TUTORING GIFTED HIGH SCHOOL STUDENTS BY DESIGN OF EXPERIMENTAL SETUP IN NUCLEAR PHYSICS

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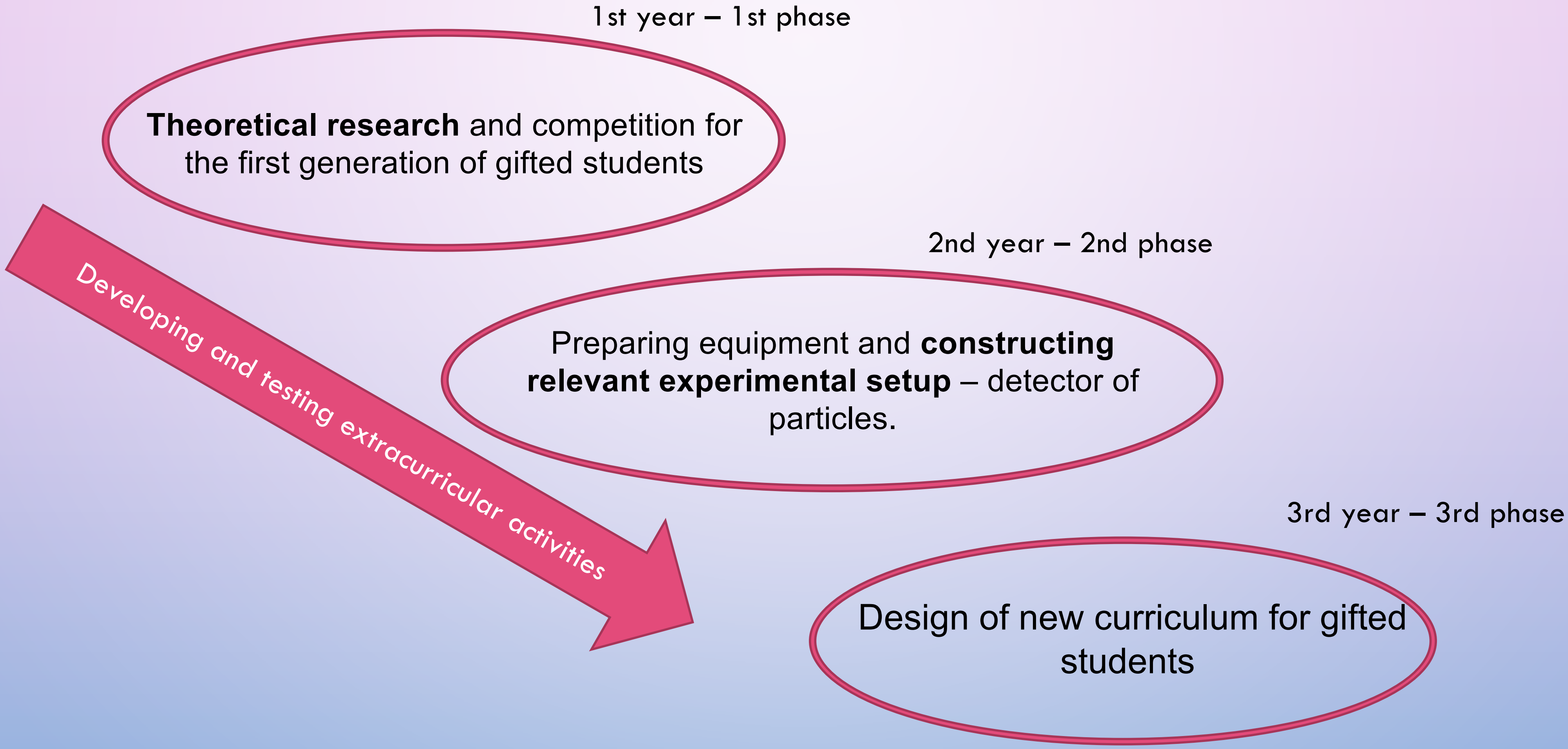
MOTIVATION

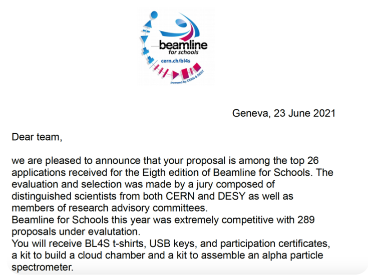
- existing educational systems and high school curricula are not able to fulfil the needs of gifted students appropriately
- many high school students are hardly able to decide about their future studies and professional orientations.
- by regular lessons in science gifted high school students often are underchallenged
- their potentials are not stimulated appropriately, which causes their loose of interests and motivation
- in order to attract gifted high school students to science and modern technology, various extracurricular challenging projects need to be systematically established

RESEARCH PHASES



THEORETICAL DESIGNING OF RESEARCH PROJECT

- 1st YEAR – 1st PHASE



Geneva, 23 June 2021

Dear team,

we are pleased to announce that your proposal is among the top 26 applications received for the Eigth edition of Beamline for Schools. The evaluation and selection was made by a jury composed of distinguished scientists from both CERN and DESY as well as members of research advisory committees.
Beamline for Schools this year was extremely competitive with 289 proposals under evalutation.
You will receive BL4S t-shirts, USB keys, and participation certificates, a kit to build a cloud chamber and a kit to assemble an alpha particle spectrometer.

BL4S 2021 short-list

This year 26 teams have been selected to be part of the shortlist. Out of them, two teams will be invited to DESY in September to perform their experiments and the others will receive special prizes including a kit to build a do-it-yourself particle detector.

Team name	Country
Academia de Ciencias SIMES Internacional - Graphene Detector	Chile
Astronaut Protection Gang	Switzerland
Cancer Stop	Argentina, Japan & Mexico
Copernican Particles	Italy
Cougar Colliders	Canada
Ecstatic Paradox	Nepal
Electron Catfish	Germany
Gamma Bears	Turkey
Last Beam Benders	Turkey
mr.beam	Turkey
PatoParticles	Poland
Quantumplaters	United States
RCTR-Caeruleum	Bangladesh
SCI-PHY	Portugal
Silly Scintillators	Netherlands
Split Tachyons	Croatia

CERTIFICATE

Beamline for Schools competition

This is to certify that

Nela Dželalija

with the team Split Tachyons representing Croatia

submitted one of the best 26 experimental proposals of the eighth edition of Beamline for Schools. The selection was based on the merit of the scientific work and made by a jury of scientists and members of research advisory committees from CERN and DESY.

Geneva, June 2021

Fabiola Gianotti, CERN Director-General
Helmut Dosch, Chairman of the DESY Board of Directors
Philip Burrows, University of Oxford, Chair of the DESY Physics Research Committee (PRC)
Jordan Nash, Chair, SPSC

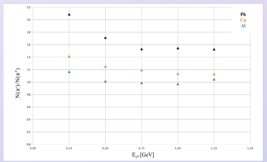
Marin Grković, Jure Jerčić, Lovre Jeličić, Bruno Rogulj, Antonio Šulenta, Nina Vuković

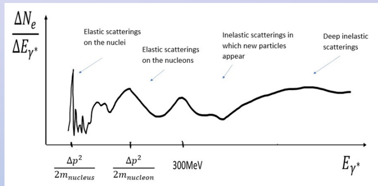
III. GIMNAZIJA, Split, Croatia
Travanj 9, 2021

Mentor: Nela Dželalija

"Beamline for Schools" je natjecanje za srednjoškolce iz područja fizike čestica koje svake godine počevši od 2014. oragnizira CERN u suradnji s DESY-jem. U natjecanju je ove godine sudjelovalo ukupno 289 timova iz 57 zemalja. Svaki tim treba osmisliti vlasititi eksperiment te ga predati do određenog roka. Osim eksperimenta, timovi trebaju napraviti i video u trajanju od jedne minute u kojem na zanimljiv način prikazuju svoj eksperiment. Radove ocjenjuju priznati fizičari iz DESY-ja i CERN-a. Ove godine je bilo izdvojeno 26 timova, među kojima je bio i naš tim "Split Tachyons". Izdvojeni timovi također dobivaju majice, USB-ove te set za izgradnju maglene komore i set za sklapanje spektrometra alfa čestice.

Tijekom rada na BL4S projektu veliku važnost imala je komunikacija sa CERN-om, DESY-em i PMF-om u Splitu. Bili smo u izravnoj komunikaciji s Markusom Joosom, inženjerom fizike koji nam je pomogao bolje razumjeti i usmjeriti naše ideje oko projekta. Što se tiče domaće pomoći, bili smo u suradnji sa voditeljem komponente obrazovanja Centrom izvrsnosti za znanost i tehnologiju Sveučilišta u Splitu. Za vrijeme trajanja pripreme projekata organizirane su videokonferencije na kojima su predavanja držali cijenjeni fizičari te smo sudjelovali na njima kako bismo produbili svoje znanje o fizici elementarnih čestica. Sva predavanja pomogla su nam u boljem razumijevanju problematike kojom smo se bavili.

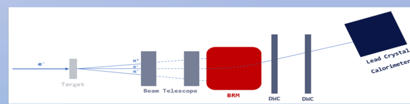




Tema našeg rada bila je određivanje udarnog presjeka elektrona i jezgre kao funkciju prijenosa energije. Željeli smo dobiti podatke potrebne za određivanje udarnog presjeka elektronskog raspršenja pri sudaru s jezgrom kao funkciju prijenosa energije i količine gibanja. Zbog različitih omjera up i down kvarkova i omjera neutrona i protona, odabrali smo bakar, srebro, olovo i jednu leguru kao mete sudara. Udarni je presjek veličina koja odgovara vjerojatnosti događanja sudara između čestica (sudara između elektrona i različitih meta u našem slučaju). Analiziranjem udarnih presjeka očekivali smo prepoznati različite vrste sudara koje smo prepoznali po kriterijima zakona očuvanja energije i količine gibanja

Radi kvalitetnijeg razumijevanja teorijske podloge rada, računalno smo simulirali različite sudare elektrona i pozitrona s različitim metama koristeći GiBUU koji generira tražene simulacije te pruža dinamičan opis reakcija i konačna stanja događaja. Simulacijama u GiBUU-u jednostavno smo primijetili povezanost omjera piona i prijenosa energije elektrona. S obzirom na to, zaključili smo da je pri nižim energijama omjer piona više povezan sa omjerom neutrona i protona mete, dok je pri višim energijama prijenosa omjer piona više povezan sa omjerom up i down kvarkova.

Kako bismo potvrdili hipotezu, bilo je potrebno osmisliti eksperimentalni postav



Cilj našeg videa bio je jednostavniji prikaz našeg rada i ciljeva. Kako bismo povezali radno i rekreacijsko okruženje, kao lokacije snimanja izabrali smo školsku ustanovu i morsku obalu. Željeli smo da video prikaže platformu GiBUU koju koristimo za istraživanje, ali i da na sportski način simbolički približi gledateljima viziju našeg projekta. Dodavanjem lopticom koja je ujedno i simbol sporta vezanog za naš grad Split, imitirali smo udarac elektrona u metu, njegov prolazak kroz Beam telescope, Big red magnet i DWC. Kratkim i šarolikim animacijama prikazali smo razmjenu kvarkova prilikom raspršenja elektrona. Kako bi pokazali ljepotu i tradiciju našeg kraja, naposljetku smo imitirajući pecanje te upad u kalorimetar prikazali posljednju fazu puta našeg elektrona.

https://www.youtube.com/watch?v=Yss5w-7vy7A

EXPERIMENTAL DESIGNING OF RESEARCH PROJECT

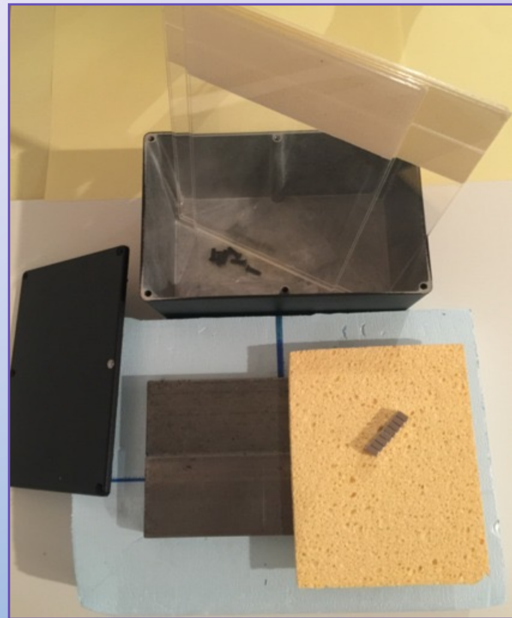
- 2nd YEAR – 2nd PHASE

- nuclear physics is a relevant topic for analysis of natural processes in the environment, and thus it can be very attractive research topic for gifted high school students
- collaboration with academic staff at universities and research institutes, which brings additional potentials for students
- the experimental setup has been designed, as a low-cost spectrometer on information technology platform to measure ionising radiation in the environment, such as alpha- and beta-particles of various energies.

Two types of experimental setups have been organised as student research projects:

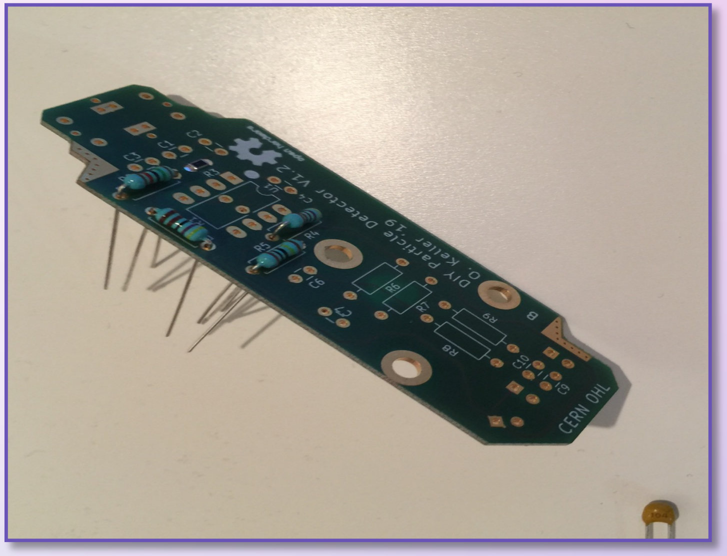
- a low-cost spectrometer based on information technology platform that measures ionising radiation in the environment (such as alpha- and beta-particles).

- experimental setup consists of simple mechanical materials



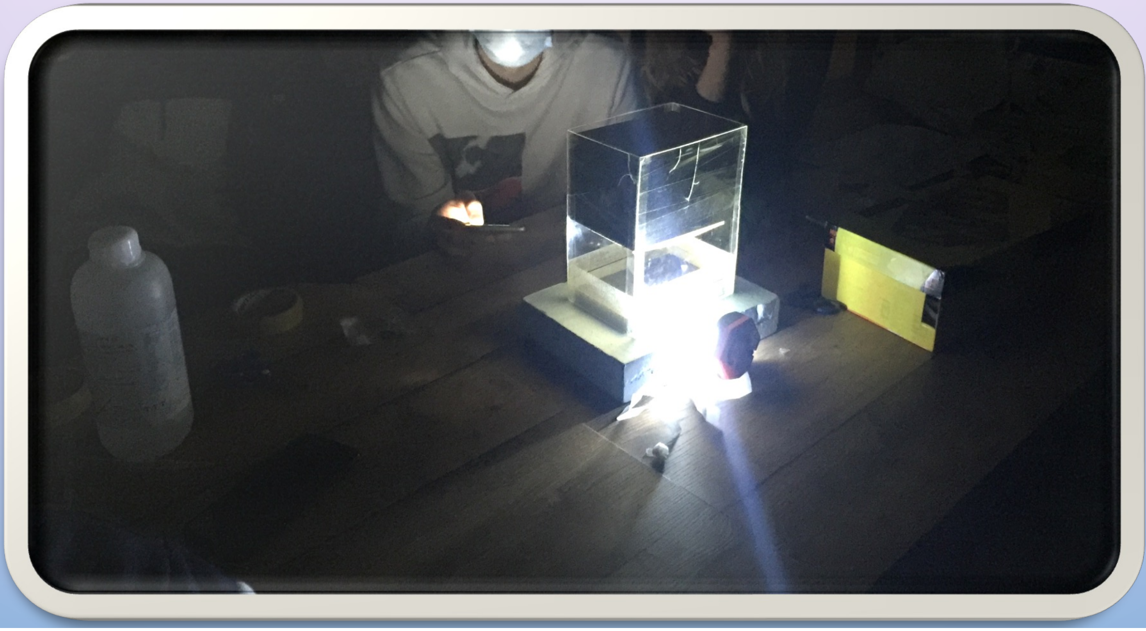
Student activities

- **build and use** the above presented **particle detector**
- **measure** some of their properties (energy, momentum, etc.) by using relatively simple, but technologically relevant equipment
- **select relevant literature and guidelines**, to assemble given particle spectrometer and cloud chamber (Manual for optional teaching in physics and relevant research papers in nuclear physics for education purposes)



Student activities

- **discuss** student observations with peers and experts
- **study** some of particle properties, particle tracks
- **research** using similar principles, with different simple techniques for particle detectors
- **present** project research reports



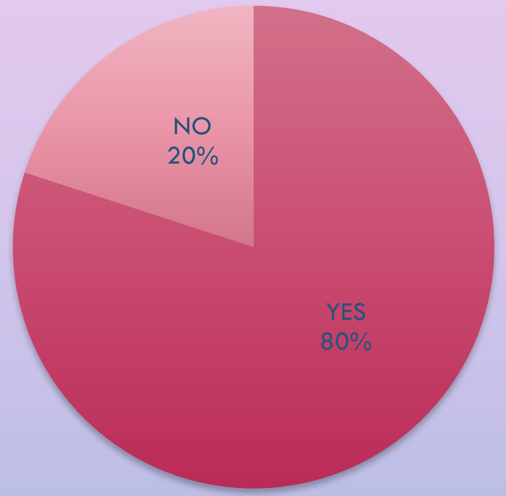
The interests of students for further work with the available particle detectors are as follows:

- impact of ionised radiation to the environment
- energy distribution of radiated particles
- second radiation of a substance that has been exposed to primary radiation

- only 20 % of students were not able to express their further scientific interests related to experiments

Student achievements have been assessed by using a set of questions:

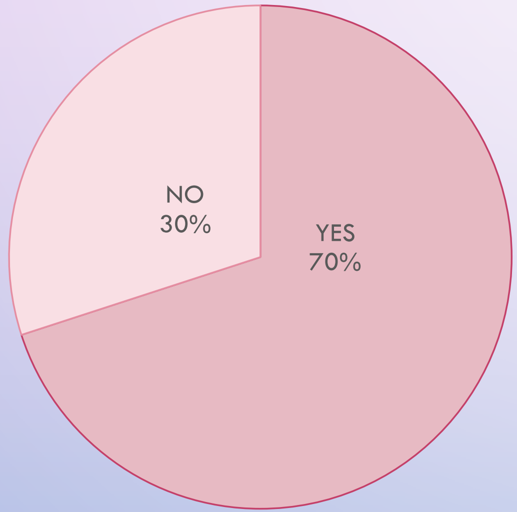
1. Are you motivated for activities with attractive experimental set?



The key factor for success of extracurricular research activities is the individual autonomous and responsible teamwork by using relevant and attractive experimental devices.

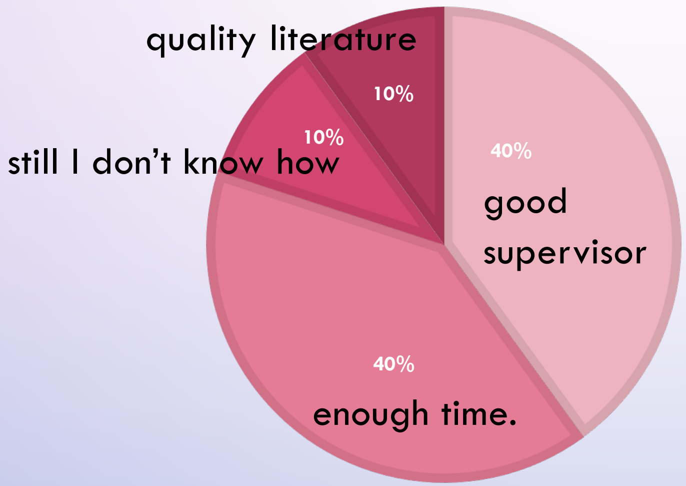
Student achievements have been assessed by using a set of questions:

2. Are you able to work autonomously by using relevant literature ?



Student achievements have been assessed by using a set of questions:

3. Which of the following do you consider crucial for research in the field of nuclear physics?



The universities should develop trainings for teachers working with gifted students, which should support the independence, motivation and creativity of students.

Assessment of Achieved Learning Outcomes

- 1st YEAR – 1st PHASE

- Describe basic characteristics of elementary particles
- Describe and applies concepts of special relativity theory
- Explain the trajectory of a charged particle in a magnetic field
- Apply concepts of the wave nature of the particles, laws of energy and momenta conservations
- Install and use the computer simulation packages in order to determine quantities that require complex mathematical calculations
- Adapt and apply information technologies, preparation of presentations and videos
- Responsibly perform accepted tasks in the project
- Successfully collaborate, communicate with other members during teamwork
- Successfully self-organise and participate in the organisation of teamwork
- Successfully communicate with researchers from universities and research institutes in foreign language

Assessment of Achieved Learning Outcomes

- 2nd YEAR – 2nd PHASE

- Describe basic characteristics of nuclear particles
- Achieve practical experimental skills such as soldering, connecting and distinguishing resistors, diodes, capacitors and similar electronic components
- Assemble an experimental set
- Install and use of relevant software
- Sort of electronic elements
- Describe principles of operation of the detector
- Describe ways for graphical representation
- Successfully communicate with researchers from universities and research institutes

CONCLUSION

3rd year – 3rd phase

The extracurricular activities with gifted students show that the acceleration and enrichment of gifted students requires the **cooperation of schools with universities and research groups**.

The experiences and the feedback from students show that the **trainings at universities should include**:

- the relevant scientific background of individual experiments including possible problems and questions of students
- possible combination of different experiments and technologies
- special equipment for making an experimental set, CNC machine, various tools
- the didactical background to accelerate experiments, making them feasible and interesting for gifted students.

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