Models of the Transmission Efficiency of TRIUMF's EMMA Recoil Mass Spectrometer

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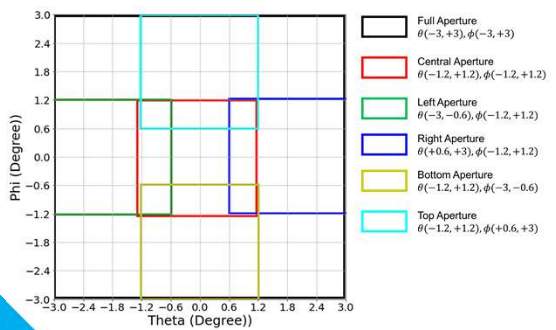
Introduction

EMMA is TRIUMF's ISAC-II recoil mass spectrometer. Measuring its transmission efficiency (TE) for all angles (θ,ϕ) and energy deviations (δT) would be desirable but is not practical. Alternatively, one can use models to calculate TE as a function of angle and energy deviation. Based on transmission measurements with six angular apertures at five energy deviations, two different models, a piecewise Gaussian and a modified Fermi function were developed. The parameters of the models describing each energy deviation setting were optimized by χ^2 minimization. The systematic error in TE(θ,ϕ) due to modelling uncertainties was estimated from the relative difference between the two models.



Angular coverage of the six apertures used in the measurements

Transmission Efficiency Models

We developed two different models to calculate the TEs at every (θ,ϕ) pair. One is a piecewise double Gaussian function with 4 parameters and the other a piecewise modified Fermi function with 13 parameters. E.g., in the top-left region the functions are given by Equations 1 and 2. The parameters were chosen by minimizing $\chi2$ using the Minuit package.

$$TE_{Gauss\_LT}(\theta,\phi) = \exp\left(-\frac{\theta^2}{2\sigma_L^2}\right)\exp\left(-\frac{\phi^2}{2\sigma_T^2}\right) \quad (1)$$

$$TE_{Fermi\_LT}(\theta,\phi) = \frac{a*\theta+K_L}{1+\exp(-B_L(\theta-\mu_L))}\frac{K_T}{1+\exp(B_T(\phi-\mu_T))} \quad (2)$$

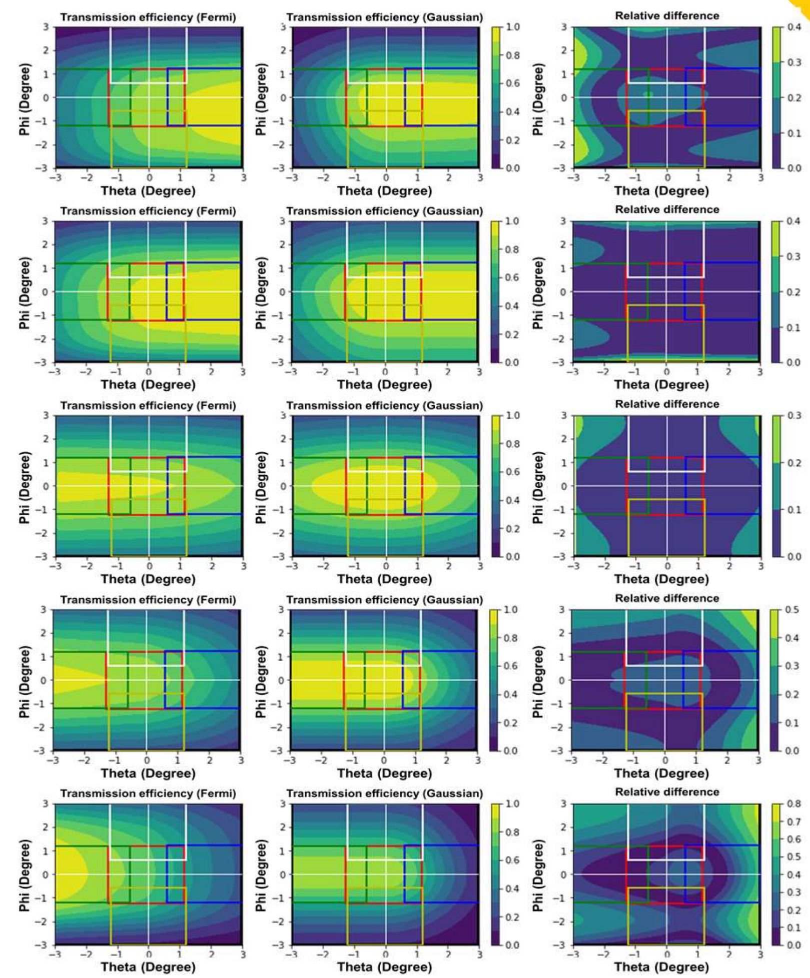
Measurement data and Chi-square values of two models

δT	Measurement data (uncertainty)						Fitting result	
	Full	Central	Left	Right	Bottom	Top	χ^2_{Fermi}	$\chi^2_{Gaussian}$
−0.1	0.61 (0.03)	0.81 (0.09)	0.57 (0.06)	0.88 (0.09)	0.75 (0.08)	0.46 (0.05)	0.027	1.352
−0.05	0.71 (0.03)	0.90 (0.1)	0.73 (0.08)	0.93 (0.1)	0.78 (0.08)	0.60 (0.06)	0.068	0.262
0.0	0.69 (0.03)	0.91 (0.1)	0.84 (0.09)	0.78 (0.08)	0.65 (0.07)	0.59 (0.06)	0.852	1.512
+0.05	0.63 (0.03)	0.84 (0.09)	0.84 (0.09)	0.57 (0.06)	0.52 (0.06)	0.55 (0.06)	3.267	5.636
+0.1	0.03 (0.57)	0.08 (0.71)	0.09 (0.86)	0.04 (0.4)	0.04 (0.4)	0.05 (0.5)	6.277	23.329

Estimation of Uncertainties

The measurement uncertainties originate from statistics and the precision of the aperture dimensions and locations. These uncertainties are compared with the integral of TE for each aperture. When considering differential TE uncertainties, the total error is the quadratic sum of the relative error of the measurement and the relative difference of the models that describe the measurement well.

δT	−0.1	−0.05	0.0	+0.05	+0.1
Relative Modelling Error (%)	10.2	6.5	13.6	12.5	24.0
Total Relative Error (%)	11.4	8.0	14.3	13.2	24.5



Contour plots of the TE obtained by Fermi (left) and Gaussian (middle) model and Relative differences (right) for δT=-0.1, -0.05, 0.0, +0.05, +0.1 (top to bottom)

Conclusion

- Two different models of the transmission efficiency of EMMA were developed and optimized to describe alpha source transmission measurements with six apertures at five energy deviation settings.
- The total uncertainty in the transmission efficiency was estimated by combining the measurement uncertainties with the relative differences between the two models.

Acknowledgement

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Discovery, accelerated