PhD theses, dec.19-20, 2016

Astroparticle Physics

December 1, 2016

Candidate: Simone Marcocci [19dec at 10 a.m.]

Title: Precision measurement of solar ν fluxes with Borexino and perspectives for $0\nu\beta\beta$ search with ^{136}Xe-loaded liquid scintillators

Abstract: After its successful Phase-I (2007-2011), Borexino has further improved its unprecedentedly low background and has entered the solar neutrino precision measurement era. Thanks to the developments in the data analysis and to a better understanding of the detector response, a global analysis of Borexino Phase-II data (2011-2016) was carried out, yielding to the (preliminary) simultaneous determination of ^{7}Be, pep and pp neutrino fluxes. This PhD thesis describes the achievements (mainly regarding an improved simulation of the experiment) which made these accurate measurements possible. Furthermore, a more long term future for a Borexino-like experiment hunting for neutrinoless double beta decay ($0\nu\beta\beta$) is discussed. The current status of uncertainties and experimental/theoretical expectations on $0\nu\beta\beta$ is summarized, and the possible sensitivity of a large, next generation ^{136}Xe-loaded liquid scintillator detector is assessed and compared to present and near future experiments. The results of the experimental investigations of optical properties of liquid scintillators loaded with xenon at high pressure are also presented, in view of possible future applications.

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Candidate: Sarah Recchia [19dec at 2.00 p.m.]

Title: Non linear cosmic ray transport and cosmic ray driven galactic winds

Abstract: Cosmic Rays (CR) escaping from the Galaxy exert a force on the interstellar medium (ISM) directed away from the Galactic disk. If this force is larger than the gravitational pull galactic winds may take place. Possible outflows from the Galaxy are important since they affect the star formation rate, the amount of baryons and the chemical composition of the galactic halo and the evolution of the Galaxy. Moreover winds advect CRs, thus changing their transport properties. The dynamics of CR-driven winds is intrinsically non-linear because, if on the one hand the gradient of the CR spectrum determine the wind properties (velocity, pressure, magnetic field) and the excitation of the plasma waves which causes CR scattering, on the other hand the wind properties influence the CR distribution function. The CR distribution in the Galaxy is the result of these non-linear effects.

In this thesis we present the first semi-analytical method to solve self consistently the hydrodynamic problem of the generation of CR-driven galactic winds and the kinetic problem of the transport of CRs in such winds and in the self-generated turbulence. In our approach the CR diffusion coefficient and the wind velocity are an output of the calculation, together with the CR distribution function. The solution of the wind problem allowed an extensive investigation of the properties and implications of CR-driven galactic winds: 1) the wind launching depends on the properties of the ISM (gas density and temperature, galactic magnetic field), on the CR pressure and on the galactic gravitational potential. All these magnitudes depend on the position in the Galaxy and are constrained by observations. We studied how the possible presence and properties of galactic winds, launched at the Sun position, are affected when changing the input parameters within the observational ranges. In particular, we considered several Dark Matter models and showed that the effect on the wind properties is quite important. 2) In our model the CR spectrum results from the complex interplay between diffusion and advection on self-generated turbulence and advection with the CR-driven wind. We investigated how the CR spectrum is modified by the presence of a self-generated wind, with a special emphasis on the comparison with the CR spectrum observed at Earth. In particular, we found that in many cases, input parameters compatible with observations lead to a spectrum quite different from the one observed. However, it was still possible to find specific cases in which there is a good agreement with the observed spectrum and the wind characteristics are compatible with the

Galactic halo properties deduced from the recent observations of O_{VII} and O_{VIII} emission lines from the ISM. 3) Recent results obtained by analizing Fermi-LAT data show a substantial variation of the CR density as a function of the distance from the Galactic Center, also accompanied by a gradual spectral softening while moving outward from the center of the Galaxy. We studied the radial dependence of the CR spectrum in the framework of our non-linear propagation model but without including galactic winds. We found that, for a realistic distribution of CR sources (following the spatial distribution of supernova remnants) and for the radial dependence of the magnetic field, can be accounted for both the CR radial profile and the spectral softening.

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Candidate: Axel Boeltzig [20dec at 10 a.m.]

Title: Direct Measurements of the 23Na(p,gamma)24Mg Cross Section at Stellar Energies

Abstract: The reaction 23Na(p,g)24Mg is the link between the stellar Ne-Na and Mg-Al cycle. Consequently a precise determination of the reaction's cross section is of fundamental importance for stellar nuclear synthesis in AGB stars at 10 - 70 MK. Laboratory measurements in the corresponding energy range between 400 and 130 keV are hampered as usual by low cross sections caused by the Coulomb barrier between the 23Na and the H nuclei. In addition, due to the chemical properties of Sodium, 23Na targets suffer high instability and unreliability, making precise measurements extremely challenging.

In his thesis Axel Boeltzig has addressed the aforementioned experimental issues obtaining improved values or upper limits for several resonances in the relevant energy range. Uncertainties in the relevant energy range are consequently significantly reduced. To reach this goal Axel has implemented a new and up to date DAQ and data analysis system for the BGO Detector used. This system is now the standard DAQ in LUNA for this detector. He furthermore produced a details background model for the BGO detector based a renewed background measurements at LNGS. This model has allowed to develop an optimized lead shielding. Axel also developed sufficiently stable 23Na targets targets produced "just in time" at ATOMKI, Debrecen, Hungry. He also took care of to analyze several of these targets by RBS and ERDA at HZDR, Dresden, Germany. Axel has performed a total of 14 weeks of beam time at LUNA-400 and 6 weeks of beam time at the Nuclear Structure Laboratory of the University of Notre Dame (USA). While the beam time at LUNA has mainly been devoted to acquiring statistics on the 23Na(p,g) reaction itself, the measurements in Notre Dome were focused on obtaining auxiliary nuclear physics information e.g. on branching ratios relevant for confining the efficiency of the BGO detector.

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Candidate: Ilia Drachnev [20dec at 2 p.m.]

Title: New spectral analysis of solar ^{8}B neutrino with the Borexino detector

Abstract: Solar neutrino was first detected in 1970's and since that time plays a great role in studies related with solar construction as well as in studies of intrinsic properties of this particle, such as features of vacuum and matter-enhanced neutrino oscillations. Borexino detector is a unique experimental apparatus which has spectral sensitivity to all solar neutrino components apart from hep neutrinos since it could cover energy range from 150 keV to as much as 15 MeV and in some cases even higher while the achieved radiopurity levels minimize background components interference.

In this thesis spectral studies of the whole solar neutrino spectrum detected in Phase II with duration of 1173 live days are reported. In particular, solar neutrinos from ^{8}B are studied from the lowest detection threshold ever used for this component of solar neutrino spectrum. Electrons produced by recoil of these neutrinos are detected above 2.17 MeV of visible energy with a measured total neutrino flux of $(5.5 \pm 0.4) \times 10^6\ cm^{-2}s^{-1}$ under assumption of LMA (Large Mixing Angle) solution of MSW theory that is compatible with Standard Solar Model(SSM) in high metalicity case. Spectral shape shows statistical compatibility with MSW-LMA.

In this thesis it is shown that Borexino detector has statistical sensitivity to CNO and pep neutrino in case of specific analysis efforts application. Measured values are $(5.2 \pm 1.8_{stat}) \times 10^8\ cm^{-2}s^{-1}$ and $(1.31 \pm 0.35_{stat}) \times 10^9\ cm^{-2}s^{-1}$ respectively, compatible with expectations of high metalicity case of SSM and MSW-LMA.

In spite of the low precision these results obtained by Borexino detector could pave the way to future solar neutrino studies aiming to improve our understanding of solar models and neutrino matter oscillations.

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