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Preliminary study for the detection of neutrons in heavy ion collisions with charged particle detectors

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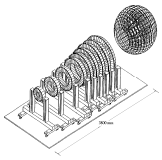
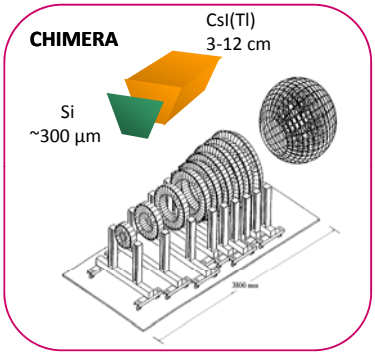
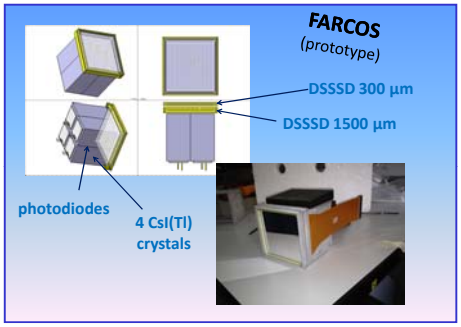


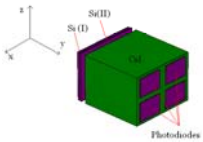
At Laboratori Nazionali del Sud (LNS) the CHIMERA 4π multidetector has been designed and setup to detect charged particles emitted in heavy ion collisions at intermediate energies. Properties and performances of CHIMERA have been widely demonstrated by published results obtained in the performed experiments [1]. Moreover, in recent years, a new charged particle detector (ChPD) for correlation studies (FARCOS) [2] has been designed, and recently a first prototype was coupled to CHIMERA, in order to test performances in view of correlation measurements in coincidence with 4π detectors.
Neutron detection with charged particle detection in heavy ion collisions, represents an important experimental progress for future experiments to be performed with both stable and exotic nuclei. In order to investigate about this possibility, Monte Carlo simulations have been performed. By means of MCNPX [3] transport code preliminary simulations have been carried out to evaluate the perturbation effects of CHIMERA and/or FARCOS Si-CsI(Tl) telescopes on (typical ~ 20MeV) neutron signals coming from heavy ion collisions. Also the cross-talk effects and time response have been taken into account.
In order to validate MCNPX simulations, a comparison among theoretical results and experimental data coming from INKIISSY [4] experiment is in progress.



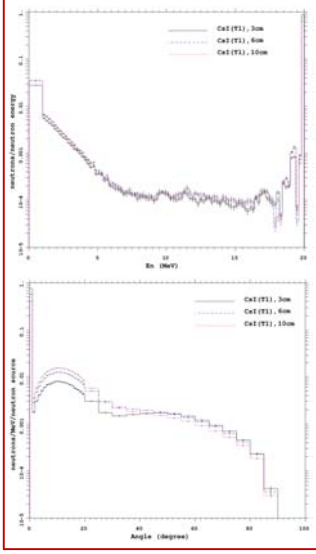


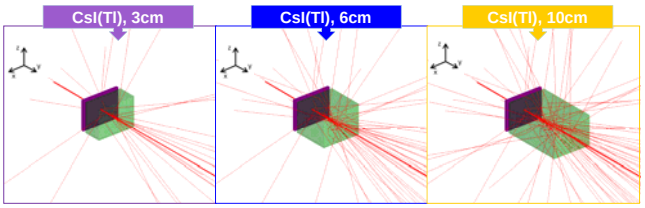
MCNPX simulations

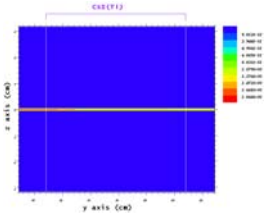
Setup: FARCOS configuration with CsI(Tl) of 3, 6 or 10cm thickness.
Libraries: LAN150N, TENDL2010/2
Cross section and table use: mix and match.
Analysis of PTRAC file, containing all the information on particle tracks.
Monoenergetic (20MeV) and monodirectional neutron beam.



Neutrons





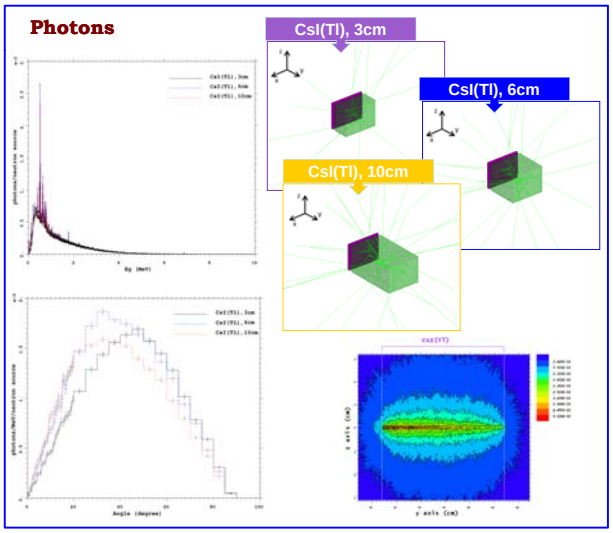


Interaction type	CsI(Tl) 3cm	CsI(Tl) 6cm	CsI(Tl) 10cm
(n,n'g)	12	16	25
(n,2n)	5	11	16
(n,3n)	1	5	5
(n,n_α)	-	5	1
(n,n') in SI(II)	2	1	1
(n,n_α) in Si(II)	1	1	1
(n,n'p) in Si(II)	1	1	1
Elastic scattering in SI(I)	-	1	-
No interaction	88	61	49

No. of interactions experienced in CsI(Tl) (100 histories)

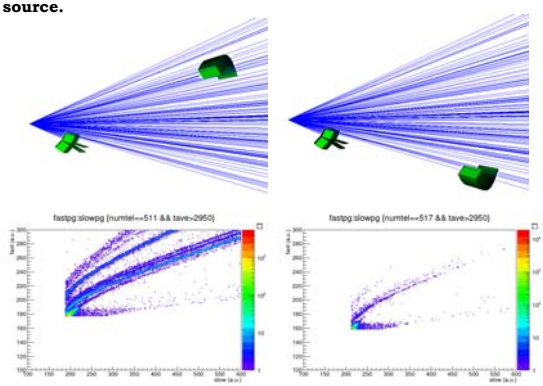
Simulations indicate that in CsI(Tl) 6cm thick, about 23% of incident neutrons experience interactions and about 13% of neutrons (both from the source and secondary ones) exit from lateral surfaces of CsI(Tl) thus probably inducing a signal in surrounding detectors.

Photons

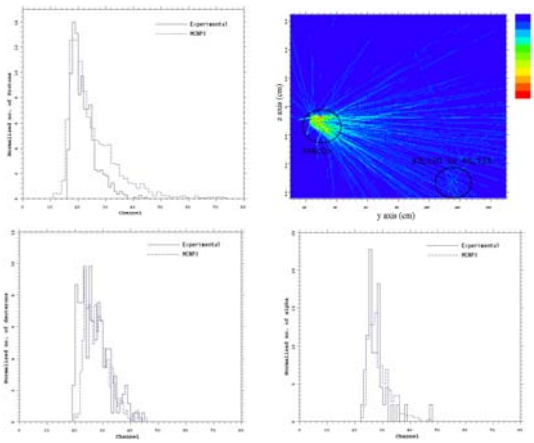


Validation of MCNPX simulations

INKIISSY experiment (^{124}Xe+^{64}Zn@35AMeV at LNS): part of ring8 and ring9 of CHIMERA are in the shadow beyond FARCOS. Only neutrons reach these detectors. Secondary particles in CHIMERA CsI(Tl) carry information on neutrons from the source.



Comparison carried out for telescope 517 (Ring8).
Theoretical neutron energy spectrum extimated upon the experimentally reconstructed energy spectrum of protons from the source in reaction ^{124}Sn+^{64}Ni@35AMeV performed at LNS [5].



Preliminary results! Analysis in progress!

Relative yield (%)	Experimental	MCNPX
Y_d/Y_p	19.7	21.7
Y_t/Y_p	3.4	11.4
Y_{3He}/Y_p	2.0	1.2
Y_{alpha}/Y_p	5.0	20

Comparison among MCNPX simulations and experimental data allows to validate theoretical models, used libraries and methods. Once validated, simulations help us to define a method to account for background and other side effects thus to reconstruct energy spectrum of neutrons coming from the source.
Finally, simulation results can be used to define the 'best' way to upgrade CHIMERA (or FARCOS) with a neutron detection system.
First data analysis results of the INKIISSY experiment would indicate the chance to detect neutrons by properly shadowing CHIMERA Si-CsI(Tl) telescopes thus suggesting an 'easy' and 'cheap' way to upgrade CHIMERA for neutron detection. Analysis is still in progress.

[1] E. De Filippo, A. Pagano, EPJ A 50 (2014) 32.
[2] G. Verde et al., J. of Phys.: Conf. Series 420 (2013) 012158.
[3] D. B. Pelowitz, ed., MCNPX User's Manual, Version 2.5.0, Los Alamos National Laboratory report LA-CP-05-0369 (April 2005).
[4] Russotto P. et al, Proc. of ECHIC2013, Messina, Italy in press on J. of Phys: Conf. Series.
[5] Pagano A. et al, Nucl. Phys. 734 (2004) 504.