



# Hrvatska na CERN-u od 1954. do danas



CERN Info Dan, 4. prosinca 2024, PMF Zagreb  
*Vuko Brigljević, Institut Ruđer Bošković, Zagreb*



# Na samom početku CERN-a



CERN/Founders



Switzerland



France



Germany



Italy



United Kingdom



Sweden



Netherlands



Greece



Norway



Denmark

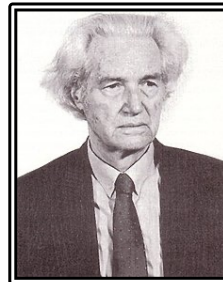


Belgium

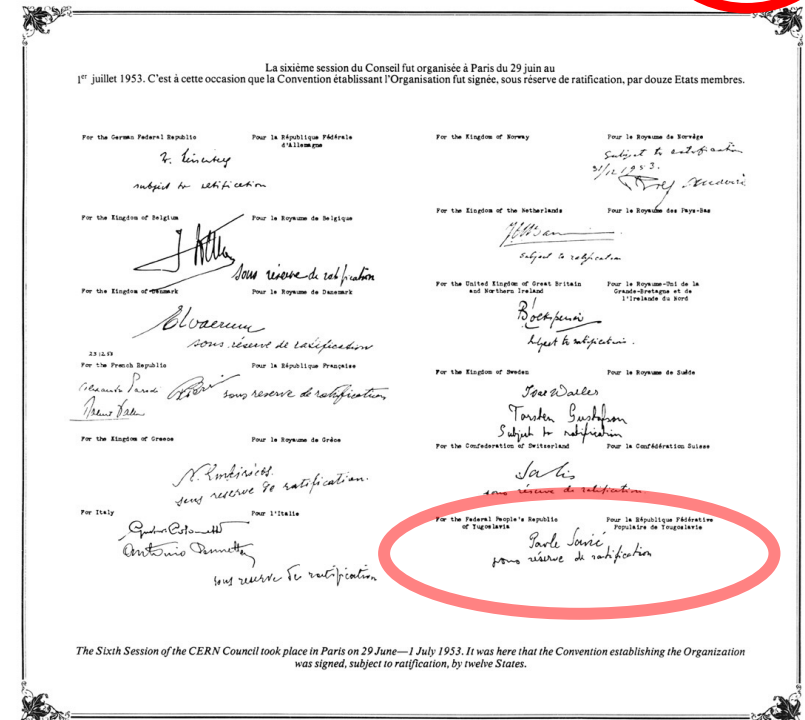


Yugoslavia

- Bivša država jedna je od zemalja osnivača CERN-a
- Predstavnik u vijeću CERN-a: Ivan Supek
- Jugoslavija izlazi iz CERN-a 1961



I. Supek





# U ranim godinama: prvi CERN-ov akcelerator

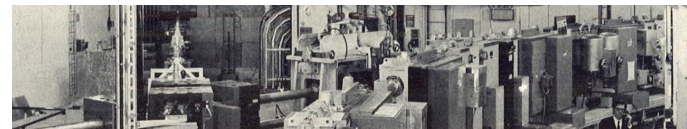
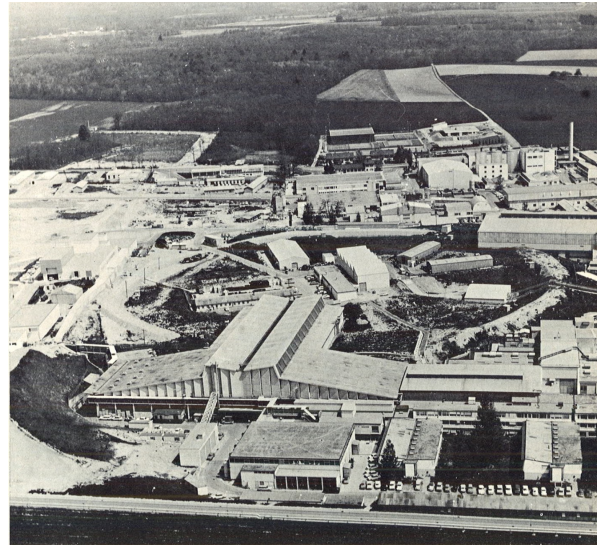


CAHIER TECHNIQUE  
No 2

Le synchrotron à protons  
de 25 GeV

Philips, Pays Bas  
Rade Koncar, Yougoslavie

Document CERN/PIO 75-4 publié par le Service d'information du public  
Juin 1975



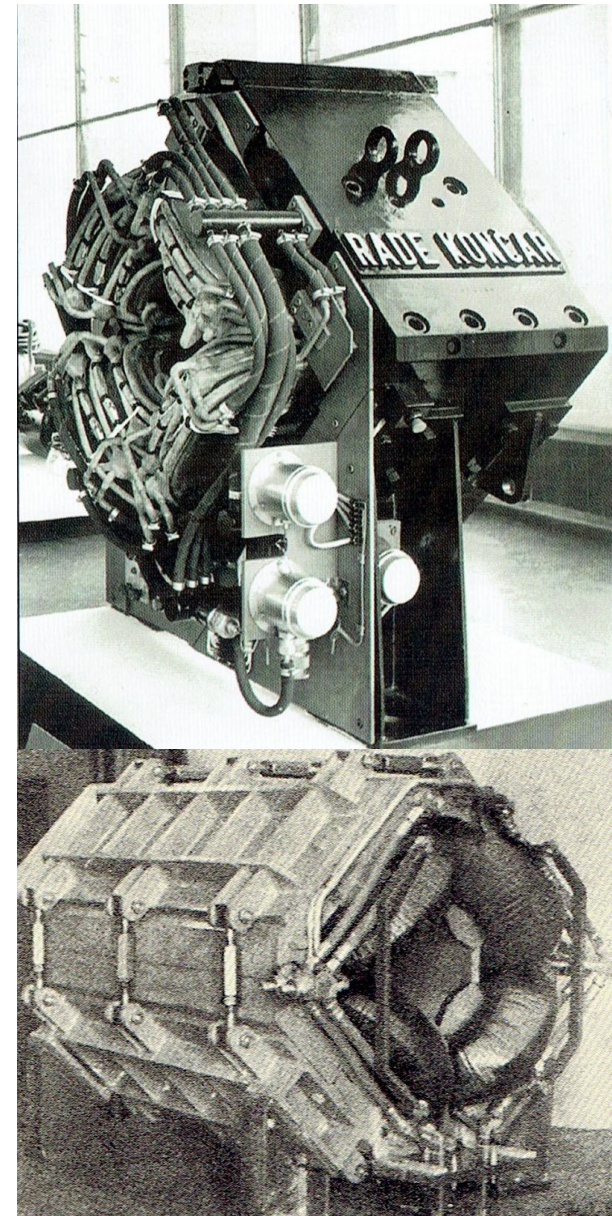
## Popis dobavljača Principaux fournisseurs

ACEC, Ateliers de Constructions Electriques de Charleroi, Belgique	Bobines et barres omnibus, enroulements potiers, lentilles septoplastes et octoplastes
Acieries d'Elgin, France	Acier inoxydable pour l'enceinte à vide du CPS
Alfa Level, Suède	Echangeur de chaleur du PSB
Alpi, Autriche	Banc de transformateurs
Anitron, France	Aliments de déflection du PSB
Aluminium Chipis, Suisse	Aluminium pour bobines du CPS et barres omnibus
A.M.S., Constructions Electriques, France	Installations électriques
Ansaldo San Giorgio, Italie	Blocs d'aliments du CPS, convertisseurs méthydes pour lentilles
Arca, Royaume-Uni	Joint d'étanchéité
Brown, Boveri & Cie, Suisse	Quadrupoles du PSB
Brown, Boveri & Cie, Allemagne	Alimentation de l'aliment principal, enroulements polaires de correction
Brown, Boveri & Cie, Suisse	Régulation Scherbus et convertisseurs de puissance
Brown, Boveri & Cie, Suisse	Câbles haute tension
Câbles de Lyon, France	Tuyauterie pour refroidissement
Curval, Millet & Cie, France	Electrodes de mesure du faisceau PSB
Desmarquest, France	Ordinateurs de contrôle
Digital Equipment Corporation, USA	Installations électriques
Düfmann, Allemagne	Quadrupoles pour PSB
Elektrotechnische Industrie, Allemagne	Installations pour cavités HF et aimants de déflection
English Electric Valve Co, Royaume-Uni	Tubes et accessoires pour cavités HF et aimants de déflection
Felten und Guillaume, Allemagne	Câbles haute tension
Gatley Jean (Usine), Suisse	Enceinte à vide du CPS
Gandini, Vandini, Guffanti, Italie	Géné civil
General Mill, USA et Royaume-Uni	Télémanipulateur
Gärtelbau-Anstalt Baltzer, Liechtenstein	Groupe de pompage
Hechly, Suisse	Alimentation Crocker-Walton de 600 kV pour préaccélérateur
IBM, USA	Ordinateurs de contrôle
ILAC, USA	Ordinateurs de contrôle
Indiana General, USA	Ferrite pour aimants de déflection rapide
Indur, Suisse	Blocs de blindage en béton
Lucchini, France	Tuyauterie pour refroidissement
Lenn, Suisse	Connecteurs haute tension
Leybold, Allemagne	Electrodes à vide
Linott, Grande-Bretagne	Aliments auxiliaires
Magnet-Marilli, Italie	Unités accélératrices HF
Metallschmelzfabrik Luzern, Suisse	Diaphragmes et enceintes spéciales ondules
Metropolitan Vickers, Royaume-Uni	Structure HF et système à vide du linac
Mitsubishi, Allemagne	Alimentations électriques
Moser-Gleaser, Suisse	Transformateurs
Norton, France	Tuyauterie d'eau déminéralisée pour PSB
Orlikon, Suisse	Diploles
Pfeiffer, Allemagne	Pompes turbomoléculaires
Plüsch, Zvezdarski	Ferrite pour aimants de déflection rapide et cavités HF
Rade Koncar, Yougoslavie	Lentilles et alimentations
	Source: CERN/PIO 75-4



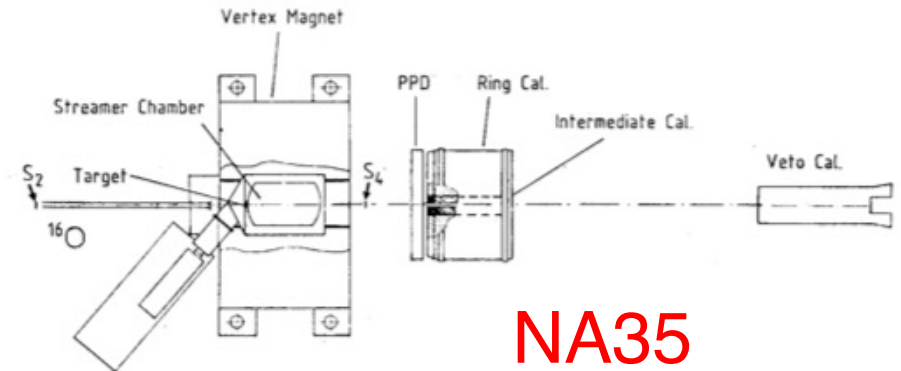
## Končarevi magneti na CERN-u

- Od 1960. do 1964. Končar isporučuje CERN-u 96 magneta ukupne težine 352 tone
- Prve magnetske leće te vrste u Europi
- Narudžbe i suradnja nažalost prestaju nakon izlaska Jugoslavije



# Prve suradnje u eksperimentima: NA35

- Prva hrvatska grupa u CERN-ovim eksperimentima:
  - 1985 grupa s IRB-a u NA35 eksperimentu **D. Vranić**, **K. Kadija**, **G. Paić**, **D. Ferenc**
  - RD26 Project: RICH Detector Development
- Gradi na bogatom iskustvu rada iz subatomske fizike na domaćem ciklotronu
- Postavlja temelj za sljedeće suradnje: NA44, NA49, ...

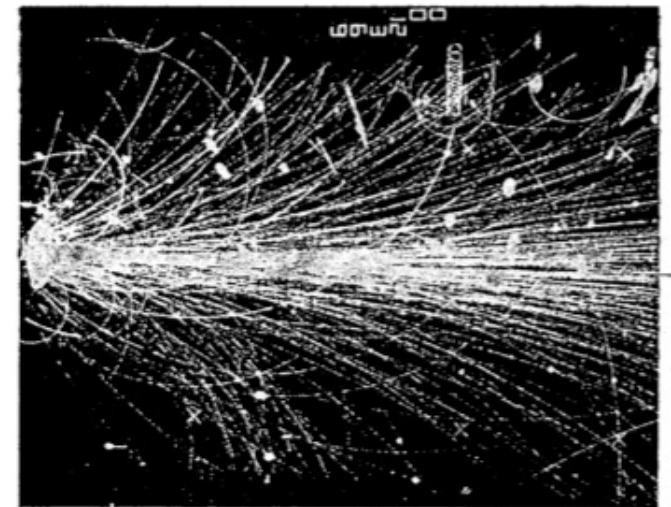


**NA35**

Fig. 1. The NA35 experimental set-up



*D. Vranić*





# 1990-2000 Suradnja raste



- 1989: ugovor o suradnji CERN-IRB
- 1991: ugovor o suradnji RH-CERN
- Broj ljudi i grupa sporo, ali kontinuirano raste:
  - grupe iz Splita i IRB-a počinju raditi na CMS i ALICE eksperimentima za budući LHC.
  - Neutrinski eksperimenti: NOMAD, OPERA
  - Potraga za aksionima: CAST





# Hrvatska na CERN-u danas





# Hrvatska na CERN-u u 21. stoljeću: projekti u kojima sudjelujemo



R&D  
projekti

RD50

RD51

RD53

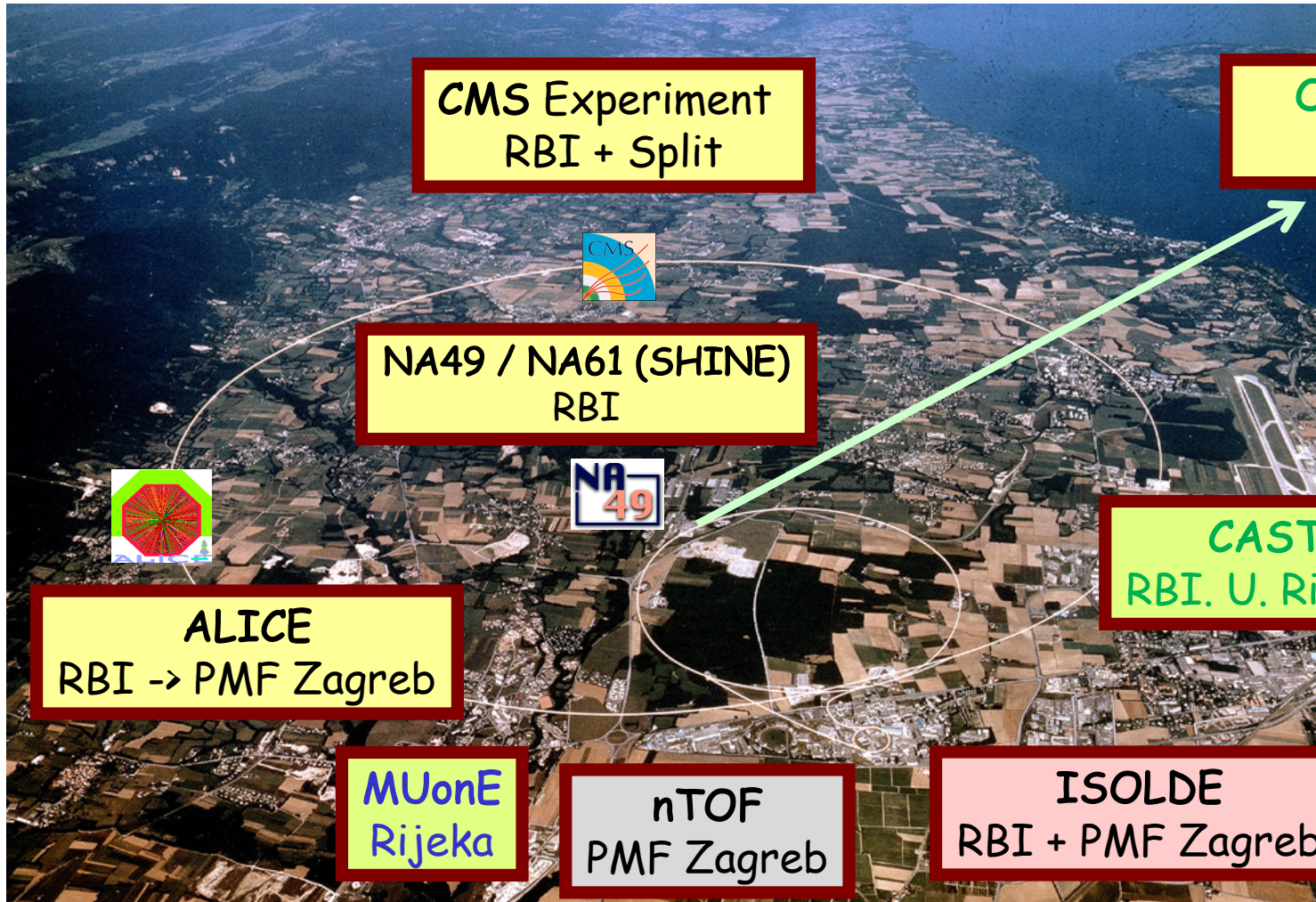
DRD1

DRD3

AIDA2020

AIDAINova

EURO-LABS



OPERA  
RBI

aktivni  
završeni  
budući

CAST  
RBI. U. Rijeka

CMS Experiment  
RBI + Split

NA49 / NA61 (SHINE)  
RBI

ALICE  
RBI -> PMF Zagreb

MUonE  
Rijeka

nTOF  
PMF Zagreb

ISOLDE  
RBI + PMF Zagreb





## Na kojim temama rade hrvatski fizičari na CERN-u



Kvarkovsko  
-gluonska  
plazma

Potruga za  
sunčevim  
aksionima

Struktura &  
dinamika teških  
jezgara

Higgsov bozon

Potruga za  
fizikom van  
Standardnog  
modela

Neutrinske  
oscilacije

Hadronske  
interakcije

Itđ. itđ.



# Uloga hrvatskih znanstvenika u rezultatima CERN-a: Aksioni



ARTICLES  
PUBLISHED ONLINE: 1 MAY 2017 | DOI: 10.1038/NPHYS4109

nature physics  
OPEN

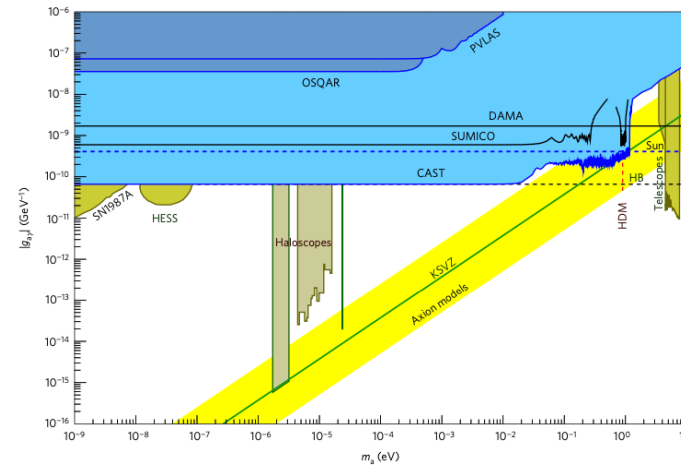
## New CAST limit on the axion-photon interaction

CAST Collaboration<sup>†</sup>

Hypothetical low-mass particles, such as axions, provide a compelling explanation for the dark matter in the universe. Such particles are expected to emerge abundantly from the hot interior of stars. To test this prediction, the CERN Axion Solar Telescope (CAST) uses a 9 T refurbished Large Hadron Collider test magnet directed towards the Sun. In the strong magnetic field, solar axions can be converted to X-ray photons which can be recorded by X-ray detectors. In the 2013–2015 run, thanks to low-background detectors and a new X-ray telescope, the signal-to-noise ratio was increased by about a factor of three. Here, we report the best limit on the axion-photon coupling strength ( $0.66 \times 10^{-10} \text{ GeV}^{-1}$  at 95% confidence level) set by CAST, which now reaches similar levels to the most restrictive astrophysical bounds.

Advancing the low-energy frontier is a key endeavour in the worldwide quest for particle physics beyond the standard model and in the effort to identify dark matter<sup>1,2</sup>. Nearly massless pseudoscalar bosons, often generically called axions, are particularly promising because they appear in many extensions of the standard model. They can be dark matter in the form of classical field oscillations that were excited in the early universe, notably by the re-alignment mechanism<sup>3</sup>. One particularly well motivated case is the quantum chromodynamics (QCD) axion, where  $q = m^2/2E$  is the  $a\text{-}\gamma$  momentum transfer in vacuum.

previous CAST results. The low-mass part  $m_a \lesssim 0.02 \text{ eV}$  corresponds to the first phase 2003–2004 using evacuated magnet bores<sup>11,12</sup>. The  $a \rightarrow \gamma$  conversion probability in a homogeneous  $B$  field over a distance  $L$  is

$$P_{a \rightarrow \gamma} = \left( g_{a\gamma} B \frac{\sin(qL/2)}{q} \right)^2 \quad (1)$$


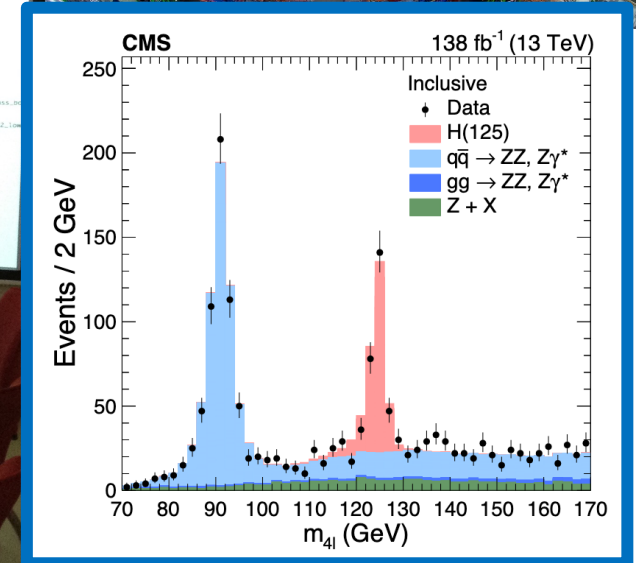
Među glavnim autorima  
naša draga kolegica

**Biljana Lakić (1971-2020)**



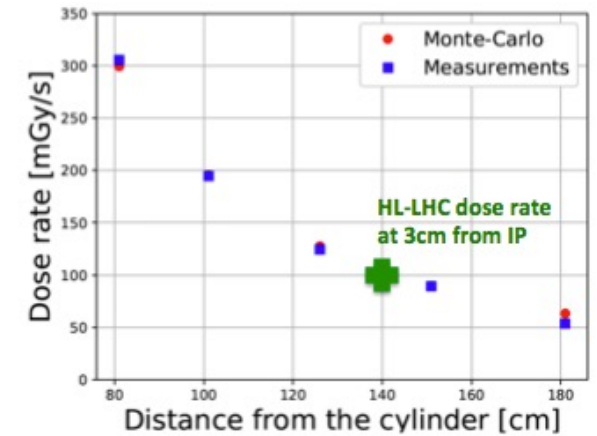
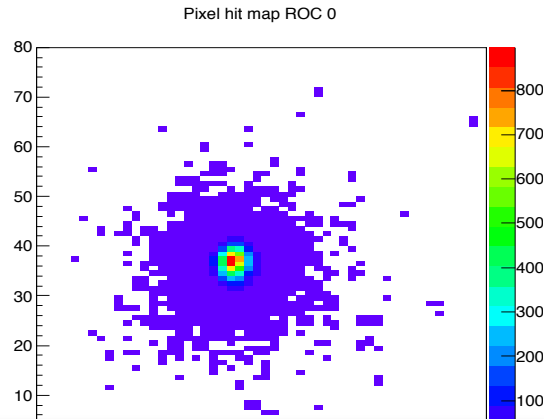


# Hrvatska u otkriću Higgsovog bozona



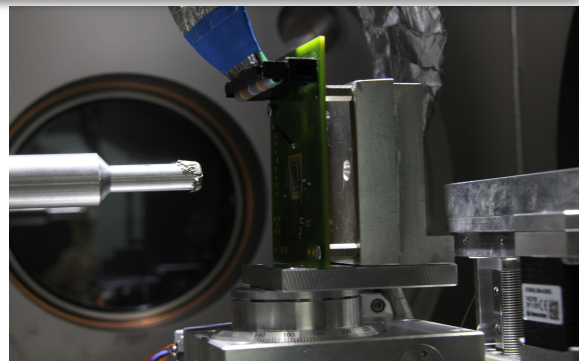


# Razvoj i testiranje detektora



CMS pixel detector measurements at RBI accelerator microprobe station

Detector long term irradiation at local Co60 source

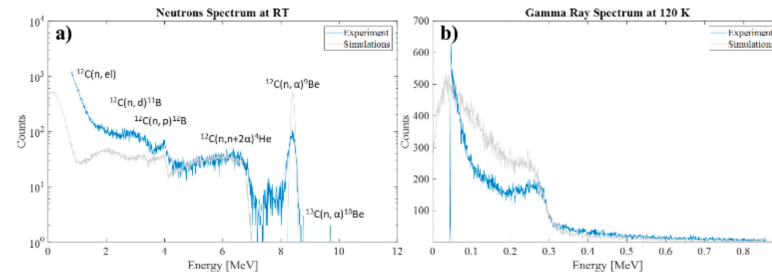


# Razvoj i testiranje detektora

## Study of Diamond detectors at cryogenic temperatures

# DRD3

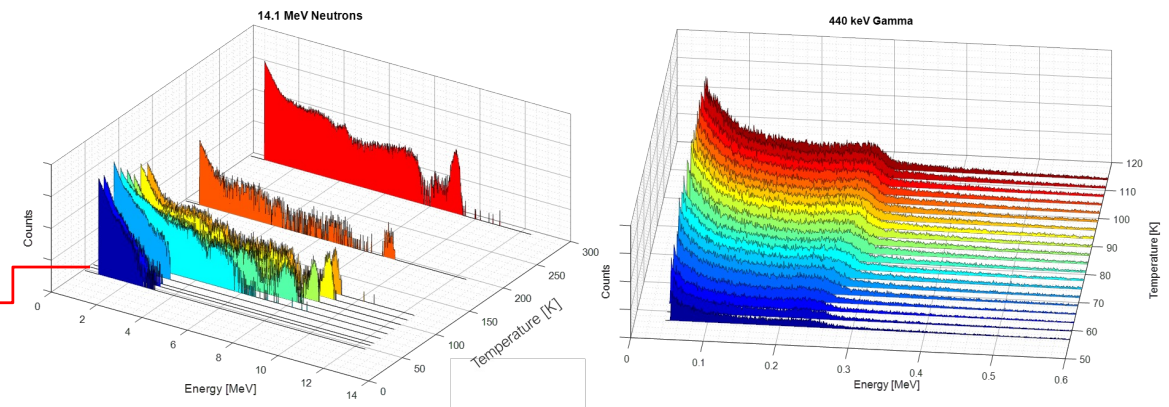
Using the 300 um thick detector, measurements were carried out in neutron and gamma ray fields.



Room temperature pulse height spectra

Predstavljeno ovaj tjedan na DRD3 sastanku na CERN-u

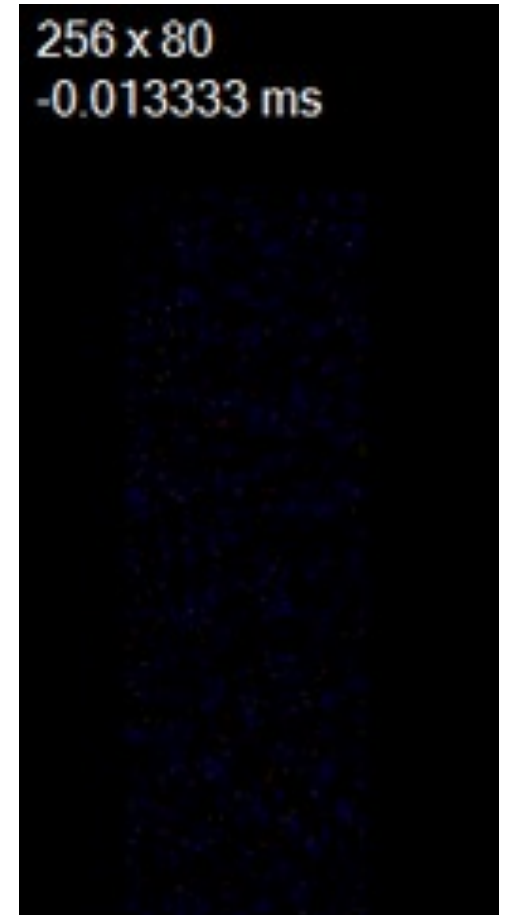
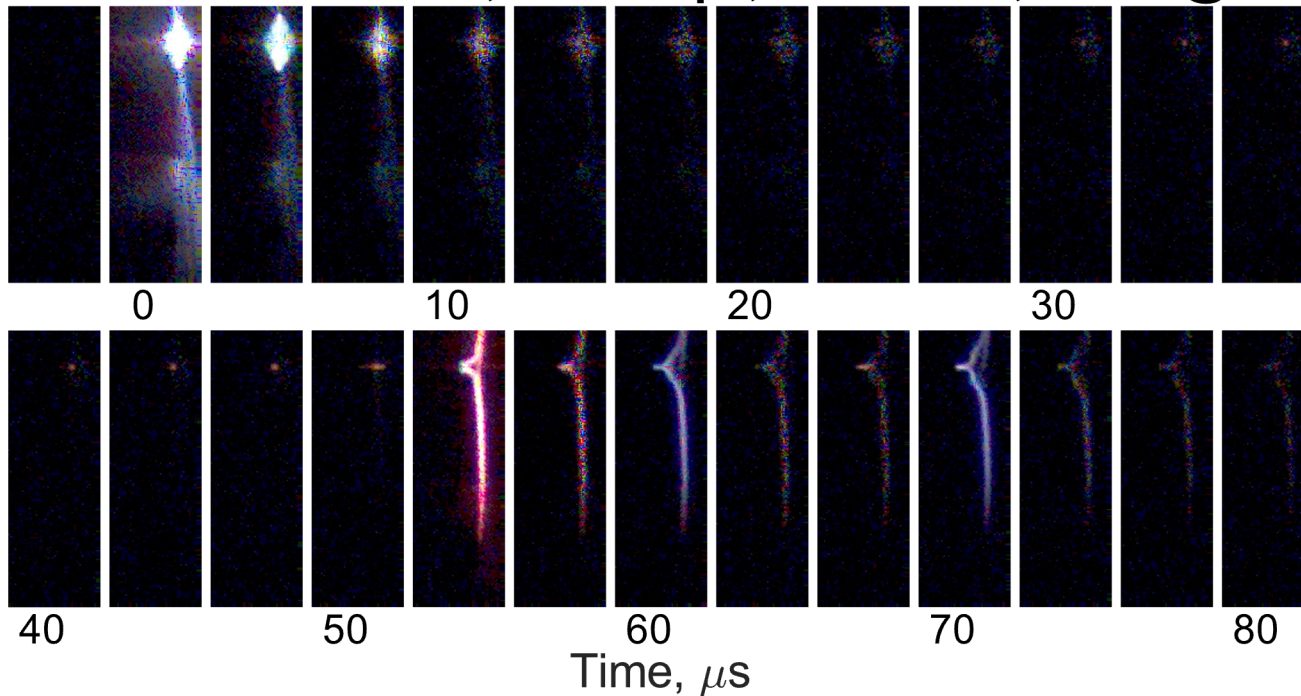
Drastic degradation of detectors signal on neutrons below 120 K !



## Prvi ikad snimljeni proboj u GEM detektoru

GEM @  $E_{ind} = 5.66$  kv/cm,  $\Delta V_{GEM} = 500$  V,  $R_{dec} = 0$  k $\Omega$

PHOTRON SA-X2: 80x256, 300000 fps, S:1/583784, A:F2.8@100 mm





# Teorijska fizika

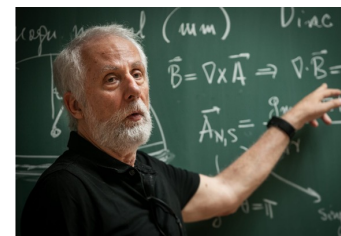
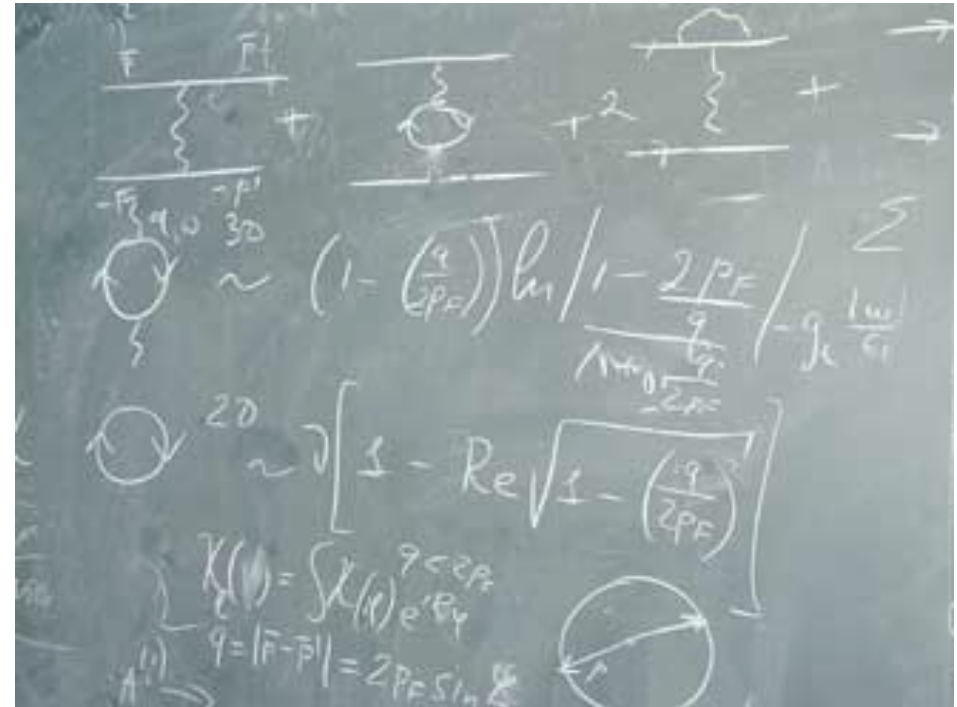


- Aktivna zajednica iz teorijske fizike u fizici čestica i srodnim područjima: QCD, fizika okusa, teorija polja, kozmologija i teorija gravitacije, ...

*Zajednica teorijske fizike je uvijek podržavala jačanje suradnje s CERN-om*

Zagreb, Split, Rijeka

- Velika vijest: otvaranje Chair pozicije iz teorijske fizike za **Gorana Senjanovića** na Sveučilištu u Splitu



G. Senjanović



# LCG – LHC Computing Grid







# Promocija i popularizacija znanosti



- Brojne aktivnosti popularizacije za sve uzraste
- International Masterclasses: oko 400 učenika godišnje





# CERN Teachers Program



- 3 dana na CERN-u: predavanja, posjete, radionice
- Preko 200 profesora fizike je sudjelovalo u programu od 2015. do danas

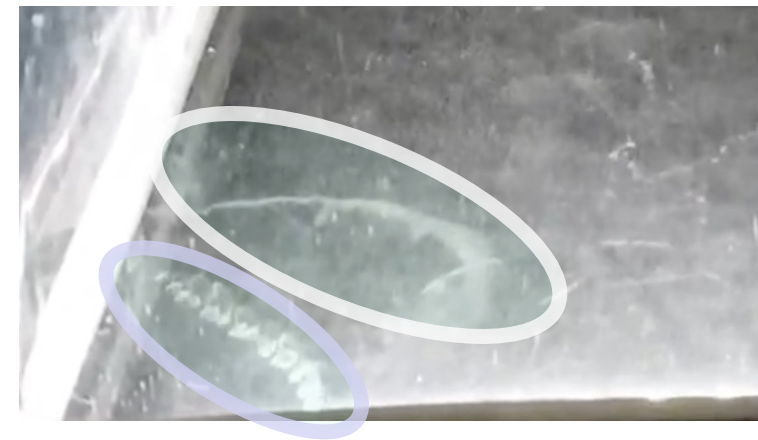




# Teachers Program: izgradi svoj detektor



... tragovi  $\alpha, \beta, \gamma$  čestica su se pojavljivali i nestajali pred našim očima u komori koju smo MI izgradili



**ULAZAK U PRIDUŽENO ČLANSTVO**



# 2019: Hrvatska postaje pridružena članica!



## Zagreb, 28.2.2019

## CERN, 10.10.2019

### Croatia to become an Associate Member of CERN

Today, the Director-General of CERN, Fabiola Gianotti, and the Minister of Science and Education of the Republic of Croatia, Blaženka Divjak, signed an Agreement admitting Croatia as an Associate Member of CERN.

28 FEBRUARY, 2019



### Croatia becomes an Associate Member of CERN

CERN welcomes the Republic of Croatia as an Associate Member State

10 OCTOBER, 2019





## Hrvatske obaveze



Godišnji doprinos CERN-ovom proračunu za pridružene članice:

≥ 10% predviđenog iznosa za punu članarinu, ali ne manje od 1 MCHF

**Hrvatski doprinos kao pridružene članice:  
1 MCHF godišnje**

*Doprinos RH za punu članarinu 2019 bi bio 3'356'300 CHF*



## Mogućnosti pridruženog članstva



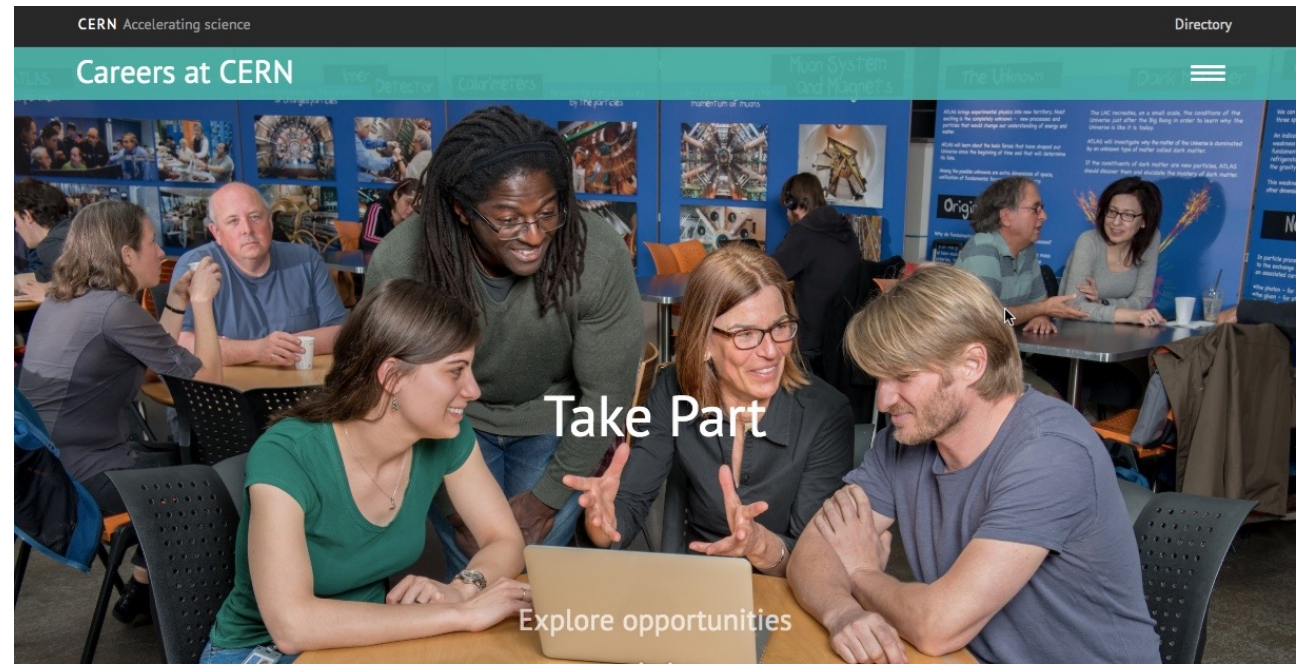
- Pristup mogućnostima zapošljavanja, usavršavanja i obrazovanja (izuzetak stalnih radnih mjesta)
- Pristup suradnji s CERN-om za hrvatsko gospodarstvo
- Predstavnici u CERN-ovom vijeću (bez prava glasanja)



# Employment opportunities at CERN



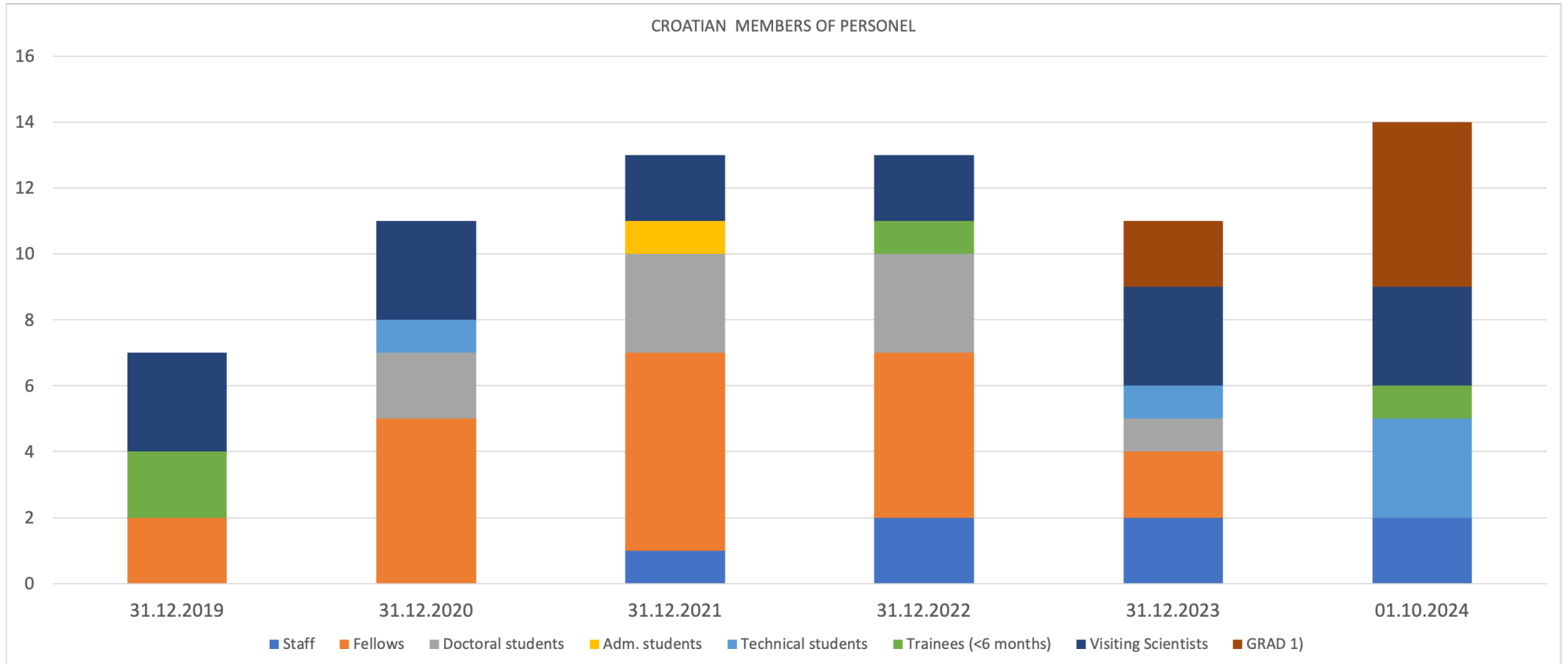
- Staff
- Fellow / Graduate program
- Technical students
- Doctoral students
- Admin. Students
- Visiting scientists
- Trainees
- etc. etc.







# Hrvati koriste mogućnosti zapošljavanja na CERN-u!





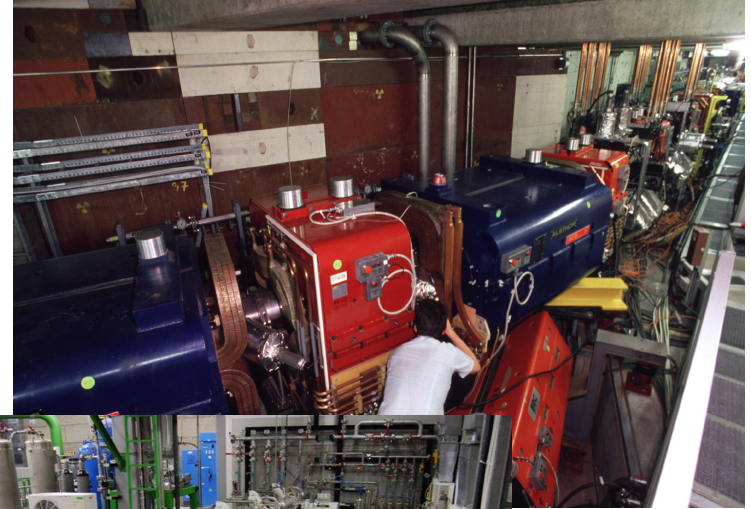
# Što rade Hrvati zaposleni na CERN-u



- Akceleratori: pogon, kontrola, razvoj
- Razvoj novih detektora
- Pogon i razvoj alata za velike računalne klustere
- Kvantno računanje i strojno učenje
- Itd. Itd. ... Samo mali broj fiziku čestica

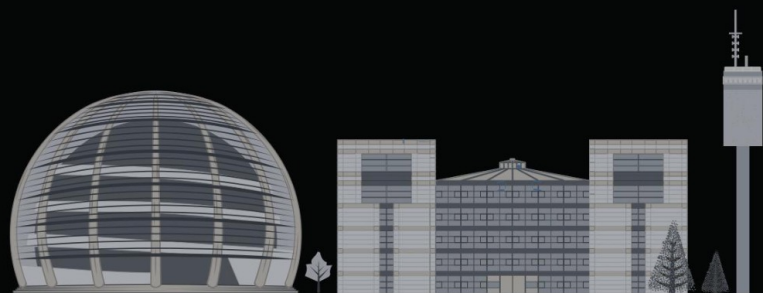
U fokusu je tehnologija koja čini istraživanja mogućim

U tim aktivnostima prije članstva nismo mogli sudjelovati





## Mogućnosti za hrvatsko gospodarstvo



Doing business with **CERN**

- Ukupna godišnja vrijednost ugovora s gospodarstvom na CERN-u ~ 300 MCHF
- Jako široki spektar traženih usluga: građevina, strojarstvo, održavanje, elektronika, IT, ...
- Hrvatske tvrtke se od 2019. mogu javiti na natječaje CERN-a



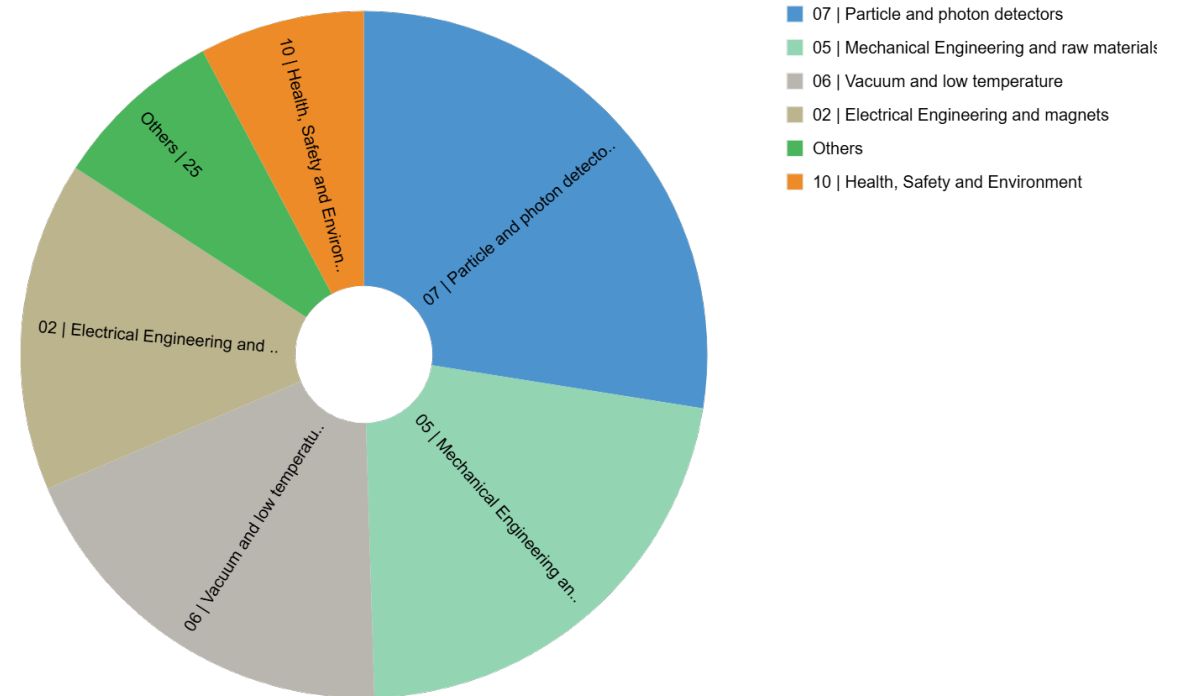
# Kako je hrvatsko gospodarstvo iskoristilo mogućnosti 2019-2023



Year	Procurement (kCHF)
2019	9
2020	148
2021	182
2022	225
2023	312
2024*	310

\* Provisional figure based on commitments

Expenditure by (Activity|Procurement) Code (kCHF) for Croatia



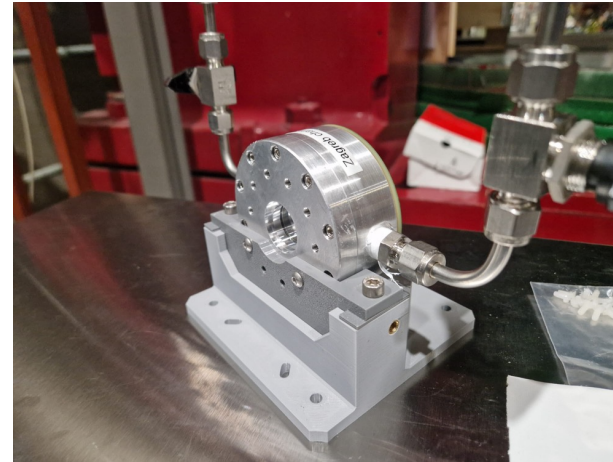


# Što rade hrvatske tvrtke na CERN-u



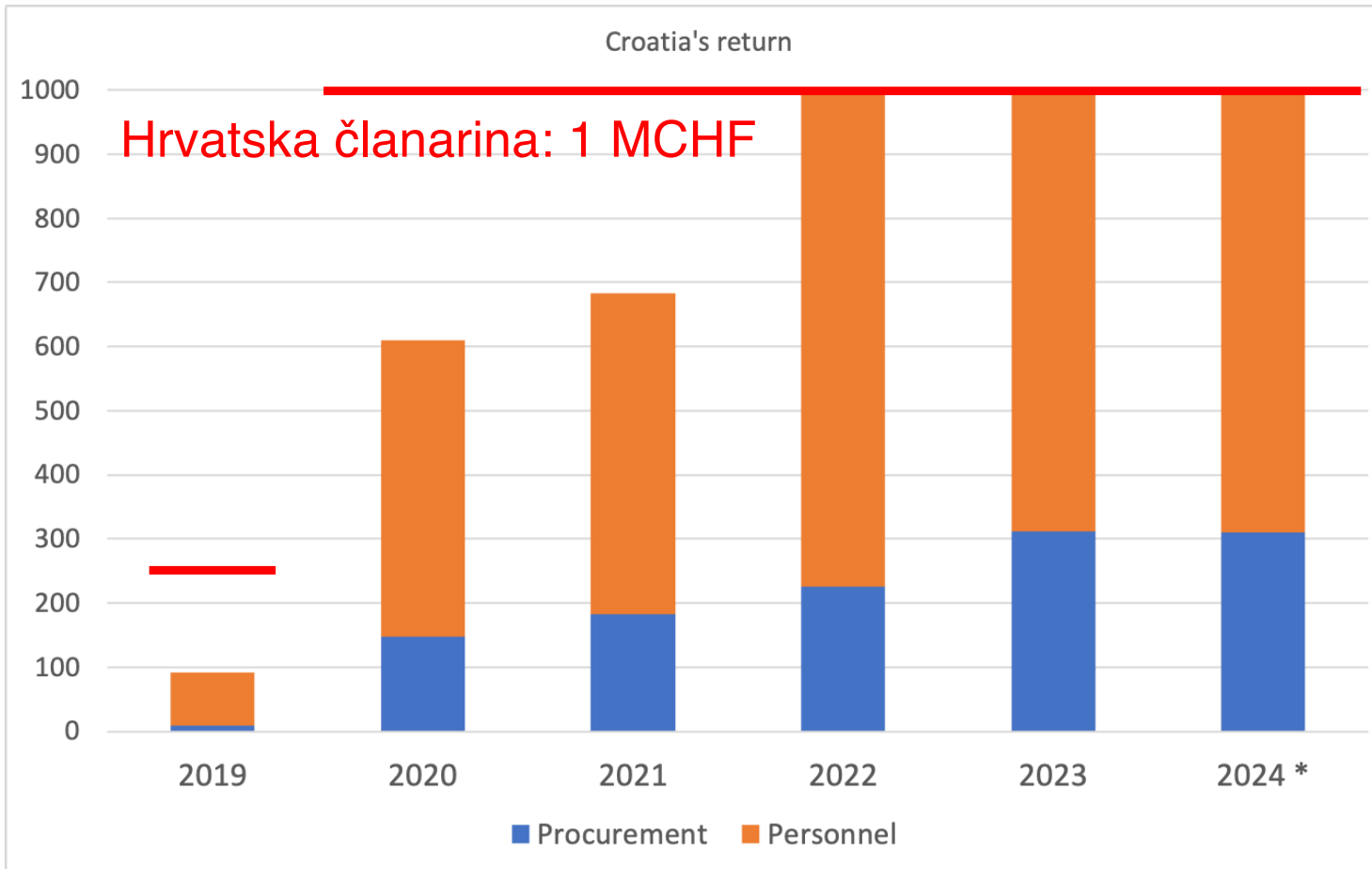
- Izrada dijelova za detektore
- Ozračivanje uzoraka za proučavanje otpornosti na zračenje
- Oprema za radionice
- Izrada prototipa za silicijske senzore
- Održavanje cijevi (hlađenje, ventilacija)
- Itd. Itd.

*Neke od tih suradnja su krenule od znanstvenih istraživanja*





## Ukupna vrijednost povrata hrvatske članarine (u kCHF)



- Za pridružene članice povrat ne smije biti veći od članarine
- Od 2022. Hrvatska u potpunosti iskorištava puni potencijal pridruženog članstva!



# Zaključak



- Hrvatski fizičari su već nekoliko desetljeća uspješno uključeni u istraživanja na CERN-u
- Sa članstvom se otvorila mogućnost širem društvu za iskorištavanje svih mogućnosti koje CERN nudi
- U prvih 5 godina je Hrvatska u potpunosti uspjela iskoristiti mogućnosti usprkos COVID-u i puno drugih izazova

**VRIJEME ZA SLJEDEĆI KORAK  
U PUNOPRAVNO ČLANSTVO!**

A photograph of a CERN Council meeting. Several people are seated at a long table with nameplates and laptops. The text "Hrvatska u vijeću CERN-a" is overlaid on the image.

Hrvatska u vijeću CERN-a

CROATIA

UNITED STATES

HVALA NA PAŽNJI