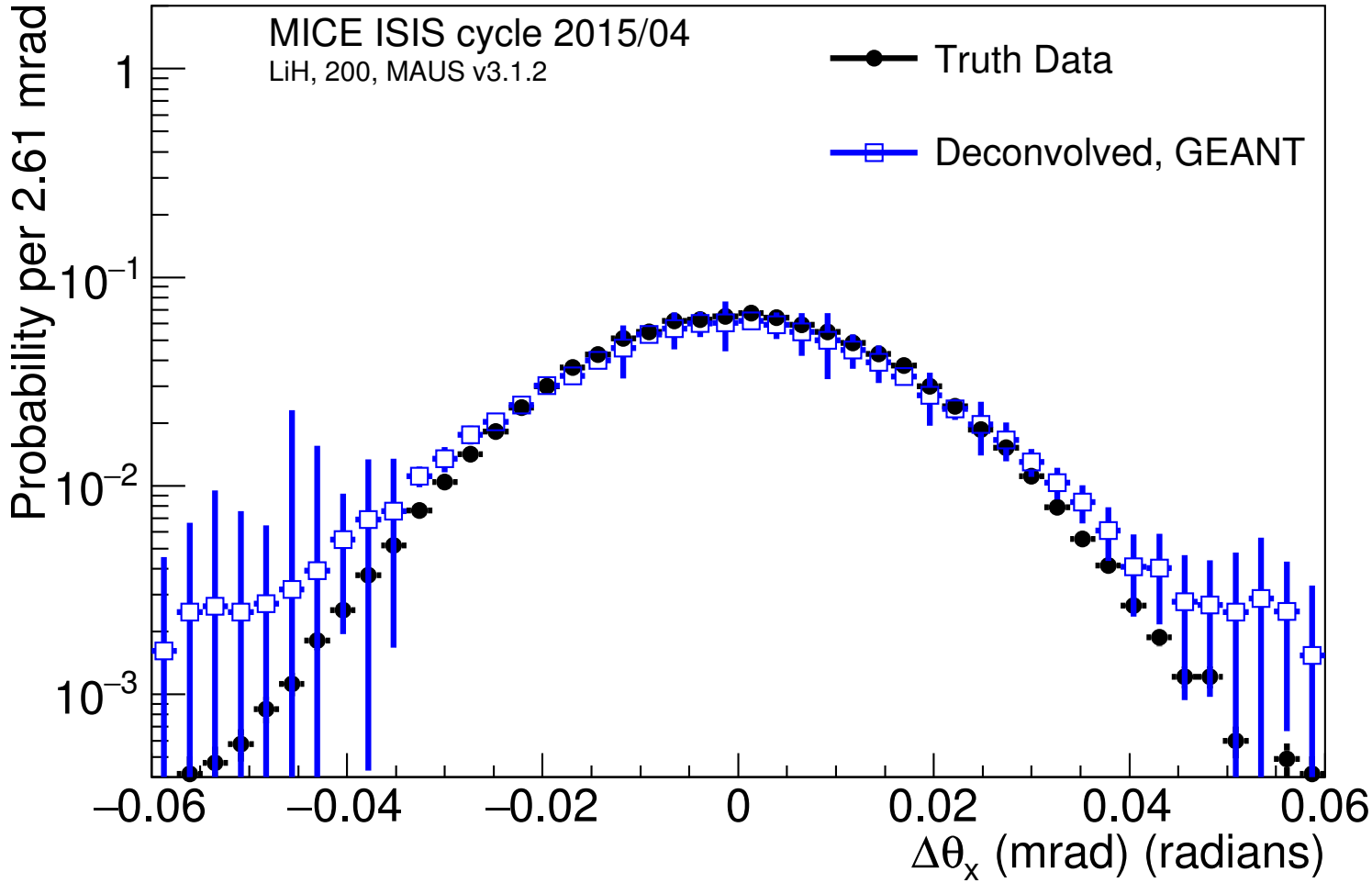
[1] A Toeplitz matrix is an $n \times n$ matrix $T_n = [t_{k,j}; k, j = 0, 1, ..., n-1]$ where $t_{k,j} = t_{k-j}$

Gold Algorithm

- This method is encapsulated in a ROOT class TSpectrum
- The ROOT class accepts histograms as input and the scattering distributions for the two cases, with and without absorber, were used as input with the output being the final measured scattering distribution.
- Full details are availble:
  `https://root.cern.ch/doc/v608/classTSpectrum.html`

MC Data comparison

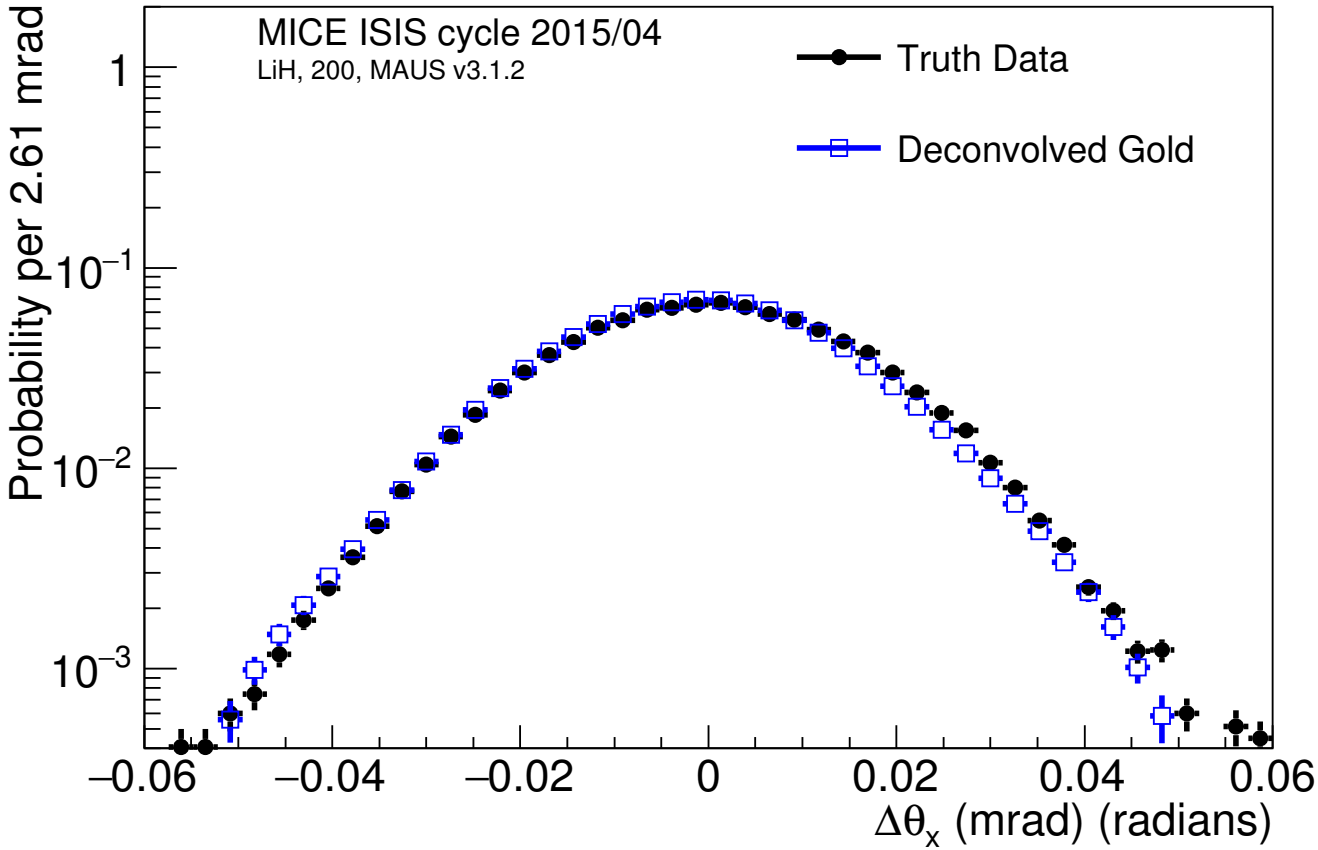
Situation at CM51 - bayesian optimal



- 200 MeV/c case
- Compare MC recon and data

MC Data comparison

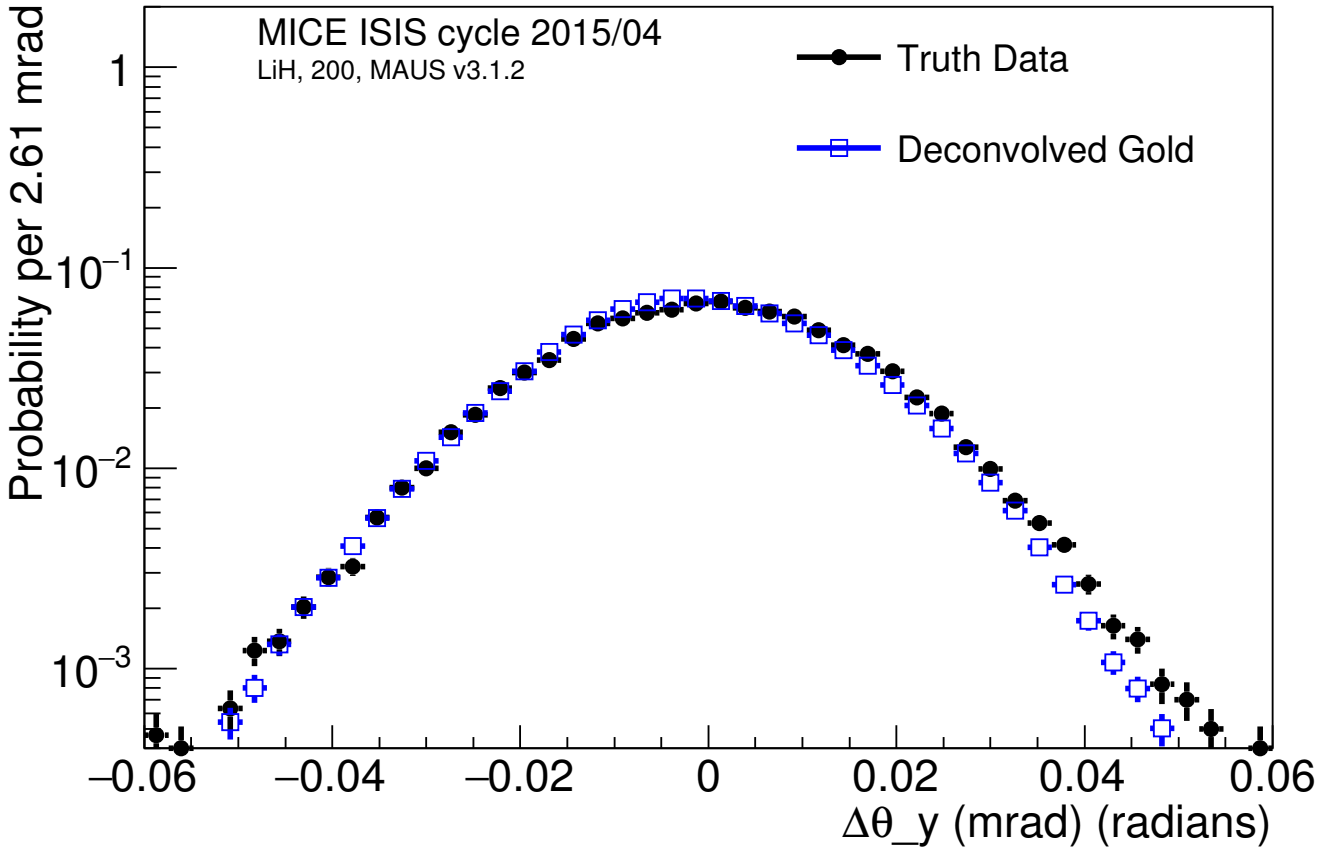
Situation at CM52



- 200 MeV/c case
- trkr acceptane + Gold iter 10

MC Data comparison

Situation at CM52

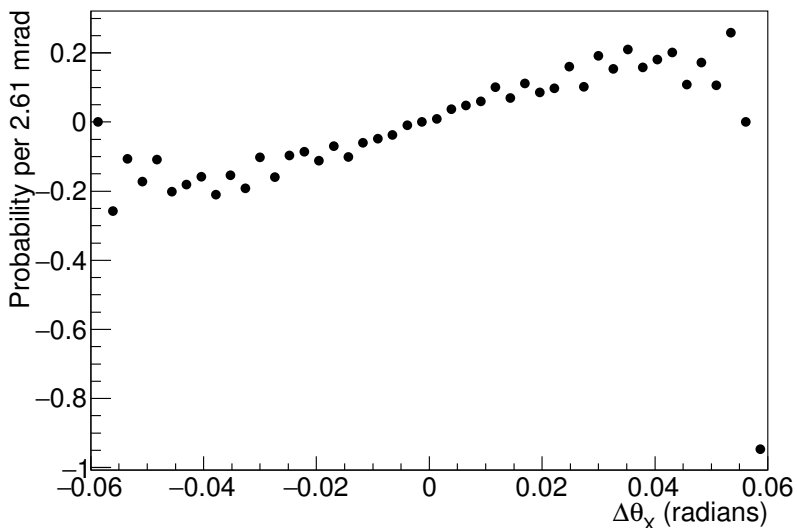


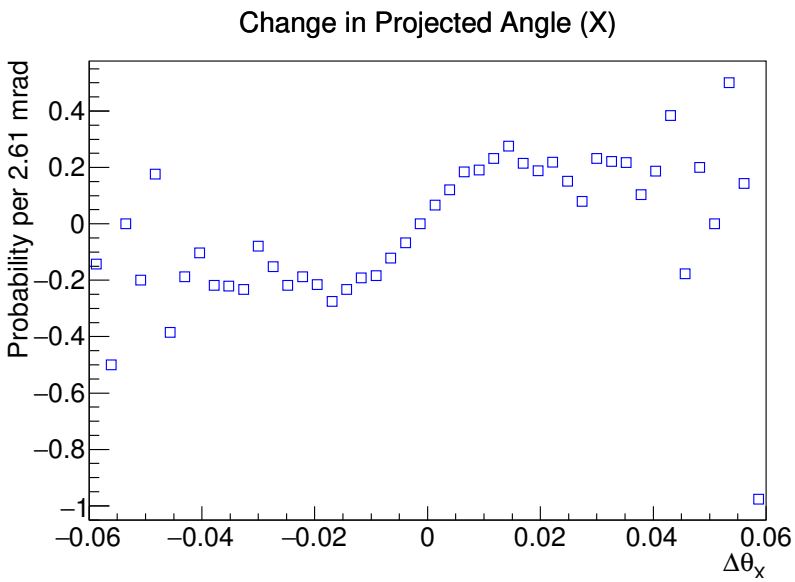
- 200 MeV/c case
- trkr acceptane + Gold iter 10

Asymmetry

$$A_i = \frac{h_1 - h_2}{h_1 + h_2} \tag{8}$$

left is LiH MC recon & right is empty MC recon





- At Warwick workshop it was shown that if such an asymmetry is present in the data then there is a misalignment in the geometry
- A similar misalignment is in the MC geometry, as shown above

Misalignment- Warwick Meeting

Studied the data

- Fiducial scan - 50, 100, 150 mm
- P scan - 170, 200, 240 MeV/c
- Core of beam
- Start vs. end of run
- chi2/ndf - 99.9% ¡ 4
- Confirmed by Durga that tracker glue is *NOT* in processed data and MC used in this analysis
- To what precision is the alignment known?

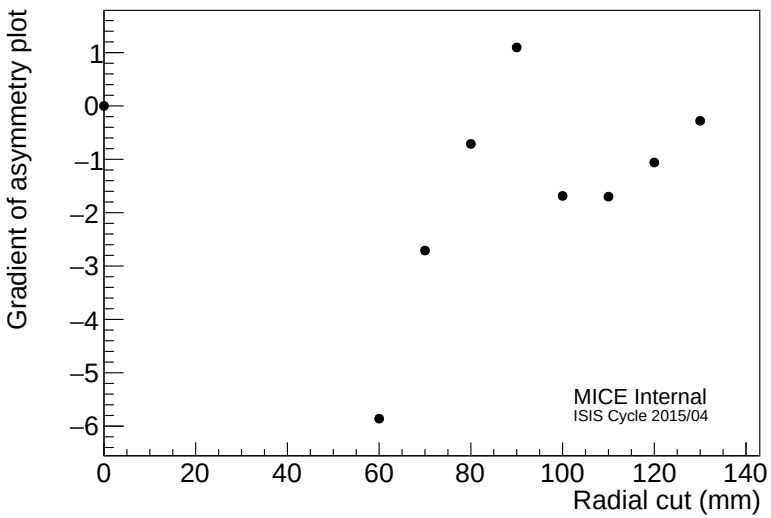
Misalignment

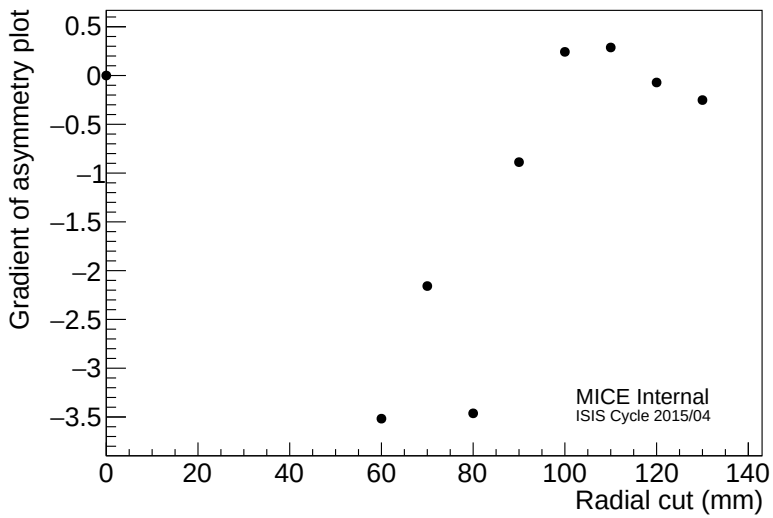
- Scan in radial
- Refactoring code
- Check in MC Truth

Asymmetry

$$A_i = \frac{h_1 - h_2}{h_1 + h_2} \tag{9}$$

left is LiH MC Truth X & right is LiH MC Truth Y





Job List

- Correct asymmetry in MC recon scattering distributions
- MC Truth selection