Field Off Scattering Studies: Current Status

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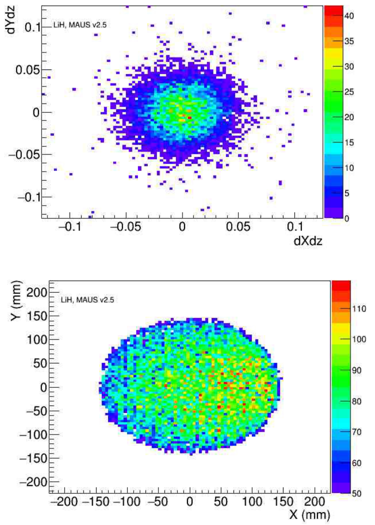
Since CM47

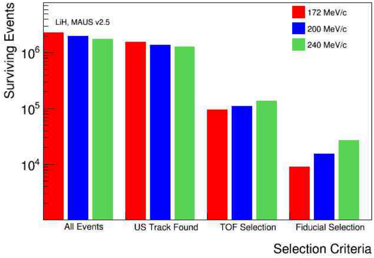
- Ryan Bayes has left Glasgow to move to a new position
- I have moved into a new position at Glasgow
- Now working on developing the field off scattering studies - Ryan is keeping in touch and providing direction
- Picked up all of the MCS analysis code and validated that it is producing values compatible with those presented by Ryan at CM46

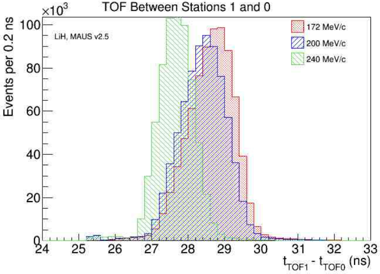
Scattering Data

- Field off data sets were collected in ISIS run periods 2015/03 and 2015/04
- A momentum dependent multiple scattering measurement is made
  - Measure empty channel scattering
  - Convolved with physics model of scattering in absorber - prediction.
  - Measure absorber scattering
  - Prediction is response in Bayesian deconvolution of absorber scattering distribution.
  - χ^2 comparison between data and prediction
  - Width of scattering distribution: Θ



Selection





Only minor changes to selection

- Require a US track. If a DS track not extant, statistics are set to overflow values.
- Analysis done in 200 ps bins, as shown in TOF plot
- Require projection of US tracks to appear, when 12 mrad radial angle is added, within central 140 mm radius of DS plane 1 projected

Scattering Data

- Define projection angles

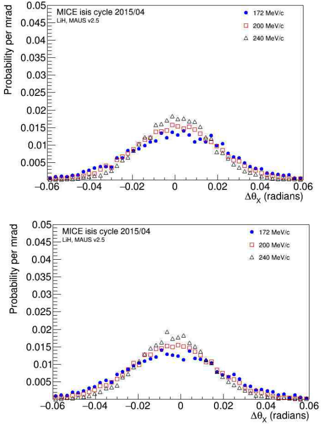
$$\theta_y = \text{atan}\left(\frac{p_{DS} \cdot (\hat{y} \times p_{US})}{|\hat{y} \times p_{US}||p_{DS}|}\right) \quad (1)$$

and

$$\theta_x = \text{atan}\left(\frac{p_{DS} \cdot (p_{US} \times (\hat{y} \times p_{US}))}{|p_{US} \times (\hat{y} \times p_{US})||p_{DS}|}\right) \quad (2)$$

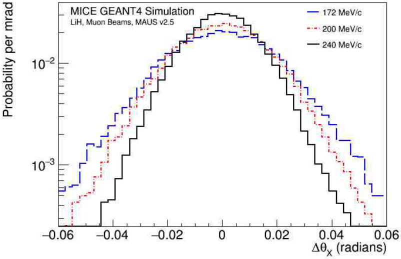
- Where $\theta_x^2 + \theta_y^2 \approx \theta_{scatt}^2$ with

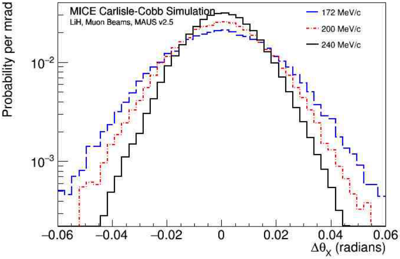
$$\cos\theta_{scatt} = \frac{p_{US} \cdot p_{DS}}{|p_{US}||p_{DS}|} \quad (3)$$

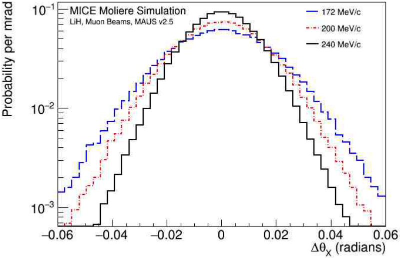


Physics Model

Three different physics models are used to make the scattering prediction, GEANT4, Carlisle-Cobb & Moliere

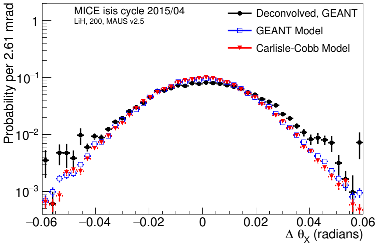






Deconvolution of Raw Scattering Data

- Use a iterative algorithm that uses the conditional probability to characterize the response of the reconstructed scattering angle to the true scattering angle

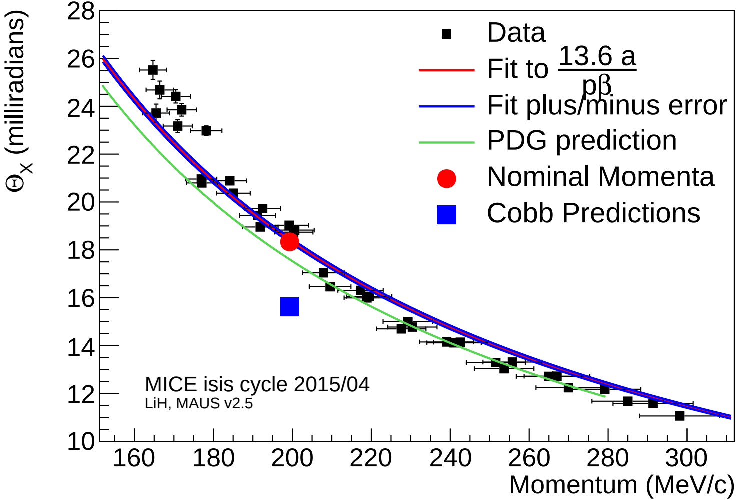


Bayes Theorem

$$P(C_i|E_j) = \frac{P(E_j|C_i)P_0(C_i)}{\sum_{l=1}^{n_c} P(E_j|C_l)P_0(C_l)}$$

- We want $C_i = \Delta\theta_Y^{abs}$ the deflection angle in the absorber material.
- We measure $E_j = \Delta\theta_Y^{tracker}$ the deflection angle measured at the first tracker plane.

Θ as a Function of Momentum



Momentum Correction

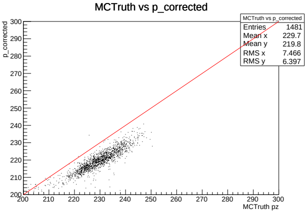
A correction must be applied to the P as reconstructed by the TOF to account for the additional path length and energy loss in the channel

- Previous corrections, MC used to correct on a statistical basis and formula on a particle by particle basis.
- MC correction shown at CM47, particle by particle correction is a work in progress. The first iteration had some anomolous behaviour
- New formula uses TOF01 information
- Caveat is constant energy loss is assumed in derivation

Proposed correction

$$p_0 = \frac{mc}{\sqrt{\left(\frac{c\Delta t}{\Delta s} - \frac{1}{2mc^2}\frac{dE}{ds}(\Delta s_0 + \Delta s_1)\right)^2 - 1}} \quad (4)$$

1st analytic correction



Neon Scattering

- In the last week of 2017/01 ISIS user cycle MICE took Neon scattering data and empty channel data
- elog → several alarms but mostly seems to be proceeding quietly
- Physics devil not running → have emailed Chris Rogers
- All data in quick turn around processing with MAUS v2.8.5
- Have some first pass plots

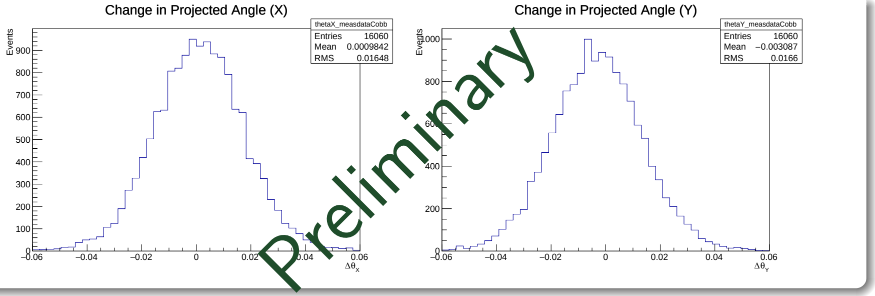
Data Summary

All data that was requested has been taken

Beam line settings (P of beam between TOF1-2 in MeV/c)							
140	240	170	200	240	170	200	140
Zero Absorber				Neon			
9387 9400 9401 9402 9403 9404 9405 9406 9407 9408 9409 9410	9382 9383 9384 9385 9386 9388 9389	9378 9390 9391 9394 9395 9396 9397 93400	9379 9380 9381 9392 9393 9411 9398 9399	9338 9339 9340 9341 9345 9348 9352	9234 9325 9328 9329 9331 9333 9335 9342	9326 9327 9330 9332 9334 9337 9351 9344 9348	9361 9362 9363 9364 9373 9374 9375 9377

Beam line settings (P of beam between TOF1-2 in MeV/c)	Absorber	No. of triggers
240	Neon (300 mm) Empty channel	$\sim 1 \times 10^6$ $\sim 1 \times 10^6$
200	Neon (300 mm) Empty channel	$\sim 1 \times 10^6$ $\sim 1 \times 10^6$
170	Neon (300 mm) Empty channel	$\sim 1 \times 10^6$ $\sim 1 \times 10^6$
140	Neon (300 mm) Empty channel	$\sim 1 \times 10^6$ $\sim 1 \times 10^6$

Raw Scattering Distributions



- All onrec plots shown by Durga at daily run meetings have been nominal
- 170 MeV/c neon raw (not deconvolved plots)
- Have work to do to deconvolve including generating MC models + tuning selection → Moliere distributions have been provided by J. Cobb (✓)

Field On Analysis

- Field on scattering measurement is being made by Jan Greis (Warwick) and Alan Young (Strathclyde)
- Jan - convolving empty channel data with physics models to test against LiH scattering data. Tracks are propagated to the absorber and the scattering evaluated. Currently a study of the systematics is being done
- Alan - building on the code developed for the field off analysis & working towards propagating tracks with Runga-Kutta and evaluating scattering in absorbers

Job List

- Validate code (✓)
- Update Note (new round of plots) (✓)
- Moliere model comparison (✓)
- Implement P correction 1 week
- Reprocess data with MAUS v2.9.0 (parallel) 1 week
- Build MC with MAUS v2.9.0 (parallel) 2 weeks

- Include tracker efficiency in analysis 2 weeks
- Incorporate Neon scattering in Xenon and LiH analysis 2 week

Selection

		μ Beams, LiH abs.			π Beam
Selection	Description	172	200	240	240
TOF1 trigger	At least two raw TOF slab hits exist and at least one in each TOF plane.	1.	1.	1.	1.
Upstream track selection	There is one US track and at most one track in the DS tracker (If is are no DS track $\theta_X = \theta_Y = 45°$).	66.8%	68.4%	74.1%	59.0%
TOF timing selection	Select muons from run at the target momentum.	3.8%	5.4%	7.5%	35.0%
Fiducial selection	For projected US tracks $\sqrt{x^2+y^2} < r_0$ at DS ref plane, where $x = x_0 + (\frac{dx}{dz} + a_0 \cos\phi)\Delta z$, $y = y_0 + (\frac{dy}{dz} + a_0 \sin\phi)\Delta z$, and $\phi = \tan^{-1}\frac{dy/dz}{dx/dz}$. $r_0 = 150$ mm and $a_0 = 0.012$ assumed.	0.3%	0.5%	0.8%	2%

[1]

[1] Taken from MCSNote

Momentum Correction

Taken from John Cobb's Note analysis Note (28/04/17)

- Pg 1 first order term of Taylor expansion

$$\frac{dt}{dp} = -(s_1 - s_2)\frac{m^2}{p^2 E}\Delta \tag{5}$$

- Pg 2 expression for corrected p

$$p_c = p_0 + \left(\frac{dt}{dp}\right)^{-1} \delta t \tag{6}$$

- expression given on Pg 2 in subsequent line of derivation

should be -ve

$$p_c = p_0 - \frac{1}{s_1 + s_2}\frac{Ep^2}{m^2}\delta t \tag{7}$$