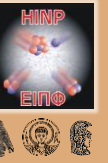


HINPw7



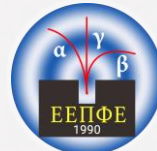
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on
Nuclear Structure, Astrophysics
and Reaction Dynamics

Under the auspices of
the Hellenic Nuclear Physics Society

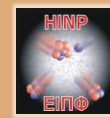
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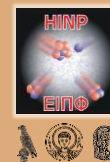


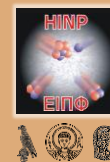


#INPW7
May 31, 2024 • Ioannina, Greece



Opening





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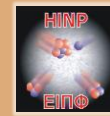
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George Floudas

Dean
of the School of Sciences

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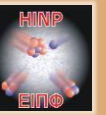
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Samuel Cohen
Head
of the Department of Physics

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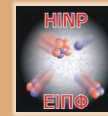
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George Souliotis
President of the
Hellenic Institute of Nuclear
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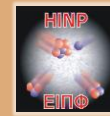
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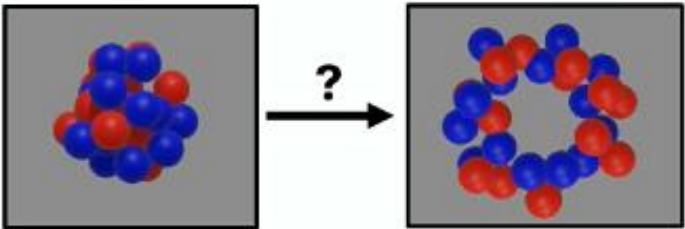


Christos Tsabaris
President of the
Hellenic Nuclear Physics Society

Session 1

Reaction Dynamics
(I)

History of Toroidal Nuclei



Wheeler Take-Home Exam (1963)

Princeton University
Physics Department
Physics 576 -- Nuclear Models
22 May 1963

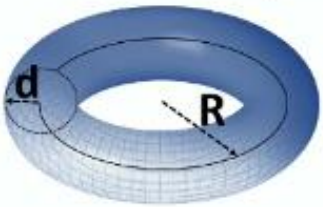
Final "Take-Home" Examination for Those Taking Course for Credit

PROBLEM 2

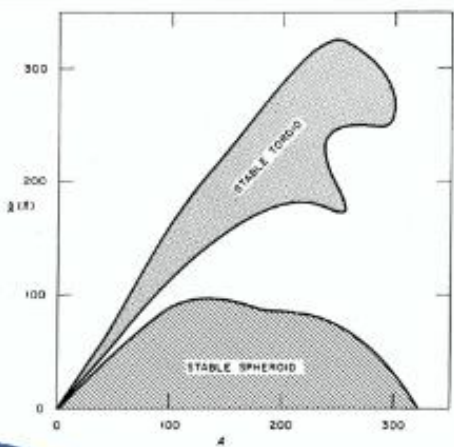
Wheeler's recent book, *The Biography of Physics*, refers in a few passing sentences to unpublished Princeton work on the theory of doughnut-shaped nuclei. (1) Develop this theory in the approximation in which the minor radius b of the torus is treated as very small in comparison with the major radius a , and in which the effect of the electrons is neglected.

(Hint: The Coulomb energy is the integral over the bent cylinder of the quantity $\frac{1}{2} \rho^2 V$, where ρ is identified as constant. The charge density per unit length of the ring is $\lambda = \pi b^2 \rho$. Outside the ring treat its electrical potential as if caused by a wire; that is (in e.s.u.),

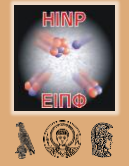
J.A. Wheeler, *Nuclear Notes* (1950) unpublished
J.A. Wheeler Princeton Graduate Course Physics 576 Take-Home Exam Problem 2, May 22, 1963



C.Y. Wong's early works (1972+)



C.Y. Wong, *Phys. Lett. B*, 41, 446-450 (1972)
C.Y. Wong, *Phys. Rev. C*, 17, 331-340 (1978)
T. Ichikawa, *Phys. Rev. Lett.*, 109, 232503 (2012)



Sherry Yennello

Texas A&M University
USA



Theodoros Depastas

Texas A&M University
USA







The NUMEN multi-channel approach

Several scattering and reaction channels open in a heavy-ion collisions above Coulomb barrier

Although the main interest is for DCE reactions, all the other quasi elastic processes are important sources of information, essential to build a constrained analysis of the nuclear states of interest for DCE and 0⁺[[1]]

Elastic scattering → nucleus-nucleus optical potential

Inelastic scattering → coupling strength to low-lying states

One-nucleon transfer reactions → single-particle spectroscopic amplitudes

Two-nucleon transfer reactions → strength of pairing correlations

Single charge exchange (SCE) → nuclear response to 1st order isospin operators (One-Body Transition Densities)

Double charge exchange (DCE) → nuclear response to 2nd order isospin operators (Two-Body Transition Densities)



Francesco Cappuzzello

University of Catania
& INFN-LNS, Italy



Onoufrios Sgouros

University of Catania
& INFN-LNS, Italy



Vassileios Soukeras
INFN-LNS, Italy

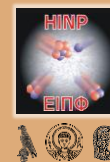
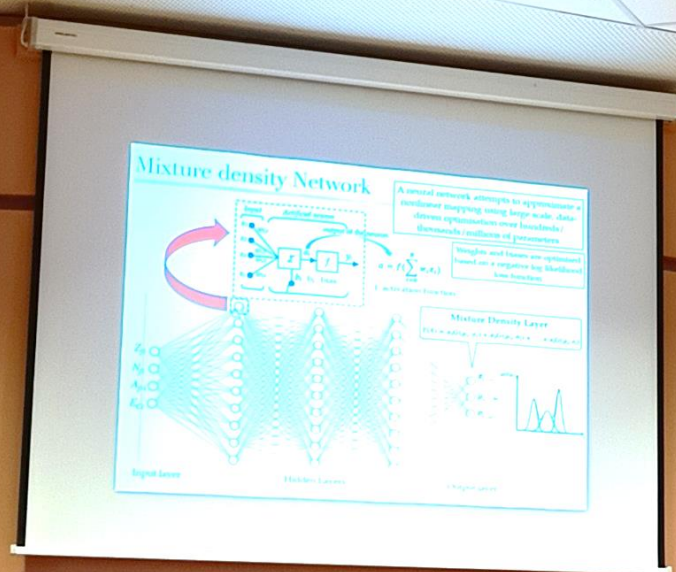
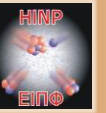


Table of Contents	
1	Introduction
2	NLD for Neutron Stars • NLD Model • NLD for β-equilibrium
3	Strangeness Threshold Effects • Conventional Models • NLD Model
4	NLD Results
5	Conclusions & Outlook

Theodoros Gaitanos

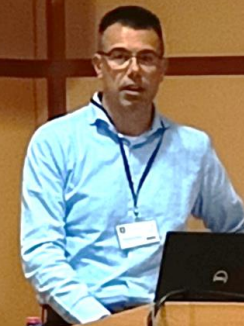
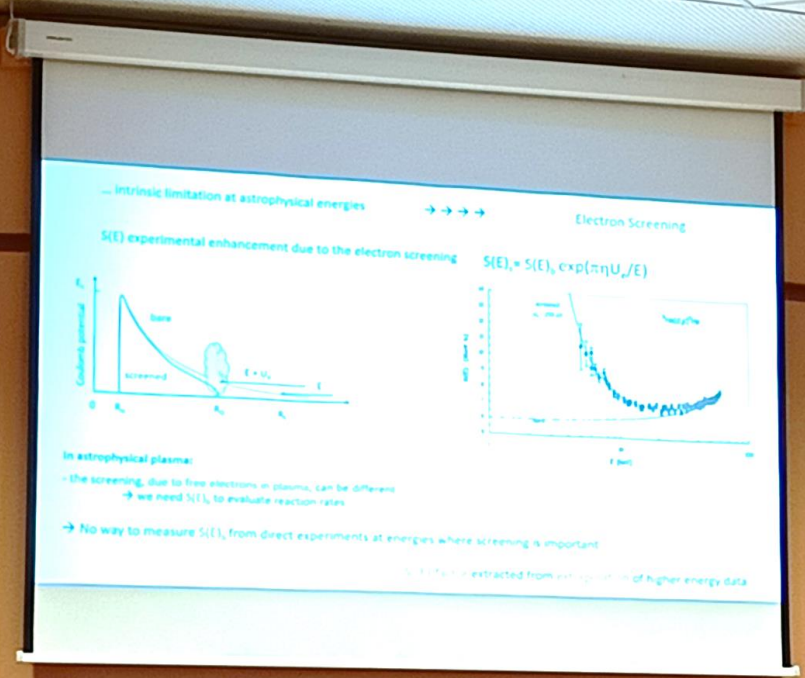
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Thessaloniki, Greece

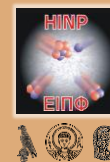




Session 2

Astrophysics





$^{57}\text{Ni}(p,\gamma)^{58}\text{Cu}$ Reaction Rate

- Assuming level density falls short of 10 levels/MeV, rate can be constrained with nuclear structure information via narrow resonance formalism

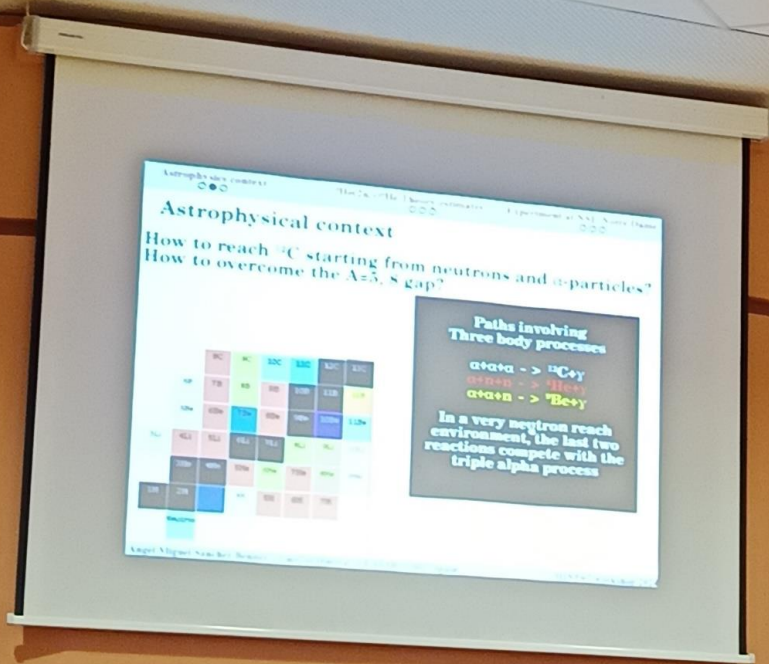
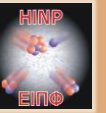
$$N_A(\sigma v) = 1.54 \times 10^{11} (\mu T_9)^{3/2} \sum_i (\omega \gamma)_i e^{-11.605 E_{\text{res}}/T_9}$$
$$\omega \gamma = \frac{2J_i + 1}{(2J_1 + 1)(2J_2 + 1)} \frac{\Gamma_p \Gamma_\gamma}{\Gamma_i}$$

- Requires precise determination of ^{58}Cu level energies, as well as proton/gamma branching ratios and spin
- Further, structure information of ^{58}Cu should be better known before proceeding with a RIB experiment

7th Workshop of the Hellenic Institute of Nuclear Physics on Nuclear Structure, Astrophysics, and Reaction Dynamics - May 31, 2024

UNIVERSITY OF NOTRE DAME
AND THE CENTER FOR NUCLEAR PHYSICS



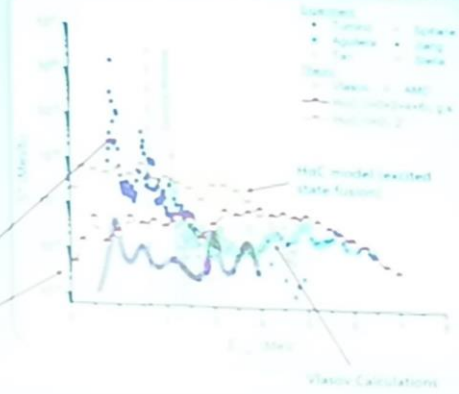


Ángel Sánchez-Benítez

University of Huelva, Spain

Astrophysical Factors : HaC Model

- S^* smooth function $\sim 10^{10} - 10^{11}$ MeVb
- Confirm Neck Model: Vlasov + Experimental (high energy)
- Trojan Horse Method $\rightarrow$ Low energy measurements
- Fusion with 2^{nd} excited state $\rightarrow$ Possible THM study



A. Bonasera, V. Kondratiev, Phys. Lett. B 838 (2018) 100000-100000; A. Bonasera, V. Kondratiev, Phys. Lett. B 102 (2020) 100000-100000.
 A. Tumino et al., Nature 557 (2018) 413-416; A. Tumino et al., Phys. Lett. B 782 (2018) 100000-100000.



Theodoros Depastas
 Texas A&M University, USA

Neutron skin thickness

The neutron skin thickness (related with the isovector character of the nuclear forces) defined as

$$\Delta R_{\text{skin}} = R_n - R_p$$

with

$$R_n = \left(\frac{1}{N} \int_V \rho^2 r^2 dr \right)^{1/2} = \left(\frac{1}{N} \int_V \rho^2 r^2 \frac{(1+\alpha)}{2} dr \right)^{1/2}$$

and

$$R_p = \left(\frac{1}{Z} \int_V \rho^2 r^2 dr \right)^{1/2} = \left(\frac{1}{Z} \int_V \rho^2 r^2 \frac{(1-\alpha)}{2} dr \right)^{1/2}$$

It is worth mentioning that ΔR_{skin} is not directly dependent on $S(\rho)$ compared to the case of κ_A . However, it is dependent indirectly via the asymmetry function $\alpha(r)$. We expect ΔR_{skin} and κ_A , κ_A^{eff} and $\rho_{\text{asym}}^{\text{eff}}$ to be strong indicators of the isospin character of the nuclear interaction.

The experimental values of the skin of ^{208}Pb reported by PREX-2

$$\Delta R_{\text{skin}} = (0.283 \pm 0.071) \text{ fm}$$

Charalambos Moustakidis

Aristotle University of
Thessaloniki, Greece

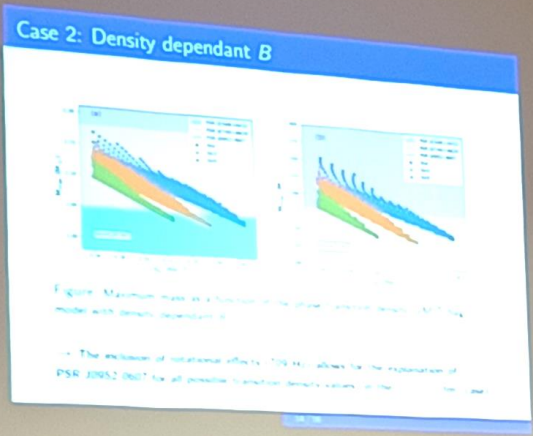
Discussion of results

After this initial effort we can note some interesting features of quarkyonic matter.

- Quarkyonic matter provides the sound speed as a non - monotonic function of the baryon density. We obtain a rapid increase up to a maximum value, after it decreases and eventually it is reaching asymptotically the value of $\frac{1}{\sqrt{3}}$ (conformal limit).
- Quarkyonic matter can predict more massive neutron stars (about $2.5 - 3.5 M_{\odot}$), without violating the causality in contrast with pure hadronic matter. Also, for neutron stars with mass $1.4 M_{\odot}$ predict radii about 13 - 14 km, a little greater compared to the pure neutron case.
- We constrained the value of parameter $\Lambda_{QW} < 210 \text{ MeV}$ from causality and also the value of transition density to be $n_{tr} \geq 0.25 \text{ fm}^{-3}$ from observational data resulting from LIGO and HESS experiments.
- This state of matter may be a consistent way to explain the phase transition in the interior of a neutron star

Konstantinos Folias

Aristotle University of
Thessaloniki, Greece



Pavlos Laskos-Patkos

Aristotle University of
Thessaloniki, Greece



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2. Exotic Condensates
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 - Exotic meson condensates
 - Exotic meson condensates
 - Exotic meson condensates
 - Exotic meson condensates
4. Conclusions

P. Koliogiannis (THALES)

THALES, 2019-2021, and the University of Thessaloniki, 2021-2022, 2022-2023

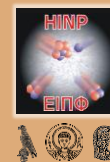
10/11/2023 - 10/11/2023

10/11/2023



Polychronis Koliogiannis

Aristotle University of
Thessaloniki, Greece



02 Two Fluid

The simple neutron star is explained with the solution of the Tolman Oppenheimer Volkoff (TOV) equations, the equations that describe a structure that exists in hydrostatic equilibrium.

The way we insert dark matter is the following:

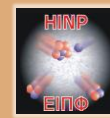
1. We need to define the dark matter particle mass m_χ , the interaction between the dark matter particles χ (we use repulsive interaction)
2. Instead of the neutron star central pressure that we use as initial condition, we also need the initial central pressure for dark matter and in order to create the M-R diagram, we need some kind of fraction between those two
3. The TOV equation now become 4 instead of 2, one set for each fluid.

TOV equations for simple one-fluid

$$\begin{aligned} \frac{dM(r)}{dr} &= 4\pi r^2 \rho(r) \\ \frac{dP(r)}{dr} &= -\frac{GM(r)\rho(r)}{r^2} \left(1 + \frac{P(r)}{\rho(r)r} \right) \\ &\quad \left(1 + \frac{4\pi r^3 P(r)}{M(r)\rho(r)} \right) \left(1 - \frac{2GM(r)}{r} \right)^{-1} \\ \exp(-2\lambda(r)) &= 1 - \frac{2GM(r)}{r} \\ \frac{d\Phi(r)}{dr} &= \frac{1}{1 - 2GM(r)/r} \left(\frac{GM(r)}{r^2} + \frac{4\pi r^3 P(r)}{r^4} \right) \end{aligned}$$

Michael Vikiaris

Aristotle University of
Thessaloniki, Greece



Session 3

Exotic-Weakly Bound
Nuclei

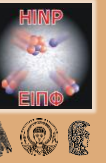
Construction of the optical potential

In coordinate space, the OMP for elastic scattering is

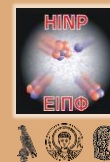
$$\begin{aligned} U(\mathbf{r}, \mathbf{r}'; E) &= \delta(\mathbf{r} - \mathbf{r}') \sum_i n_i \int \varphi_i^*(\mathbf{s}) g_D(\mathbf{r}, \mathbf{s}; E) \varphi_i(\mathbf{s}) d\mathbf{s} \\ &\quad + \sum_i n_i \varphi_i^*(\mathbf{r}') g_E(\mathbf{r}, \mathbf{r}'; E) \varphi_i(\mathbf{r}) \\ &= U_D(\mathbf{r}, E) \delta(\mathbf{r} - \mathbf{r}') + U_E(\mathbf{r}, \mathbf{r}'; E). \end{aligned}$$

- ✓ First term is the “ $g\rho$ ” (direct) potential.
- ✓ Second term is the exchange term.
- ✓ All nonlocality stems from the exchange term.
- ✓ Structure enters through the single particle wave functions and occupation numbers, n_i .
- ✓ For non-zero spin targets, terms with non-zero spin coupling may be included via the DWA.

Structure of the target is critical.



Steven Karataglidis
University of Johannesburg
South Africa



^8B , ^7Be Experiment 2022

- 70% of beam at ^7Be and ^8B (from LIFE-UHU)
- "SIMAS x 2" to "SIMAS x 4" (1 from LIFE-UHU)



K. Palli et al., PHYSICAL REVIEW C 107, 064613 (2023)

K. Palli et al., (Recently ACCEPTED)

K. Palli TALK more recent results!!!



Luis Acosta

UNAM, Mexico/IEM-CSIC, Spain

Motivation

Non-Newtonian Gravity model

$$V(r) = -\frac{Gm_1m_2}{r} \left(1 + \alpha e^{-r/\lambda} \right) = V_N(r) + V_Y(r)$$

$$\alpha = \pm \frac{g^2 \hbar^2}{4\pi G m_b^2} \quad \lambda = \frac{\hbar}{\mu} \quad g^2/\mu^2$$

λ represents the range of the Yukawa force mediated by the exchange of a boson with mass μ

$\pm$ sign refers to scalar(+) and vector(-) boson

g is the boson-baryon coupling constant

m_b is the baryon mass

Weakly Interacting Light Boson (WILB)

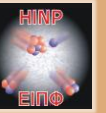
- Theories BSM include a number of new particles, some of which might be light and weakly coupled to ordinary matter
- Such particles affect the EoS of nuclear matter and can shift admissible masses of neutron stars to higher values
- Then the internal structure of neutron stars is modified, provided the ratio between coupling strength and mass squared of a weakly interacting light boson (WILB)



Vlasios Petousis

Czech Technical University in Prague, Czech Republic





Session 4

Nuclear Structure

Vector boson model with broken $SU(3)$ symmetry in heavy mass limit. Heavy $SU(3)$ defined multiplets. VBM model

$SU(3)$ irreducible representations (irreps) and Casimir c

$U(6) \supset U(3) \times SU(3)$
 $U(6)$ representations: (λ, μ, ν)
 $SU(3)$ irreps: (λ, μ)
 $SU(3)$ invariants (Casimir operators):
 $C_2 = \lambda^2 + \mu^2 + \lambda\mu$
 $C_3 = \lambda^3 + \mu^3 + 3\lambda\mu$
 Eigenvalues:
 $C_2 = \frac{1}{3}(\lambda^2 + \mu^2 + \lambda\mu)$
 $C_3 = \frac{1}{6}(\lambda^3 + \mu^3 + 3\lambda\mu)$



Nicolay Minkov

Bulgarian Academy of Sciences,
Bulgaria

Chiral potentials derived in ChPT

- Nucleons interact via pion exchanges and short-range contact interactions. The long-range forces are ruled by the symmetries of QCD, while short-range forces - which are not resolved - are absorbed into contact terms proportional to low-energy constants (LECs)

- Chiral potentials are organized in a systematic low-momentum expansion, where two- and many-body forces are generated on an equal footing



Angela Gargano
INFN-Naples, Italy

How the bands can be described?

Bohr-Mottelson Collective Rotor

$$E(I) = \frac{\hbar^2}{2\mathcal{I}} I(I+1), \quad \epsilon = \frac{\hbar^2}{2\mathcal{I}}$$

$$E_x = E(I) - E(I-2) = \frac{\hbar^2}{2\mathcal{I}} (4I-2) = 2\epsilon(2I-1)$$

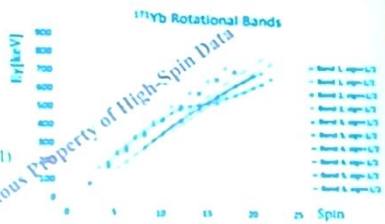
$$\Delta E_x = E_x(I) - E_x(I-2) = 8\epsilon = \frac{4\hbar^2}{\mathcal{I}}$$

New Parametrization (averaging behavior)

$$E_x = 2\epsilon(2I + k - \frac{1}{2}), \quad k \text{ integer}$$

- 2ϵ Moment of Inertia, Real
- $(2I+k-1)$ Angular Momentum, Integer

Fig. (E_x 's versus spins)



171Yb Rotational Bands

Property of High-Spin Data

Fig. (E_x 's versus spins)

Quasi-linear beam almost parallel and equidistant

Average behavior: $2\epsilon(2I+k-1)$, k integer

Determine from fit over all bands: ϵ range

$2\epsilon, k$'s from $\sum (E_x(I) - 2\epsilon(2I+k-1))^2 = \min$

Same slope 2ϵ for all k bands $\rightarrow$ same $J_{eff}^{(2)} = \frac{\hbar^2}{2\epsilon}$



A mechanism for the onset of deformation

interactions between valence protons and neutrons

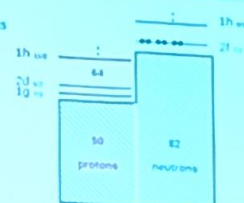
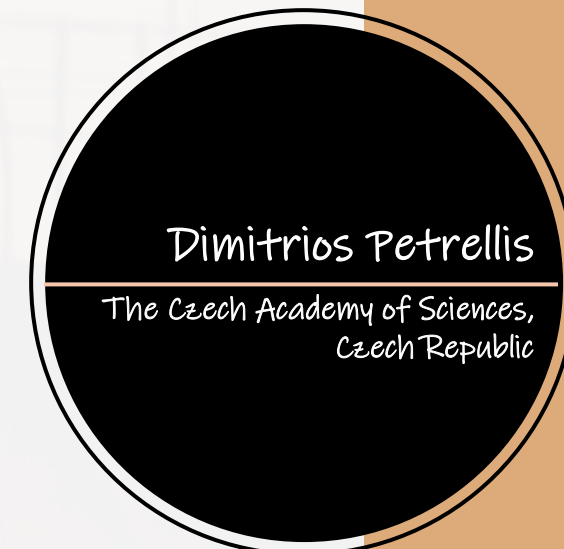
midshell $\Rightarrow$ increased collectivity $\Rightarrow$ low-lying 2^+_1

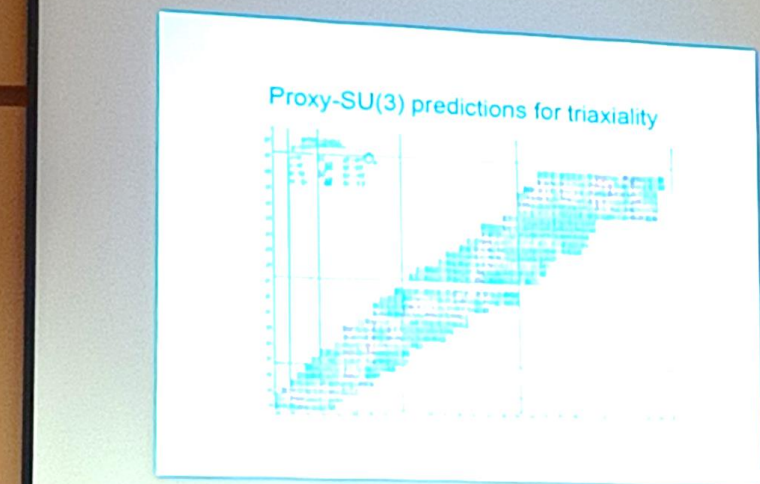
subshell structure (gaps) depend on the number of protons and neutrons present $\Rightarrow$ effective shells

e.g. for $Z = 60, N = 90$
 when $N < 90$ effective proton shell: $Z = 50 - 64$
 $\Rightarrow$ midshell at $Z = 56$
 $\Rightarrow$ as the neutron $h_{11/2}$ begins to fill

monopole p-n interaction between spin-orbit partner orbitals $h_{11/2}$ proton and $h_{11/2}$ neutron lowers the $h_{11/2}$ proton level, eliminating the $Z = 64$ gap

P. Federman and S. Pittel, Phys. Lett. B 69, 365 (1977)
 R. F. Casten, Nuclear Structure from a Simple Perspective (Oxford University Press, Oxford, 1990)
 T. Otsuka, Physics 4, 253 (2022)



Dennis Bonatsos
NCSR "Demokritos", Greece

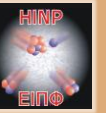


Introduction

The ground state properties of the nuclei, especially nucleon densities, are generally calculated using Skyrme and Gogny forces. The nucleon densities of Praseodymium-141 (^{141}Pr) have been calculated by using:

- Hartree-Fock-Skyrme (based Woods-Saxon Potential) (SHF-WS)
- Hartree-Fock-Skyrme (based Harmonic Oscillator Potential) (SHF-HO)
- Hartree-Fock-Bogolyubov-Skyrme (HFB-S)
- Hartree-Fock-Bogolyubov-Gogny (HFB-G)

methods. The obtained nucleon densities for ^{141}Pr have been compared with each other.

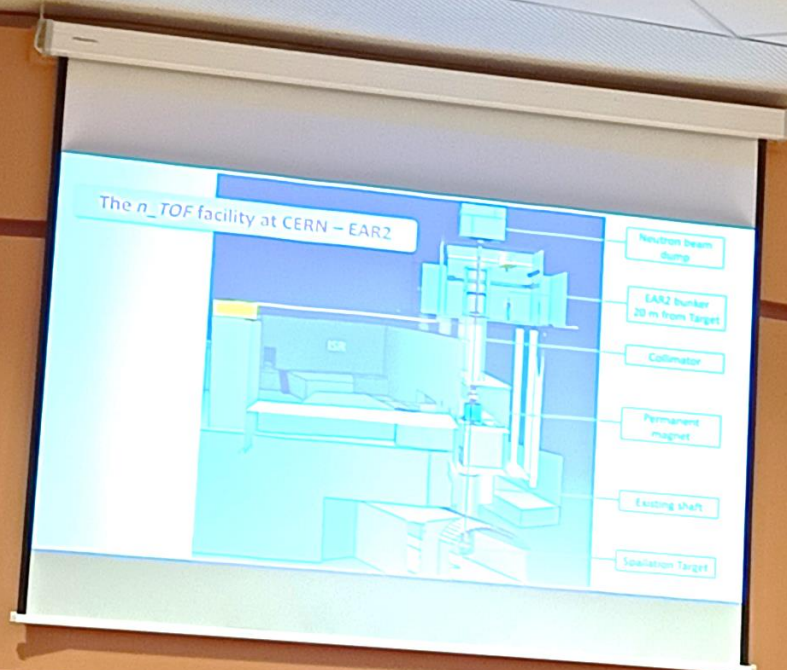


Unal Yildirim

MEB Geymen Science High School,
Turkey

Session 5

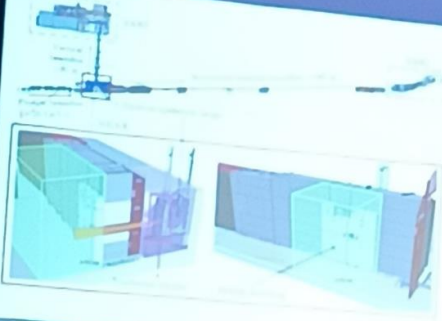
Reaction Dynamics
(II)



Agatino Musumarra
University of Catania & INFN-CT,
Italy



Motivation



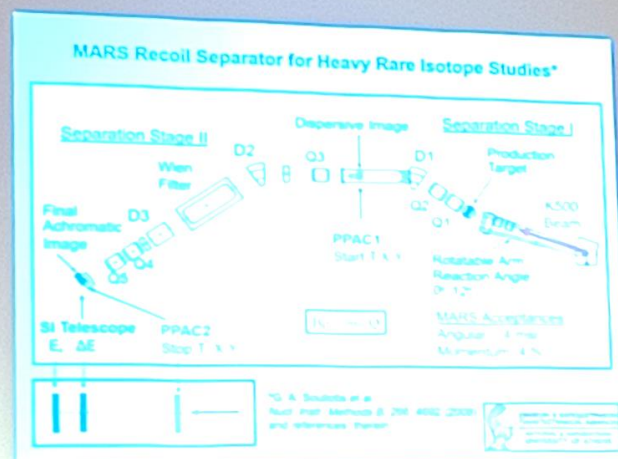
- Operational since 2002
 - New low production rate operation
 - Production of 20 GeV protons on a 10 target
- Motivation (NTAR station)**
- High neutron flux values
 - Radiation damage studies
 - Cross section measurements of astrophysical interest on the activation technique

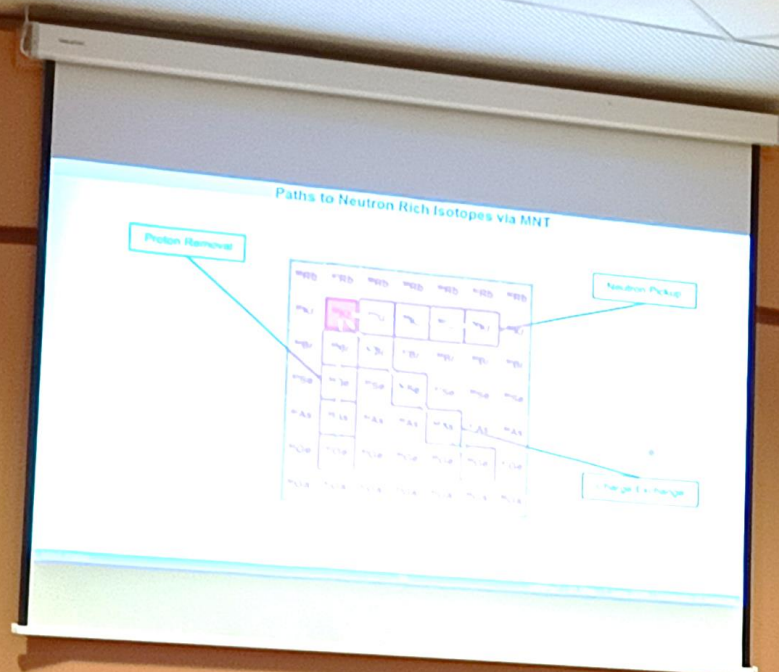
HINP-7 UDR



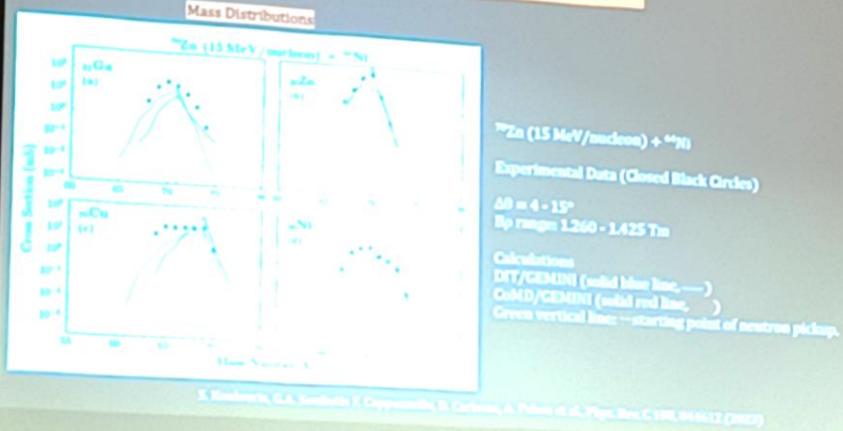
Michael Kokkoris

National Technical University of
Athens, Greece



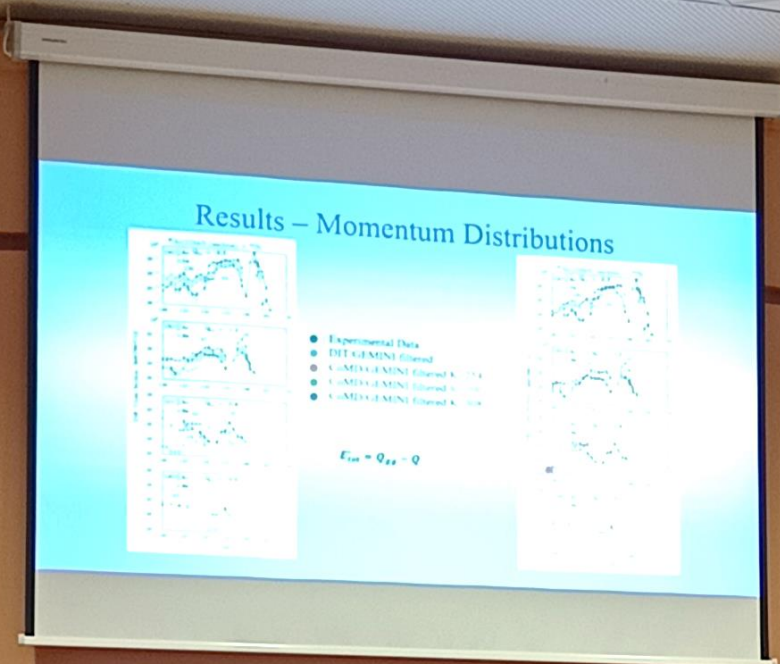


Experimental Results



Stergios Koulouris

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Probing Cluster Transfer in Peripheral Collisions of ^{40}Ar on ^{64}Ni and ^{58}Ni at 15 MeV/nucleon

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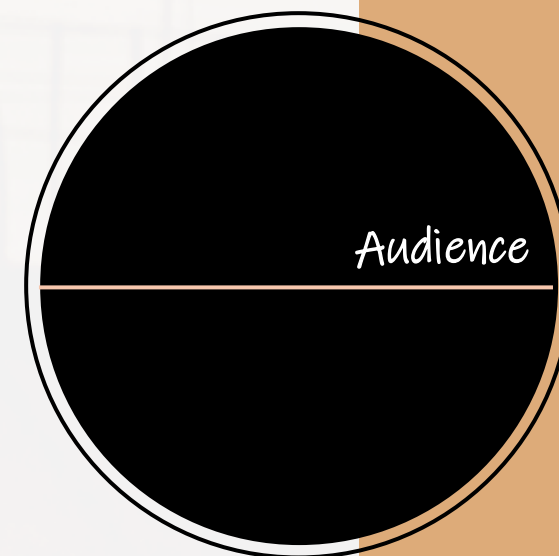
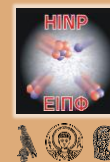
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Coffee Breaks





Trip

Ancient Theatre of Dodoni