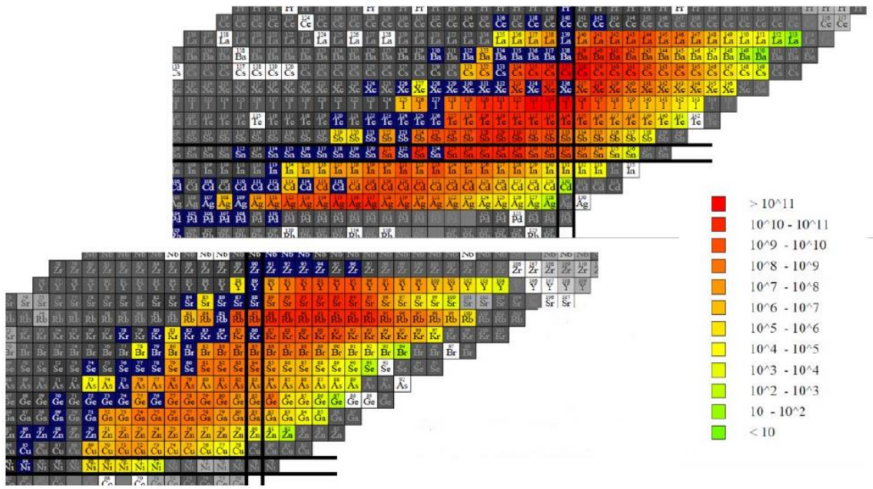
Activities of GAMMA

[1]sezione INFN - Perugia

17 Luglio 2023

Index

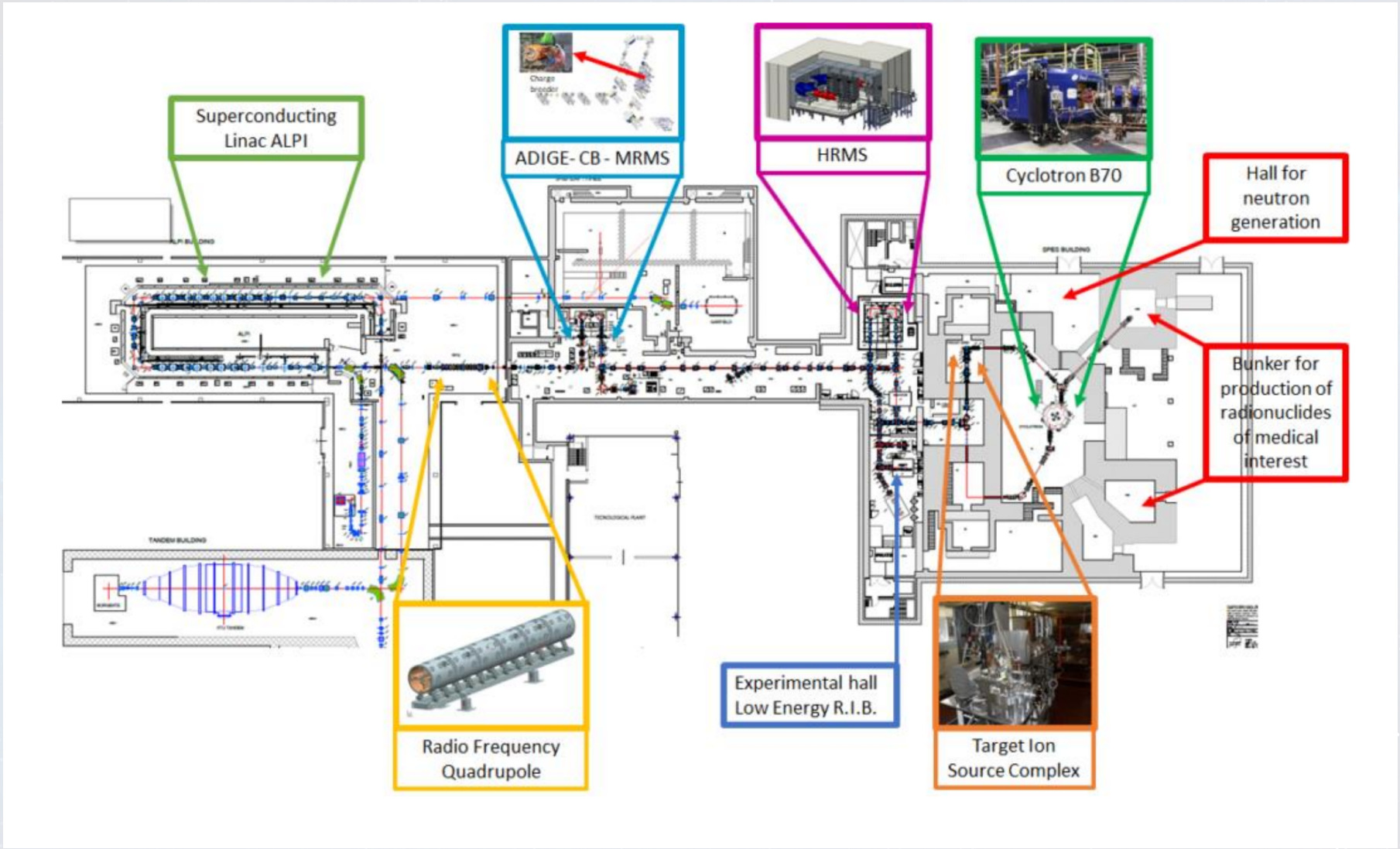
SPES physics



Ions expected to be produced

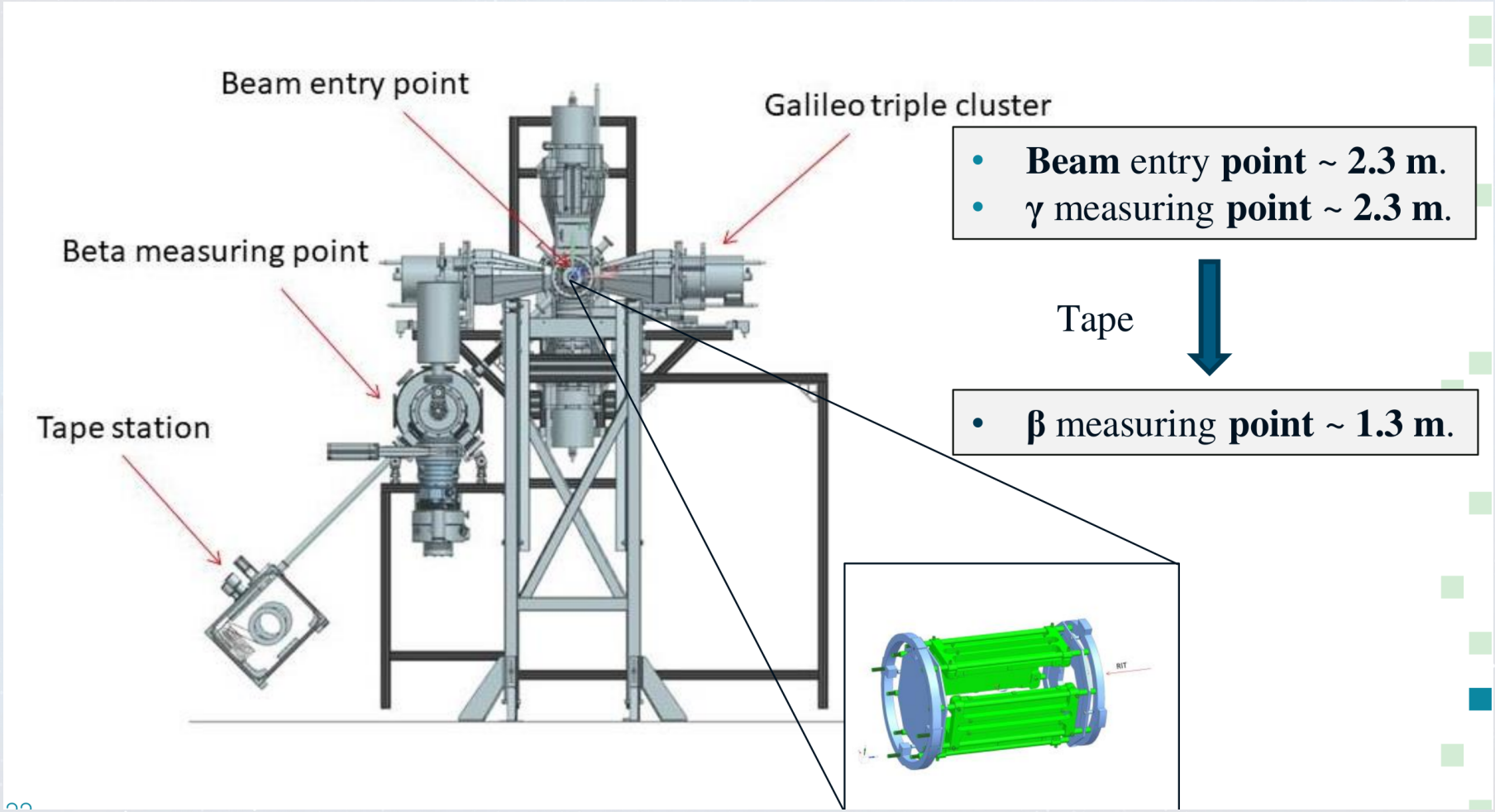
Cyclotron

SPES layout


Superconducting Linac ALPI
ADIGE- CB - MRMS
HRMS
Cyclotron B70
Hall for neutron generation
Bunker for production of radionuclides of medical interest
Experimental hall Low Energy R.I.B.
Radio Frequency Quadrupole
Target Ion Source Complex

β-decay station

The Beta decay station will be built in the 'Laboratori nazionali di Legnaro' in the next few years.



SLICE spectrometer

- SLICE=Spes Low energy Internal Conversion Electrons Spectrometer
- SLICE spectrometer consists of a large area Si(Li) detector cooled to liquid nitrogen[1][2]

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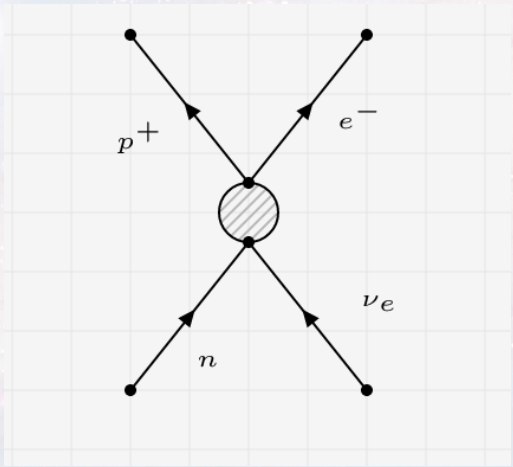
[1] Marchini, N. and Nannini, A. and Ottanelli, M. and Saltarelli, A. and Benzoni, G. and Gamba, E. R. and Goasduff, A. and Gottardo, A. and Ha, J. and Krings, T. and Perri, M. and Polettini, M. and Rocchini, M. and Sona, P. 'Electric monopole transitions and structure of low-spin states in 106Pd', Phys. Rev. C, DOI: 10.1103/PhysRevC.105.054304 (2022)

[2] *Emergence of triaxiality in ^{74}Se from electric monopole transition strengths*, N. Marchini, ... A. Saltarelli et al (in press)

Four-fermion generalized Fermi's Theory

1. Fermi's golden rule (first order perturbation theory)

$$\Gamma_{i\to f} = 2\pi \left|\langle f|V|i\rangle\right|^2 \rho_i \rho_f \delta(E_i - E_f)$$

2. Weak interaction 

treated by means the relativistic generalized Fermi theory

$$V = \int d\vec{r} \frac{G_F}{\sqrt{2}} \left[\hat{\bar{\psi}}_p(\vec{r})\gamma^\mu \left(1 - x\gamma^5\right) \hat{\psi}_n(\vec{r})\right] \left[\hat{\bar{\psi}}_e(\vec{r})\gamma_\mu \left(1 - \gamma^5\right) \hat{\psi}_\nu(\vec{r})\right] + c.c.$$

3. $x = 1.26 \pm 0.02$ e $G_F = 1.16637 \times 10^{-5} GeV^{-2}$

Independent particle approximation

1. Separation of hadronic and leptonic parts

$$\begin{aligned}\langle f|V|i\rangle &= \int d\vec{r}\frac{G_F}{\sqrt{2}}\left\langle f_{p,n}\left|\hat{\bar{\psi}}_p(\vec{r})\gamma^\mu\left(C_V+C_A\gamma^5\right)\hat{\psi}_n(\vec{r})\right|i_{p,n}\right\rangle \\ &\left[\left\langle f_e|\hat{\bar{\psi}}_e(\vec{r})|i_e\right\rangle\gamma_\mu\left(1-\gamma^5\right)\left\langle f_\nu|\hat{\psi}_\nu(\vec{r})|0_\nu\right\rangle\right]+\cdots\end{aligned}$$

   where $|i\rangle = |i_{p,n}\rangle \otimes |i_e\rangle \otimes |i_\nu\rangle$ e $|f\rangle = |f_{p,n}\rangle \otimes |f_e\rangle \otimes |f_\nu\rangle$

2. Factorization of the hadronic current

$$|i_{p,n}\rangle = |i_p\rangle \otimes |i_n\rangle$$

3. Need to calculate the wave functions of the four fermions (p^+, n, e^-, ν)

Dirac equation time-independent

1. Vectorial potential $A_\mu \equiv \left(V, -\vec{A}\right)$

$$\begin{pmatrix} mc^2 + V & c\left(\vec{p} - \frac{1}{c}\vec{A}\right)\cdot\vec{\sigma} \\ c\left(\vec{p} - \frac{1}{c}\vec{A}\right)\cdot\vec{\sigma} & -mc^2 + V \end{pmatrix} \begin{pmatrix} \psi \\ \varphi \end{pmatrix} = E \begin{pmatrix} \psi \\ \varphi \end{pmatrix}$$

2. Scalar potential W

$$\begin{pmatrix} mc^2 + W & c\vec{p}\cdot\vec{\sigma} \\ c\vec{p}\cdot\vec{\sigma} & -mc^2 - W \end{pmatrix} \begin{pmatrix} \psi \\ \varphi \end{pmatrix} = E \begin{pmatrix} \psi \\ \varphi \end{pmatrix}$$

3. Pseudoscalar potential W_P

$$\begin{pmatrix} mc^2 & c\vec{p}\cdot\vec{\sigma} + W_P \\ c\vec{p}\cdot\vec{\sigma} + W_P & -mc^2 \end{pmatrix} \begin{pmatrix} \psi \\ \varphi \end{pmatrix} = E \begin{pmatrix} \psi \\ \varphi \end{pmatrix}$$

4. Pseudovectorial potential $\left(V_P, -\vec{A}_P\right)$

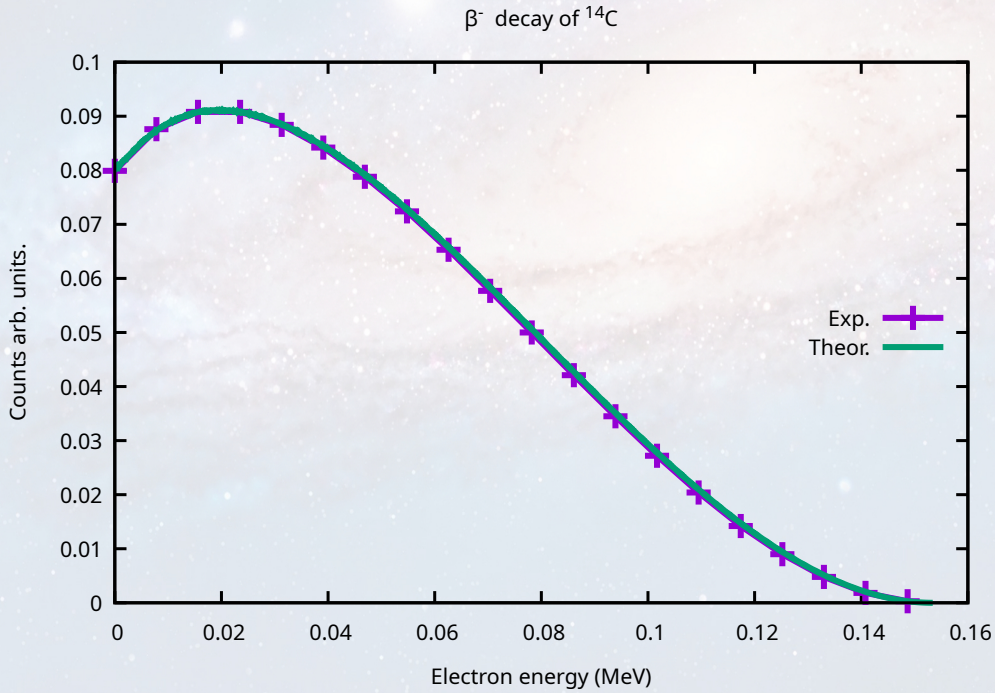
$$\begin{pmatrix} mc^2 - \vec{A}\cdot\vec{\sigma} & c\vec{p}\cdot\vec{\sigma} + V_P \\ c\vec{p}\cdot\vec{\sigma} + V_P & -mc^2 - \vec{A}\cdot\sigma \end{pmatrix} \begin{pmatrix} \psi \\ \varphi \end{pmatrix} = E \begin{pmatrix} \psi \\ \varphi \end{pmatrix}$$

Main features of this approach

1. Geometrical coupling between nucleons involved and the remaining ones
2. Mean fields calculations: Dirac-Hartree-Fock for the electrons and Wood-Saxon for the nucleons
3. The shape of the calculated spectrum reproduces experiments well in cases of low prohibition
4. but .....

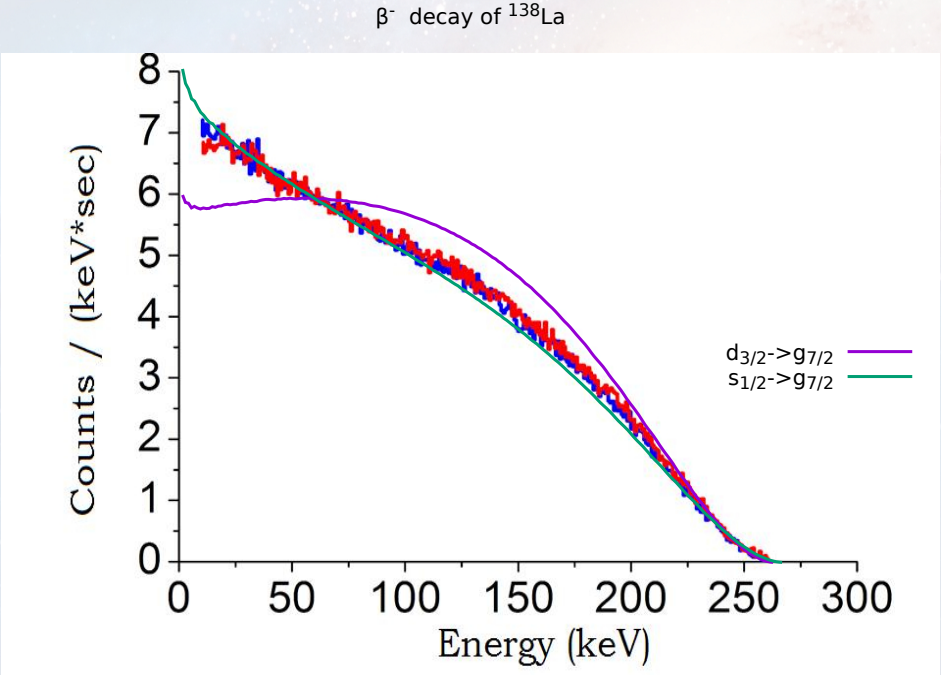
Disadvantages

1. Poor reproduction of total decay rates also for permitted transitions
2. Ex. ^{14}C



Disadvantages

1. Poor reproduction of the spectrum shape for prohibited transitions
2. Ex. ^{138}La: the discrepancy of the rate is small (25%) but the spectrum shape is incorrected



Total rate

For accurate rates:

1. Inclusion of the neutron-proton correlation (not important for the spectrum shape)
2. Inclusion of the proton-electron correlation (important for the spectrum shape)

Inclusion of the nuclear correlations

1. Configuration Interaction methods (like NuShellX): (cpu-time consuming)
2. Green-function methods: the hadronic current can be calculated from the poles of the two-particle (proton-neutron) green function

Beyond the hadronic and leptonic current factorization

1. Green-Function method: the interaction between the electron and the hadronic part can be calculated from the poles of the three-particle (neutron-proton-electron) green function
2. Fano-Feshbach continuum-discrete interaction: (cpu-time consuming)[3][4]

[3] *Elastic scattering of electrons by water: An ab initio study*, Frontiers in Materials 10, 1145261

[4] *Simulating the nanometric track-structure of carbon ion beams in liquid water at energies relevant for hadrontherapy,* Journal of Physics: Conference Series 2326 (1), 012017

Current works

1. Calculation of the nuclear correlations and the correlated proton-electron wave functions in the Tritium molecule
2. Applications to ^{10}Be, ^{85}Kr,^{93}Zr,^{60}Co, ^{192}Ir

Talks and thesis

1. *Equazione di Dirac in uno spazio-tempo curvo,* Cittadini Federico, **Bachelor's Degree**
2. *GAMMA Electron Spectroscopy with the SLICES setup,* Marchini Naomi, **PhD**
3. *Il confinamento del plasma nei reattori a fusione,* Casci Simone, **Bachelor's Degree**
4. *Novel Techniques for High Density Channels Gamma Measurements Based on SIPM* - 41st Internations Conference on High Energy Physics
5. *ASIC based techniques for high density channel y - spectroscopy* - 108° Congresso Nazionale della Società Italiana di Fisica SIF2022
6. *Novel gamma spectroscopy measurements with ASIC front-end electronics* - IEEE-Nuclear Science Symposium
7. *Electric monopole transitions and low-lying level structure in 106Pd* - 28th International Nuclear Physics Conference (INPC 2022)

Richieste e Fte

cognome	nome	struttura	contratto	profilo	Aff. Gruppo	perc
Cottone	Francesco	PG	Associato	Scientifica Ricercatori/Professori unive	3	100%
Perri	Marco	PG			3	100%
Saltarelli	Alessandro	PG	Associato	Tecnologica Ricercatori/Professori uni	3	100%
Simonucci	Stefano	PG	Associato	Scientifica Ricercatori/Professori unive	3	50%

Capitolo	Descrizione	Parziali (K-EUR)	Parziali SJ (K-EUR)
consumi	Materiale di consumo da vuoto Pfeiffer/Allectra per chiusura camere della BdS di SPES. Realizzazione linee pneumatica per apertura e chiusura valvole gate su linea di fascio. Acquisto dei PLC e HMI per il controllo in sicurezza delle stazioni di pompaggio (vedi schema allegato in fondo ai preventivi). Cavi lunghi per driver motori inerenti la movimentazione dei TDC per la BdS di SPES. Relé per l'apertura e la chiusura delle elettrovalvole.	6	
missioni	5 missioni di 5 giorni per due persone a Legnaro per montaggio e spostamento nella sala definitiva della beta-decay SPES 2 missioni a Milano per una persona, per configurazioni del setup degli scintillatori di trigger 2 missioni per riunioni nazionali per 2 persone + 2 missioni ECT per una persona per 5 giorni 4 missioni di una settimana ciascuna presso LNL nell'ambito della collaborazione PD/LNL, PG per: -produzione di rivelatori per misura di elettroni ad alta efficienza di raccolta, tramite deposizione di elettrodi innovativi. -caratterizzazione rivelatori con sorgenti di calibrazione presso i LNL	13	
inventario	Completamento linea da vuoto per la BdS di SPES	14	
trasporti	Trasporto a Legnaro di manufatti realizzati all'officina di Camerino	1	
Totale		34	