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McStas

CAMEA

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Benching Mark CAMEA Against Present Inelastic Neutron Spectrometers

The CAMEA concept will be compared to the world leading spectrometers to grade performance. The exact performance of CAMEA will be detailed in the instrument proposal, whereas here we will compare two key areas where CAMEA has a clear gain factor. Additional gain factors from improved resolution, and background suppression are not considered here. Furthermore a comparison to a direct geometry time-of-flight spectrometry will be made by instrument simulations.

As CAMEA is an indirect time-of-flight spectrometer we will compare it to other indirect time-of-flight spectrometers capable of performing similar science. CAMEA's performance can also be compared to the performance of multiplexed triple axis spectrometers (TAS), and the flux of world leading TAS. The two gain factors for CAMEA that we will consider are neutron flux, and solid angle of analysis of the scattered neutrons.

In table one we outline a comparison of the neutron fluxes of triple-axis Spectrometers (TAS) and indirect geometry spectrometers with respect to CAMEA. The optimization of the CAMEA guide was for a vertical divergence of ±1.5° vertically and ±0.75° horizontally. As of March 2014 neutron simulations of the CAMEA guide were indicating a neutron flux of 1.8 x 10^{10} $\mathrm{ncm}^{-2}\mathrm{s}^{-1}$ for 1.7 Å wavelength band centred at 3.25 Å in the maximum flux mode. In the resolution matching mode the incident resolution is matched to the resolution of the secondary spectrometer for a specific energy transfer and neutron final energy, for this mode the flux is approximately a factor of 3 lower. We compare the maximum flux mode for a flux gain factor of CAMEA in table one. We note that TAS have a monochromatic incident beam, so the comparison in table one should not be taken as an absolute gain factor for every possible experiment. As far as we are aware there is no published data on the neutron flux of the indirect geometry spectrometer PRISMA, which could operate at similar final neutron energies as CAMEA. From consideration of source brightness and >80% brilliance transfer for CAMEA's guide, a highly conservative estimate of the flux gain factor of CAMEA over PRISMA is >20. As can be seen in the values quoted in the table, for cold neutron spectrometers CAMEA has a gain factor that is between 100-1000 times that of present neutron instruments with cold neutron energy resolution. The THALES upgrade to IN14 will reduce this gain factor to 50, but for a larger beam divergence that will lower the resolution of the instrument, particularly the wavevector resolution. The low gain factor in comparison to MACS is due to MACS' flux being quoted for thermal neutrons, i.e. a ~0.9 meV energy resolution.

Table 1:

Instrument	Facility	Instrument Type	Flux	CAMEA Gain	Final Neutron Energy	Energy Range	Resolution at E = 0 for stated Final Energy
			n per cm^2 per s		(meV)	(meV)	(meV)
IN14[§]	ILL	TAS - PG(002)	1.7x 10^8	105	5	0.1-17*	0.120
PANDA[$]	FRM-II	TAS - PG(002)	1.9 x 10^7	947	5	0.1-20*	0.120
MACS[+]	NIST	TAS - PG(002)	5x10^8	36	14.7	2.3-14[#]	0.85
THALES[§]	ILL	TAS - PG(002)	3.5x10^8@ k_i = 2.0 $Å^{-1}$	51	5	0.1-20*	0.060
OSIRIS	ISIS	Time-of-Flight	3.24x10^7@ 180uA	554	1.84	-3 to 4	0.0254
IRIS	ISIS	Time-of-Flight	1.2x10^7 @180uA	1500	1.84	-3.5 to 4	0.0175
IN20 (Polarized)	ILL	TAS - Heusler	1.05 x 10^7	>20[Ξ]	14.7^	2-90*	0.85

[§] The values given for THALES and IN14 are from instrument simulations. With the measured flux of IN14 being 50% of this value: M. Boehm, *et. al.*, Meas. Sci. Technol. **19**, 034024 (2008), M. Boehm, *et. al.*, unpublished.

*A range of negative energies below 0 meV can be reached on TASs.

[$] The quoted flux of PANDA is for a vertically focused and horizontally flat monochromator. Employing that uses both vertical and horizontally focusing would increase PANDA's flux by a factor of 3.

[+] The flux quoted for MACS is for thermal neutrons of 12 meV energy.

[#] This energy range is only accessible for lower final neutron energies.

^In practise a final neutron energy of 14.7 meV is rarely used above 30 meV for studies of magnetic excitations. Higher energies are reached by using a final neutron energy of 34.8 meV.

[Ξ] This value represents a first estimate, and is variable depending on beam divergence at the supermirror polarizer's position on CAMEA and the m value that is used.

The flux gain alone gives CAMEA the ability to out-perform other spectrometers, but an additional gain comes from efficient detection of the scattered neutrons. In table two we compare the solid angle of analysers to represent detection efficiency. The back scattering instruments IRIS and Osiris use a large vertical divergence of analyser coverage to achieve high count rates at the cost of poor out of horizontal plane resolution. We therefore compare the solid angles of existing instruments to that of the typical solid angle of a single CAMEA analyser arc, covering ±1.4°vertical divergence. Within a ±1.4° vertical divergence CAMEA gains a factor of 2.4 or greater for existing multiplexed spectrometers, this is because of either the need of the instrument to move around the monochromator restricting size, or the use of a double bounce analyser system introducing large dead angles. For the indirect geometry spectrometers CAMEA has slight gains on the ISIS backscattering spectrometers, but has a large gain on the double bounce analyser setup of PRISMA. On top of the larger solid angle for a single analyser, CAMEA also has the advantage of using analyser arcs sat behind each other, each detecting a different final energy of the scattered neutrons. The multiple analyser arcs will therefore provide an additional gain factor, which will be dependent on the needs of each experiment.

Table 2:

Instrument	Facility	Analyzer Bragg Reflection	Solid Angle (steradians)	±1.4° Solid Angle (steradians)	CAMEA Gain ±1.4° single analyzer	CAMEA Gain for All Analysers⁺
CAMEA		PG (002) or (004)	0.13 x 10	0.13 x10	-	-
OSIRIS	ISIS	PG (002) or (004)	1.09	0.12	1.08	7.7
Iris	ISIS	PG (002) or (004)	0.36	0.11	1.18	8.4
IN14/THALES	ILL	PG(002) double focusing analyser	0.016	0.0051	25.5	181
PRISMA	ISIS	PG (002)	0.021 @ 5 meV	0.0112	11.6	82.4
MACS	NIST	PG (002)	0.15	0.0525	2.5	17.8
Flatcone	ILL	Si(111)*	0.066	~0.033	3.9	27.7

* The Si(111) Bragg reflection has an approximately 2 times lower reflectance than PG(002), but Si(111) on TAS gains an advantage in not having contamination from second order Bragg reflections. We do not include a reflectance gain factor for using PG(002) over Si (111), this is because Flatcone could be constructed using PG(002) analysers.

⁺ This number represents the total analyser coverage of CAMEA corrected for transmission efficiency of the CAMEA analysers, a total gain factor of 7.1.

In table 3 we summarise the combined gain factor CAMEA can achieve in neutron flux and analyser solid angle.

Table 3:

Instrument	CAMEA Flux Gain	CAMEA Analyser ±1.4° Solid Angle Gain[§]	CAMEA Gain Factor
IN14 with Flatcone	105	27.7	2910
PANDA with Flatcone[*]	947	27.7	26200
THALES with Flatcone[#]	51	27.7	1410
MACS[+]	36	17.8	640
OSIRIS	554	7.7	4270
IRIS	1500	8.4	12600
PRISMA	>20	82.4	>1650

[§] The full multiplied gain factor is only applicable for cases where the entire coverage of $S(q,\varpi)$ is scientifically relevant.

*Flatcone is not available at FRM-II for PANDA. The CAMEA flux gain is in comparison to PANDA using a monochromator with vertical focusing only.

[#] This gain factor is reduced to 199 for THALES using a CAMEA type secondary spectrometer.

[+] Flux gain compares CAMEA to the low energy resolution, high flux thermal setup of MACS.

Conclusions

To summarize, in terms of both incident neutron flux and neutron detection efficiency, CAMEA offers clear gain factors on present cold inelastic neutron spectrometers. In comparison to presently built TAS combined with available multiplexing analysis the gain factor of a single CAMEA analyser is of the order of 400-3700, which can be reduced to 199 for THALES using Flatcone with PG(002) analysers installed. In comparison to the nearest equivalent indirect geometry spectrometer to CAMEA, namely PRISMA, a gain factor >230 can be expected for a single CAMEA analyser. For the resolution matching mode of CAMEA a higher resolution than that of TAS can be achieved, with an incident flux a factor of three lower, see [Guide Report]. The gain factor for CAMEA is 7.1 times larger when all analyser arcs of CAMEA are taken into consideration.

References:

The information for this report was obtained from the following sources:

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