

# S E R B I A

## Midterm Report

pECFA Meeting, 16-17 November 2017

P.R. Adžić



# SERBIA and CERN

(a brief history)



- September, 1954:** The Former Yugoslavia was one of twelve European founding states of CERN.
- January, 1961:** Yugoslavia pulls out from CERN and receives an observer status.
- June, 1995:** CERN Council abolishes an observer status of Federal Republic of Yugoslavia and Serbia establishes formal relations with CERN as an independent state and successor of Yugoslavia.
- June 9, 2001:** Serbia signs with CERN the General Agreement on Scientific and Technical Cooperation.



# SERBIA and CERN

(a brief history)



**August 12, 2005: Serbia signs Memorandum of Understanding for M&O for ATLAS and CMS Experiment**





# SERBIA and CERN

(a brief history)



**November, 2008:** Serbia sends a letter of intent for admission to the CERN membership

**March, 2009:** Serbia applies for a candidate for the CERN membership



# SERBIA and CERN

(a brief history)



10-01-2012



10-01-2012

**January 10, 2012: Serbia signs the Agreement as an associate member state of CERN in the pre-stage to the membership**

**March, 2012: Serbia's parliament ratifies this Agreement and Serbia becomes an associate member of CERN**



# SERBIA and CERN

(a brief history)



**February 26, 2014**

**Signed Agreement:  
CERN - Faculty of Physics  
of University of Belgrade**



26-02-2014

**February 26, 2014**

**Signed Agreement:  
CERN - Institute of Physics  
of University of Belgrade**





# SERBIA and CERN

(a brief history)



**25-11-2014: Agreement between CERN and University of Belgrade**

# HIHG ENERGY PHYSICS IN SERBIA



## HEP THEORY:

University of Belgrade:

Faculty of Physics and Institute of Physics

University of Niš:

Faculty of Science

## HEP EXPERIMENTS:

ATLAS, CMS, LHC-GRID, SHINE, MICE

University of Belgrade

VINČA Institute

Faculty of Physics

Institute of Physics

University of Kragujevac

Faculty of Science

HEP THEORY:

University of Belgrade

Institute of Physics

Faculty of Physics



<http://www.gravity.ipb.ac.rs/>

The Group of GRAVITATION, PARTICLES and FIELDS, composed of physicists from the Faculty of Physics and Institute of Physics of University of Belgrade, involved in HEP research, represents a part of the theory division of University of Belgrade. **It consists of 14 researchers and 6 PhD students.** The work of the Group covers subjects mainly within gauge models and quantization of gravity. The research topics belongs to the following fields:

- **string theory;**
- **alternative theories of gravity based on non-Rieman geometry;**
- **discrete spacetime models;**
- **non-commutative field theories in particle physics and gravity.**

The main results in the period 2012-2016 include studies of the following topics:

- boson and fermion duality in string and superstring theory, T-duality on curved and weakly curved backgrounds, open and closed string non-commutativity;
- conformal Chern-Simons holography, conserved charges in 3D gravity, Siklos waves in Vayida solution in 3D gravity, conformally flat black holes and gravitational waves in Poincare gauge:
  - theory, models of massive gravity, solutions of 5D Lovelock gravity;
- Poincare 2-group theory, spincube model, cosmological constant problem in Regge quantum gravity;
- renormalizability of non-commutative chiral electrodynamics, properties of gauge theories on kappa-Minkowski space and on general curved non-commutative spaces, properties of D-deformed Wess-Zumino model, non-commutative gravity as  $SO(2,3)$  gauge theory and the second order Seiberg-Witten expansion, spherically-symmetric spaces and cosmological models in non-commutative geometry;
- algebraic Bethe ansatz for the Gaudin model, algebraic symmetry approach to three body problems.

## PUBLICATIONS 2012-2017:

- a monograph: M. Blagojevic and F. Hehl, *Gauge Theories of Gravitation: A Reader with Commentaries*, Imperial College Press, 2013
- 60 original research papers in *Journal of High Energy Physics, Physical Review D, European Physical Journal, Classical and Quantum Gravity, Nuclear Physics B*, etc.
- 30 papers in conference proceedings

PARTICIPATION AND TALKS at 20 CONFERENCES on the topics of gravity, quantum gravity, noncommutative field theory, mathematical physics, symmetry and supersymmetry in Vienna, Munich, Bad-Honnef, Bayrishzell, Porto, Rome, Prague, Dubna, Wroclaw, Szczecin, Zakopane, Varna, Sinai, Corfu, Athens, Banja Luka, Zagreb, Belgrade.

## CONFERENCES and SCHOOLS organized by the GPF group:

19 - 22 September 2013, Divčibare, Serbia

Gravity: New Ideas for Unsolved Problems II

<http://www.gravity.ipb.ac.rs/divcibare2013.html>

23 June 2015, SANU, Belgrade

GR100 Centennial of General Relativity

21-27 June, 2015 University of Belgrade, Serbia,

CERN – SEENET-MTP PhD Training Program: Supergravity

21 - 28 August 2016, Belgrade, Serbia

COST QSPACE training school: Quantum Structure of Spacetime and Gravity

<http://www.qssg16.ipb.ac.rs/>

18 - 23 September 2017, Belgrade, Serbia

9th Meeting on Modern Mathematical Physics

<http://www.mphys9.ipb.ac.rs/>

THEORY: Heavy Ion Physics

**Institute of Physics:**

**QGP Tomography Project**

**ERC Grant since 2017**

# Quark Gluon Plasma (QGP)

- **A new state of matter**, consisting of deconfined and interacting quarks, antiquarks and gluons.
- Existed a few  $\mu\text{s}$  after Big-Bang, today created in Little Bangs.
- Allows studying the origin of matter at its basic level

# Goal of heavy ion program

To form, observe and understand QGP



Little Bangs at RHIC and LHC

**Current state of the art**

QGP discovered at LHC and RHIC

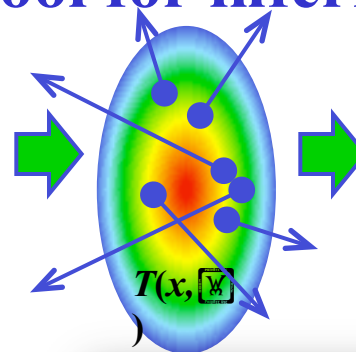
**Current challenge: Understand QGP properties**



## QGP Tomography Project Goal:

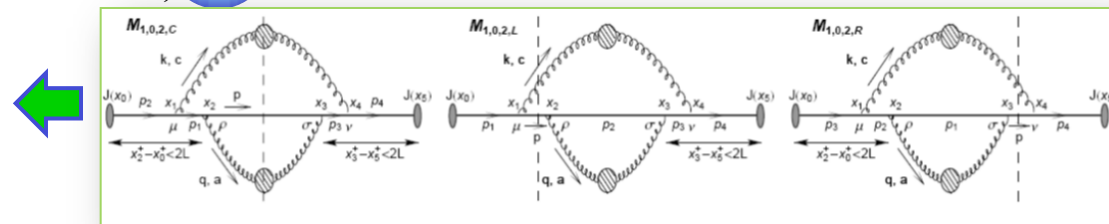
Developing new tool for inferring QGP properties

**Main idea:** When high energy particles go through QGP they lose energy



Energy loss (to be theoretically predicted) depends on QGP properties

Infer the QGP properties by comparing these predictions with experimental data.



# Dynamical energy loss (a basis for the tomography tool)

- Dynamical (moving) partons in finite size medium
- Based on finite  $T$  field theory
- Same framework for radiative and collisional energy loss
- Finite magnetic mass effects
- Treats both light and heavy flavor partons
- No free parameters for generating predictions
- Temperature as a natural variable in the model.

- Explains  $R_{AA}$  for different probes, collision energies, and centralities
- Resolved the longstanding “heavy flavour puzzles at RHIC&LHC”.
- Provided clear predictions for future experiments.
- 18 papers published on this topic during the last five years.



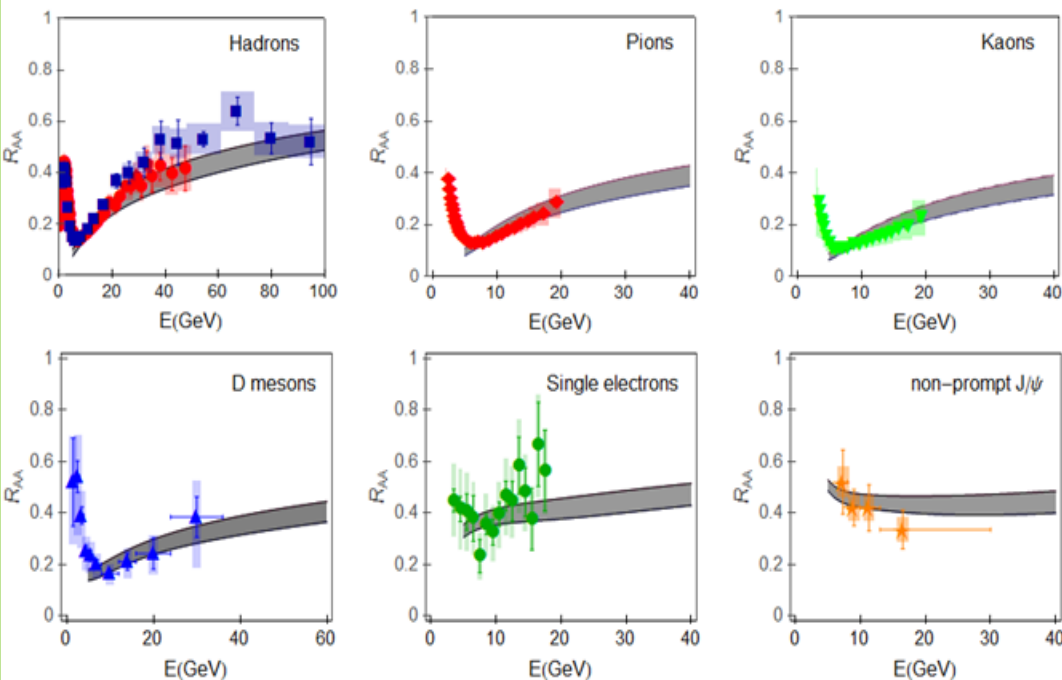
The developed dynamical energy loss formalism can well explain the jet-medium interactions in QGP.



However, the model does *not* include QGP evolution.



Redeveloping the energy loss model and the numerical procedure, so that it accounts for evolving QGP medium, is our major future goal.





HEP THEORY:

University of Niš:

Faculty of Science

# Niš Group for Cosmology and Astroparticle Physics\*

- **Members:** 5\*\*
- **Associated members:** 3\*\*\*
- **Research Topics:** Early Universe; Inflation, Dark Matter and Reheating; Braneworld - Tachyonic Dynamics; Planck-scale Physics and Black Holes; Active Galaxies – Computational methods
- **Number of publications (ISI journals):** 2012-2017: **12**; 2016-2017: **7**
- **Total number of publications 2012-17: 35**
- **Publications with CERN:** CERN-Pro-2014-001; *Cosmology and Particle Physics beyond Standard Models: Ten Years of the SEENET-MTP Network* Luis Álvarez-Gaumé (ed.), Goran S. Djordjević (ed.), Dejan Stojković (ed.)
- **International Cooperation:**  
Niš Group has been the host and coordinating node of the *Southeastern European Network in Mathematical and Theoretical Physics* (SEENET-MTP) since 2003
- **Joint programs:**
  - CERN – SEENET-MTP PhD Training Program <http://phd.seenet-mtp.info>
  - CERN – SEENET-MTP Framework Agreement for Scientific and Technical Collaboration KN3847 <http://seenet-mtp.info/agreements/CERN-SEENET-MTP.pdf>

Department of Physics, Faculty of Science, University of Nis, Serbia

\*\* Professor Goran Djordjević, Asistant Professor Dragoljub Dimitrijević, Asistant Professor Milan Milošević,  
PhD student Marko Stojanović, PhD student Danilo Delibašić

\*\*\* Professor Ljubiša Nešić, Dr. Darko Radovančević, PhD student Marko Dimitrijević

- **Conferences** – main organizer (with CERN TH, CEI-Trieste) 2012-2017:
  - Workshop BW2013 Beyond the Standard Models (<http://bw2013.seenet-mtp.info>)
  - School COSMO 2014
  
- **Coorganizer\*** – Schools:
 

CERN – SEENET-MTP PhD Training Program

  1. *Supergravity* (2015, **Belgrade**, Serbia)
  2. *Modern Aspects of Quantum Field Theory* (2015, **Bucharest**, Romania)
  3. *Computational methods in Cosmology and GR* (2016, **Timisoara**, Romania)
  4. *New Trends in High Energy Theory* (2017, **Sofia**, Bulgaria)
  
- International agreements, projects and the main research partner groups (RPG)
  - With SISSA: MoU on Scientific Exchange and Academic Cooperation (2012-2015)
  - With ICTP
    1. Cosmology and Strings PRJ-09 (2008-2012)
    2. Cosmology and Strings PRJ-09 (2012-2016)
    3. Cosmology - Classical and Quantum Challenges NT-03 (2016-)
  - UNESCO and UNESCO Office Venice: 9 projects (2003-2015)
  - RPG: Institute Rudjer Boskovic, Croatia; University of Timisoara, Romania
  
- In progress (with CERN, ICTP and EPS):
  - **Balkan School and Workshop BSW2018** (<http://bsw2018.seenet-mtp.info>)

\* Coorganizer of 10 Conferences and Schools in Bulgaria, Romania and Turkey (2006-2017)

# HEP EXPERIMENTS

Institute of Physics:

Contribution to the

Muon Ionisation Cooling Experiment (MICE)

Collaboration

# Institute of Physics Belgrade (IPB): Muon Ionisation Cooling Experiment (MICE)

Aim of the MICE collaboration is demonstration of ionisation cooling at the ISIS synchrotron at the Rutherford Appleton Laboratory (RAL), UK.

Muon beams of low emittance provide the basis for the intense, well-characterised neutrino beams necessary to elucidate the physics of flavour at a neutrino factory and to provide lepton-antilepton collisions at energies of up to several TeV at a muon collider.

Ionization cooling is the technique by which it is proposed to reduce the phase-space volume occupied by the muon beam at such facilities. In an ionization-cooling channel, the muon beam passes through a material in which it loses energy. The energy lost is then replaced using RF cavities. The combined effect of energy loss and re-acceleration is to reduce the transverse emittance of the beam (transverse cooling).

Group of researchers from IPB joined MICE collaboration in February 2015.

Contributing in development of MAUS software and running of official grid MC simulation of the MICE experiment, development of on-line and off-line Event Viewer, involvement in Energy loss analysis and shifts.

On the author list since 2016. One paper so far in *Physical Review Accelerators and Beams*: "Design and expected performance of the MICE Demonstration of Ionization Cooling".

Users of MICE EUCARD2 Transnational access program from April 2015 to April 2017.

Organisers of 48<sup>th</sup> MICE collaboration meeting in Belgrade, in June 2017.

48<sup>th</sup> MICE collaboration meeting  
Belgrade 27-29 June 2017

✓ Depends on upstream beam line (mostly diffuser)  
✓ Depends on magnetic lattice  
✓ Depends on material  
✓ Depends on particle species → backgrounds!

Ionisation Cooling → Measure a change in emittance → Multiple scattering

$$\frac{d\varepsilon}{ds} = \frac{-\varepsilon_n}{\beta^2 E} \frac{dE}{dX} + \frac{\beta_t (13.6 \text{ MeV})^2}{2\beta^3 E m_\mu X_0}$$

$\frac{v}{E} = \beta, E = \sqrt{p^2 + m_\mu^2}$   
 → depends on D2 selection



7th February 2015



# Contributions of Serbia's scientists and engineers to CERN projects



# Contributions of Serbian scientists and engineers at CERN



## 1) ISOLDE (Nuclear Physics) experiment:

VINČA Institute – Belgrade and Faculty of Science of University of Novi Sad (since 1990).

## 2) DELPHI experiment at LEP:

University of Belgrade: VINČA Institute (since 1993).

## 3) CMS Experiment at the LHC:

University of Belgrade: VINČA Institute and Faculty of Physics (since 1997).

## 4) ATLAS Experiment at the LHC:

University of Belgrade: Institute of Physics (since 2004).

## 5) LHC GRID (Computing) Project:

University of Belgrade: Institute of Physics (since 2006).

## 6) SHINE experiment at SPS:

University of Belgrade: Faculty of Physics and Institute of Physics (since 2011).

ISOLDE:

University of Novi Sad:  
Department of Physics



# ISOLDE – NICOLE

## Nuclear spectroscopy (currently: two physicists, one PhD student)

- **Physics:**

- Two approved experiments

- IS460 Magnetic dipole moments of High-K isomeric states in Hf isotopes ;
- IS575 Beta-delayed neutrons from oriented  $^{137,139}\text{I}$  and  $^{87,89}\text{Br}$  nuclei.

- **Two new directions under discussion:**

- Application to medical physics: The observation of angular distribution of gamma rays can yield accurate multipole mixing ratios. This knowledge may enable the best way to estimate conversion electron and Auger transition intensities, data required for cancer therapy.
- Time-reversal (TR) non-conservation : The polarization detection efficiency could be increased by ~order of magnitude if, instead of traditional detection of Compton scattered polarized photons from oriented nuclei, recoil electrons were detected as well and Compton event electronically reconstructed. This could be achieved if high-pressure noble gas detectors were used. This new technology would bring back interest in (TR) experiments.

- **Conference participation:**

- ISOLDE Workshop, CERN 2012.

- **Publications (3):**

- Ohtsubo, T., Rocchia, S., Stone, N.J., Stone, J.R., Gaulard, C., Köster, U., Nikolov, J., Simpson, G.S., Veskovíc, M., The on-line low temperature nuclear orientation facility NICOLE, *Journal of Physics G: Nuclear and Particle Physics* Volume 44, Issue 4, 8 March 2017, Article number 044010.
- Muto, S., Stone, N.J., Bingham, C.R., Stone, J.R., Walker, P.M., Audi, G., Gaulard, C., Köster, U., Nikolov, J., Nishimura, K., Ohtsubo, T., Podolyak, Z., Risegari, L., Simpson, G.S., Veskovíc, M., Walters, W.B., Magnetic properties of Hf 177 and Hf 180 in the strong-coupling deformed model, *Physical Review C - Nuclear Physics* Volume 89, Issue 4, 7 April 2014, Article number 044309.
- Ohtsubo, T., Stone, N.J., Stone, J.R., Towner, I.S., Bingham, C.R., Gaulard, C., Köster, U., Muto, S., Nikolov, J., Nishimura, K., Simpson, G.S., Soti, G., Veskovíc, M., Walters, W.B., Wauters, F., Magnetic dipole moment of the doubly-closed-shell plus one proton nucleus Sc49, *Physical Review Letters* Volume 109, Issue 3, 19 July 2012, Article number 032504.

Contributions to  
ATLAS and **CMS** experiments

# Contributions to the ATLAS experiment

## Institute of Physics – Belgrade:

### In-kind contribution (2004-2008)

- Disk Shielding (JD) and A-frame supports for the forward shielding (JF)

### Physics studies (since 2004)

- from 2004: preparation for data analysis;
- since 2010: physics analysis of experimental data.



# In-kind contribution to the **ATLAS** experiment



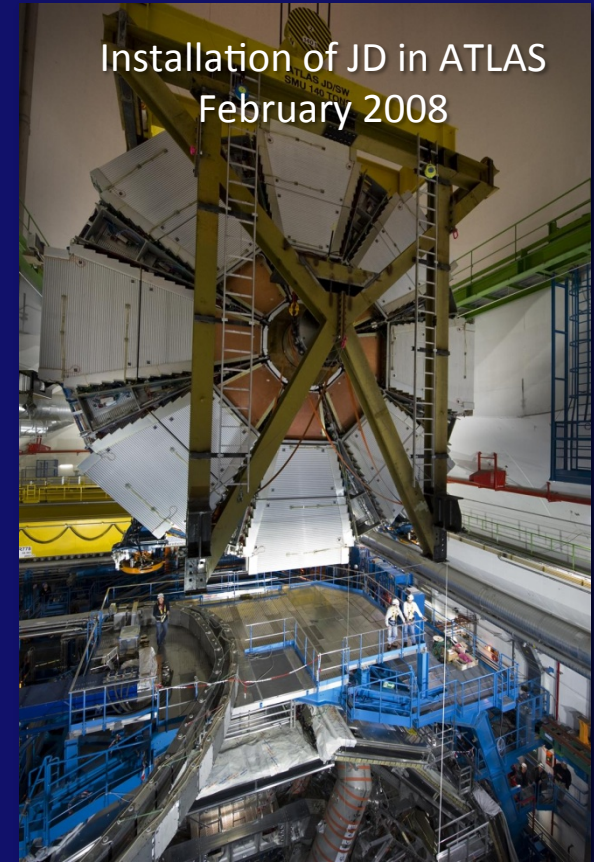
## **In-kind contribution to the forward shielding system:**

Disk Shielding (JD) and A-frame supports for the forward shielding (JF), produced by “Lola Corporation” (Belgrade) and “Kryooprema” (Belgrade), and transported to CERN in 2004.



Test assembly of JD disks at the Lola factory in October 2004.

1 10 2004



Installation of JD in ATLAS  
February 2008

Institute of Physics - Belgrade

Physics Contribution to

the ATLAS Experiment

(2012-2017: 7 physicists, 5 PhD students)

# INSTITUTE OF PHYSICS BELGRADE (IPB)

## ATLAS GROUP

- DETECTOR OPERATION: Trigger, Luminosity
- PHYSICS STUDIES: Precision measurement of the  $m_W$  and  $m_H$ , SUSY searches, BSM Higgs
- APPOINTMENTS WITHIN ATLAS: **Leadership positions (convinerships, coordinations), editorial boards**
- HUMAN RESOURCES: 5 senior members (currently) , **7 PhD students during last 5 years**
- EDUCATION: Three PhD theses finalized in the past 5 years

### TRIGGER

- TDAQ member since 2015, mainly involved in High Level Trigger software
- B-jet trigger group:
  - Leadership position (2015 – 2017)
  - L1Topo and HLT development for muon +jet triggers
  - B-jet trigger software development
- Trigger Menu development
- Release and validation coordination roles
- Trigger operation support

### LUMINOSITY

- Luminosity:
  - Absolute calibration from beam parameters in van-der-Meer (vdM) scans
  - Operation support

### UPGRADE

- Upgrade – Phase I
  - B-jet trigger software migration
- Upgrade – Phase II
  - Physics studies for trigger

- **W BOSON MASS**

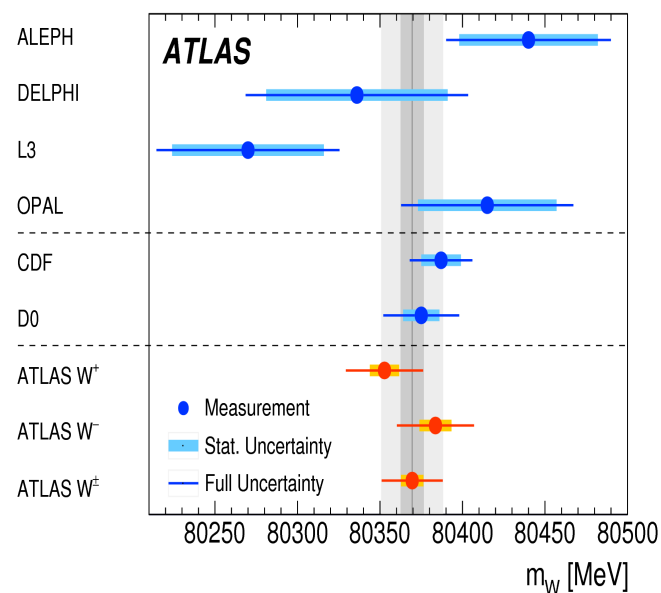
- **Leading contribution** in first LHC measurement (**corresponding author** of the publication).
- Muon momentum calibration, hadronic recoil reconstruction, overall muon channel analysis.
- **Convener** of the W,Z Standard Model subgroup.

- **HIGGS BOSON MASS**

- Contribution to the H→4 lepton analysis, measurement of the Higgs mass and couplings in run-1.

- **PERFORMANCE STUDIES**

- Muon momentum calibration in run-1.
- W boson tagging using jet substructure (used in many BSM Higgs, Exotics and SUSY searches).



- BSM HIGGS
  - Search for 2HDM heavy neutral Higgs boson produced in association with b-jets, decaying to bbar.
  - Trigger studies.
- SUPERSYMMETRY
  - **Coordination** of the search based on signatures with jets and missing transverse momentum during run-1 (most stringent limits on the squark and gluino masses in many models).
  - Participated in the search based on signatures with jets, missing transverse momentum and one isolated lepton.
  - **Corresponding author** of the **two** run-1 summary publications on inclusive searches for squarks and gluinos.
  - **Leading role** in the analysis for several SUSY publications.

ATLAS SUSY Searches* - 95% CL Lower Limits						ATLAS Preliminary		
May 2017						$\sqrt{s} = 7, 8, 13 \text{ TeV}$		
Model	$e, \mu, \tau, \gamma$	Jets	$E_T^{\text{miss}}$	$[\mathcal{L} dt(dn^{-1})]$	Mass limit	$\sqrt{s} = 7, 8 \text{ TeV}$	$\sqrt{s} = 13 \text{ TeV}$	
Inclusive Searches	MSUGRA/CMSSM	0-3 $e, \mu$ /1-2 $\tau$	2-10 jets/3 $b$	Yes	20.3	$\tilde{q}, \tilde{g}$	1.85 TeV	$m(\tilde{q})=m(\tilde{g})$
	$\tilde{q}\tilde{q}, \tilde{q} \rightarrow q\tilde{\chi}_1^0$	0	2-6 jets	Yes	36.1	$\tilde{q}$	1.57 TeV	$m(\tilde{\chi}_1^0) < 200 \text{ GeV}, m(1^{\text{st}} \text{ gen. } \tilde{q})=m(2^{\text{nd}} \text{ gen. } \tilde{q})$
	$\tilde{q}\tilde{q}, \tilde{q} \rightarrow q\tilde{\chi}_1^0$ (compressed)	mono-jet	1-3 jets	Yes	3.2	$\tilde{q}$	608 GeV	$m(\tilde{q})-m(\tilde{\chi}_1^0) < 5 \text{ GeV}$
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	36.1	$\tilde{g}$	2.02 TeV	$m(\tilde{\chi}_1^0) < 200 \text{ GeV}$
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}\tilde{\chi}_1^0 \rightarrow qgW^{\pm}\tilde{\chi}_1^0$	0	2-6 jets	Yes	36.1	$\tilde{g}$	2.01 TeV	$m(\tilde{\chi}_1^0) < 200 \text{ GeV}, m(\tilde{\chi}_1^{\pm})=0.5(m(\tilde{\chi}_1^0)+m(\tilde{g}))$
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}\ell\ell/\nu\nu\tilde{\chi}_1^0$	3 $e, \mu$	4 jets	-	36.1	$\tilde{g}$	1.825 TeV	$m(\tilde{\chi}_1^0) < 400 \text{ GeV}$
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{g}WZ\tilde{\chi}_1^0$	0	7-11 jets	Yes	36.1	$\tilde{g}$	1.8 TeV	$m(\tilde{\chi}_1^0) < 400 \text{ GeV}$
	GMSB ( $\tilde{\ell}$ NLSP)	1-2 $\tau$ + 0-1 $\ell$	0-2 jets	Yes	3.2	$\tilde{g}$	2.0 TeV	$c\tau(\text{NLSP}) < 0.1 \text{ mm}$
	GGM (bino NLSP)	2 $\gamma$	-	Yes	3.2	$\tilde{g}$	1.65 TeV	$m(\tilde{\chi}_1^0) < 950 \text{ GeV}, c\tau(\text{NLSP}) < 0.1 \text{ mm}, \mu < 0$
	GGM (higgsino-bino NLSP)	$\gamma$	1 $b$	Yes	20.3	$\tilde{g}$	1.37 TeV	$m(\tilde{\chi}_1^0) > 880 \text{ GeV}, c\tau(\text{NLSP}) < 0.1 \text{ mm}, \mu > 0$
	GGM (higgsino-bino NLSP)	$\gamma$	2 jets	Yes	13.3	$\tilde{g}$	1.8 TeV	$m(\tilde{\chi}_1^0) > 430 \text{ GeV}$
	GGM (higgsino NLSP)	2 $e, \mu$ (Z)	2 jets	Yes	20.3	$\tilde{g}$	900 GeV	$m(\tilde{g}) > 1.8 \times 10^{-4} \text{ eV}, m(\tilde{g})=m(\tilde{q})=1.5 \text{ TeV}$
	Gravitino LSP	0	mono-jet	Yes	20.3	$\tilde{g}^{1/2}$ scale	865 GeV	



# ATLAS@IPB: SIGNIFICANT PUBLICATIONS

## DETECTOR OPERATION

- Luminosity determination in  $pp$  collisions at  $\sqrt{s} = 8$  TeV using the ATLAS detector at the LHC, **Eur.Phys.J. C76 (2016) no.12, 653**
- Performance of the ATLAS Trigger system in 2015, **Eur. Phys. J. C (2017) 77: 317**

## PERFORMANCE STUDIES

- Measurement of the muon reconstruction performance of the ATLAS detector using 2011 and 2012 LHC proton-proton collision data, **Eur.Phys.J. C74 (2014) no.11, 3130**
- Identification of boosted, hadronically decaying  $W$  bosons and comparisons with ATLAS data taken at  $\sqrt{s} = 8$  TeV, **EPJC 76(3), 1-47**

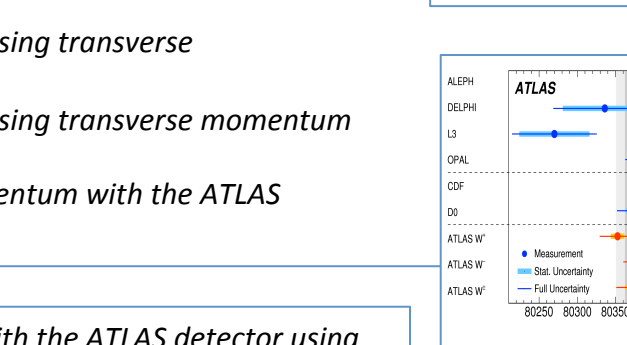
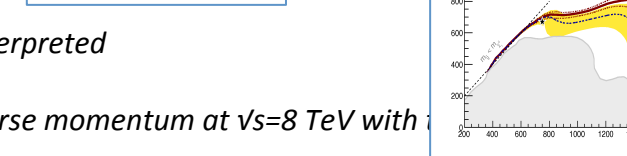
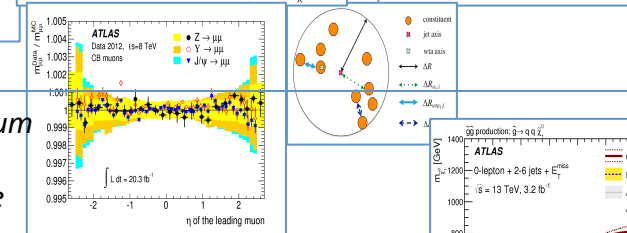
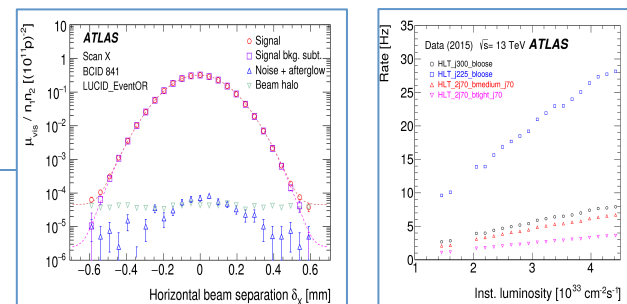
## SUSY

- Search for squarks and gluinos in final states with jets and missing transverse momentum at  $\sqrt{s}=13$  TeV with the ATLAS detector, **Eur. Phys. J. C (2016) 76 392.**
- Summary of the searches for squarks and gluinos using  $\sqrt{s} = 8$  TeV  $pp$  collisions with the ATLAS experiment at the LHC, **JHEP 10 054 (2015).**
- Summary of the ATLAS experiment's sensitivity to supersymmetry after LHC Run 1 – interpreted in the phenomenological MSSM, **JHEP 10 134 (2015).**
- Search for squarks and gluinos in events with isolated leptons, jets and missing transverse momentum at  $\sqrt{s}=8$  TeV with the ATLAS detector, **JHEP 04 116 (2015).**
- Search for squarks and gluinos with the ATLAS detector in final states with jets and missing transverse momentum using  $\sqrt{s}=8$  TeV proton-proton collision data, **JHEP 09 176 (2014).**
- Search for squarks and gluinos with the ATLAS detector in final states with jets and missing transverse momentum using 4.7  $fb^{-1}$  of  $\sqrt{s} = 7$  TeV  $p$ - $p$  collision data, **Phys. Rev. D 87, 012008 (2013).**
- Search for squarks and gluinos using final states with jets and missing transverse momentum with the ATLAS detector in  $\sqrt{s} = 7$  TeV proton-proton collision, **Phys. Lett. B 710, 67-85 (2012).**

## STANDARD MODEL

- Measurement of the Higgs boson mass from the  $H \rightarrow \gamma\gamma$  and  $H \rightarrow ZZ^* \rightarrow 4l$  channels with the ATLAS detector using 25  $fb^{-1}$  of  $pp$  collision data, **Phys.Rev. D90 (2014) no.5, 052004**
- Measurement of the  $W$ -boson mass in  $pp$  collisions at  $\sqrt{s} = 7$  TeV with the ATLAS detector, **arXiv:1701.07240 [hep-ex]**, submitted to Eur.Phys.J. C

**All together 40 publications with significant contribution from IPB**



# Serbian CMS Group:

VINČA Institute and Faculty of Physics

## Contributions to the CMS experiment

(five physicists, six PhD students, one engineer, one technician)

### Physics studies (since 1997)

- from 1997 to 2010: preparation for data analysis;
- since 2010: physics analysis of experimental data;

### In-kind contribution (2002-2003)

- connecting corner pieces for the CMS magnet;

### Hardware: ECAL DCS

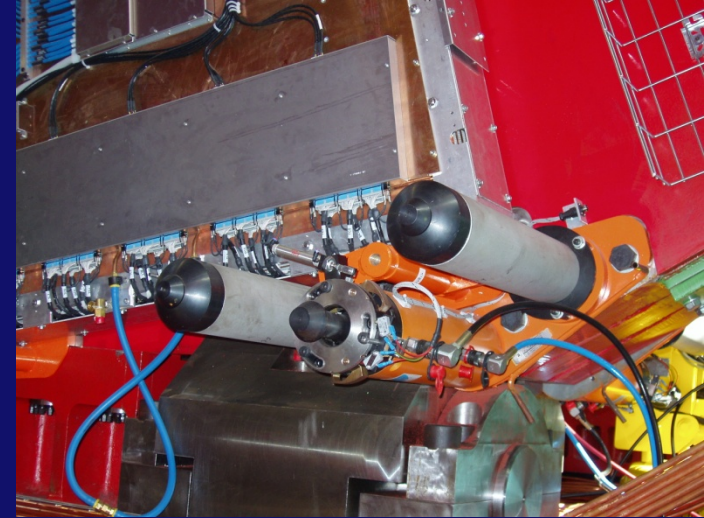
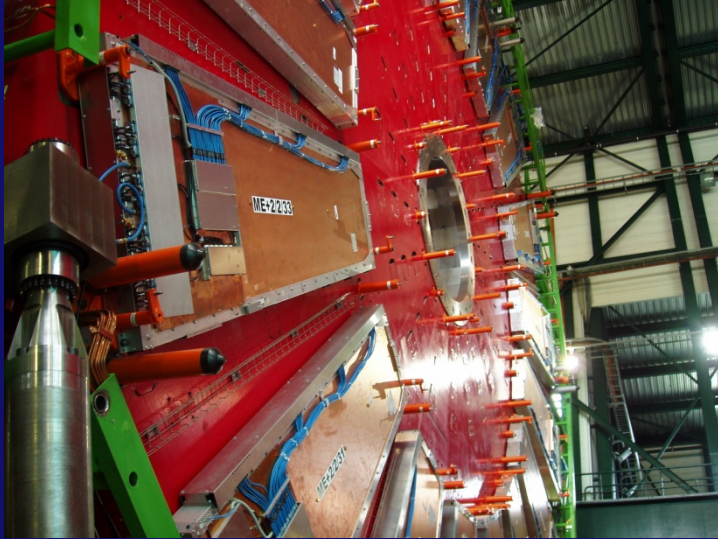
- ECAL Safety System – ESS (2002-2007);
- Relative Humidity System – RHS (2012);

### Engineering (since 2004)

- design and 3D modeling of the CMS detector.



# In-kind contribution to the CMS experiment



75 hydraulic jacks  
for the CMS magnet  
were made in 2002  
by “ZASTAVA Alati”  
in Kragujevac and  
delivered to CMS  
in July 2003.





# Contributions to the CMS experiment Hardware

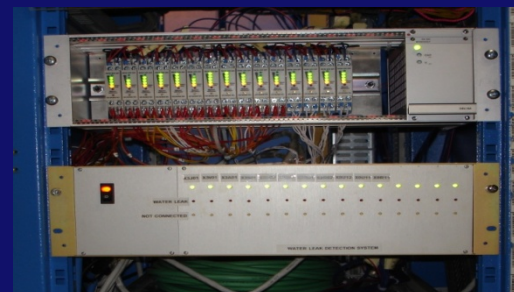


## RHS

2) ECAL Relative Humidity System – RHS  
design and construction by the Serbian  
CMSGroup: 2010-2012.

## ESS

1) ECAL Safety System – ESS  
designed, constructed and  
tested by the Serbian CMS  
Group and delivered to CMS  
in the beginning of 2007.





# HARDWARE: Contribution to the construction of the CMS detector



**1. The ECAL Safety System – ESS** designed, constructed and tested in Belgrade. Delivered to CMS in the beginning of 2006 and installed in 2007.  
The financial support: **Serbian Ministry, SDC, Serbian CMS Group.**

**2. The ECAL Relative Humidity System – RHS** designed, constructed and tested from 2010-2012. Delivered to CMS ECAL and installed in 2012.  
The financial support: **ETH Group, Serbian CMS Group** and **SCOPES.**

Both systems represent a part of the **Detector Control System – DCS** for **ECAL**. Designed and constructed in the Lab of Nuclear and Particle Physics of Faculty of Physics, University of Belgrade. They serve for control and monitoring **the ECAL crystals.**

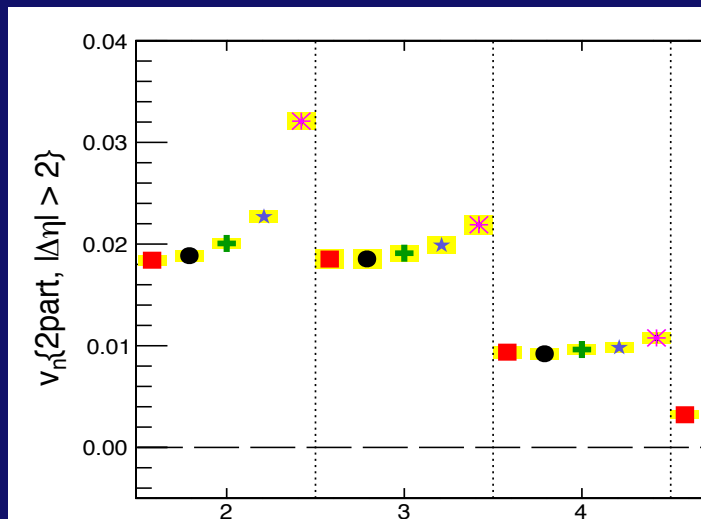
## Physics in the **CMS** experiment:

1. Particle physics (VINCA Institute + Faculty of Physics)
2. Heavy Ion physics (VINCA Institute)

# VINČA institute of nuclear sciences

## Heavy Ion physics

In UCC PbPb, the effect dominantly induced by initial state fluctuations on nucleonic level



-JHEP 1402 (2014) 088  
(arXiv:1312.1845)  
78 citations  
16 auto-citations  
-HIN-12-011  
13 citations  
-We presented it at  
ICHEP 2014, Valencia, Spain

-PRC 92 (2015) 034911 (arXiv:1503.01692)  
70 citations, 16 auto-citations  
-HIN-14-012  
2 citations, 1 auto-citation

Presented at:

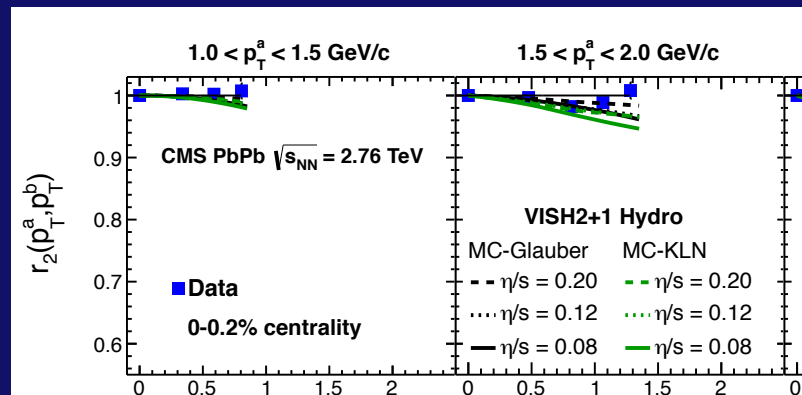
ICHEP 2014, Valencia, Spain

IWOC 2014, Kolybari, Greece

ExQCD 2015, T. Lomnica, Slovakia

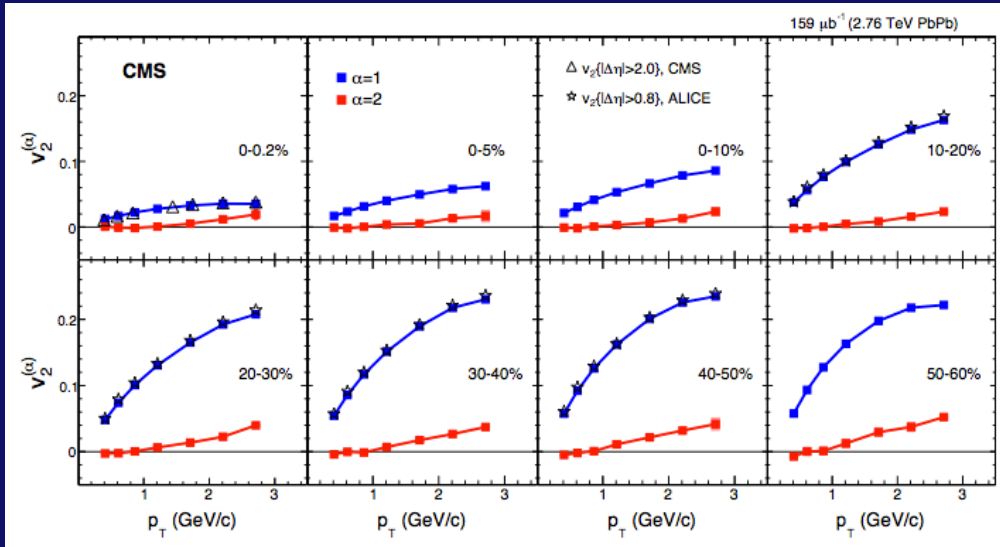
ICPP 2015, Moscow, Russia

QM 2014, Darmstadt, Germany  
EPS HEP 2015, Viena, Austria  
and seminars in: Orsay, Tokai,  
Hefei, Huzhou



Factorization breaking induced by initial state fluctuations on sub-nucleonic level

# Sub-leading flow modes seen for the first time



-Submitted to PRC  
(arXiv:1708.07113)  
-HIN-15-010  
1 citation

Presented it at:

QM 2015, Kobe, Japan

Baldin 2016, Dubna, Russia

Low-x 2016, Gyongyos, Hungary

ExQCD 2016, Costa di Caparica, Portugal

-HIN-16-018, 2 citations

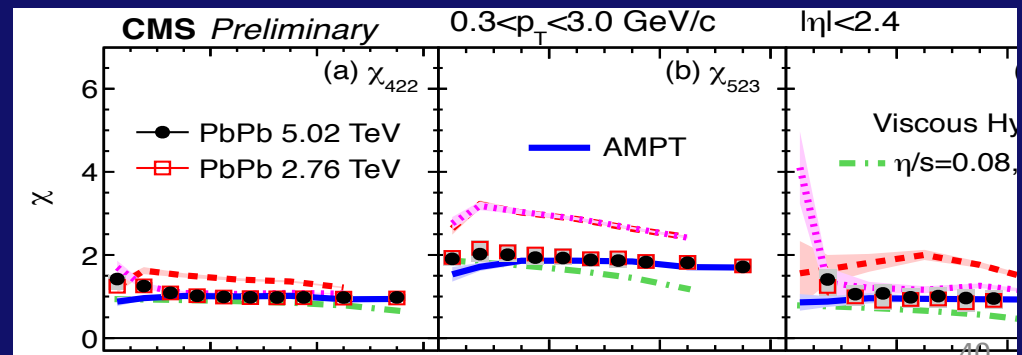
non-linear response of higher-order flow harmonics - sensitivity to initial conditions and transport properties of QGP

Presented at:

LHCP 2017, Shanghai, China

EPS HEP 2017, Venice, Italy

ExQCD 2017, Sintra, Portugal



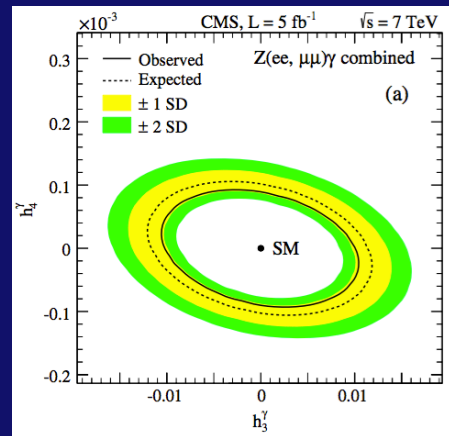
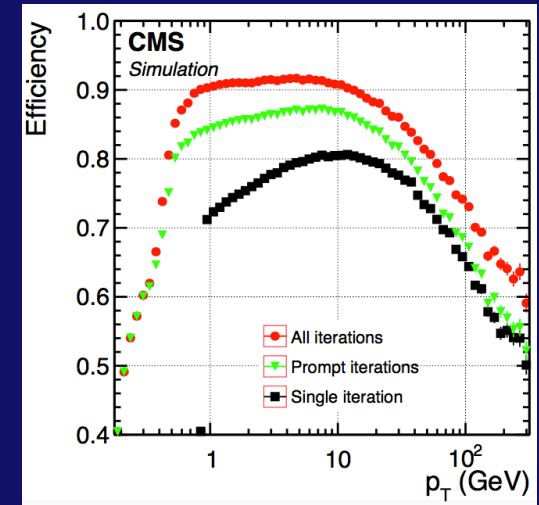


# VINČA Institute: Particle physics I

Particle-flow reconstruction and global event description with the CMS detector, accepted in JINST, arXiv:1706.04965

The CMS trigger system, JINST 12 (2017) no.01, P01020

Performance of missing energy reconstruction in 13 TeV pp collision data using the CMS detector, CMS PAS JME-16-004



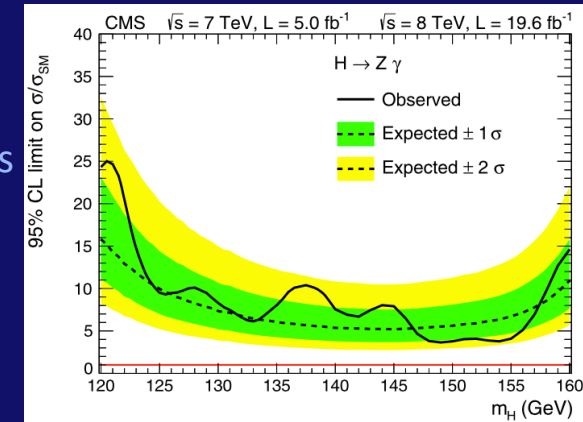
Z $\gamma$  cross section at 7 TeV and aTGC search

Phys.Rev. D89 (2014) no.9, 092005, 109 citations

Presented it at Protvino 2014, Moscow Region, Russia, LaThuile 2015, Italy and ICPPA 2015, Moscow

Higgs  $\rightarrow$  Z $\gamma$  search at the 7 TeV and 8 TeV

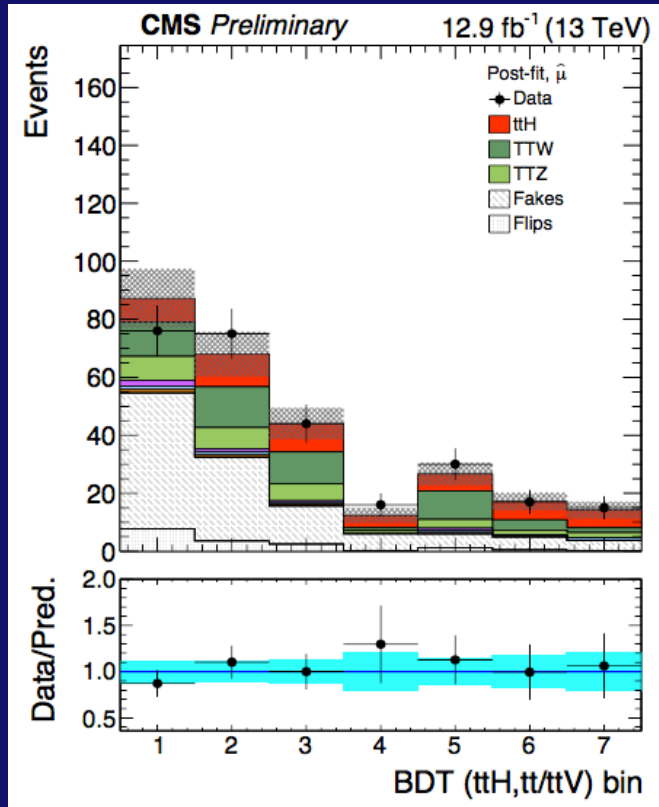
Phys.Lett. B726 (2013) 587-609, 143 citations



# VINČA Institute: Particle physics I

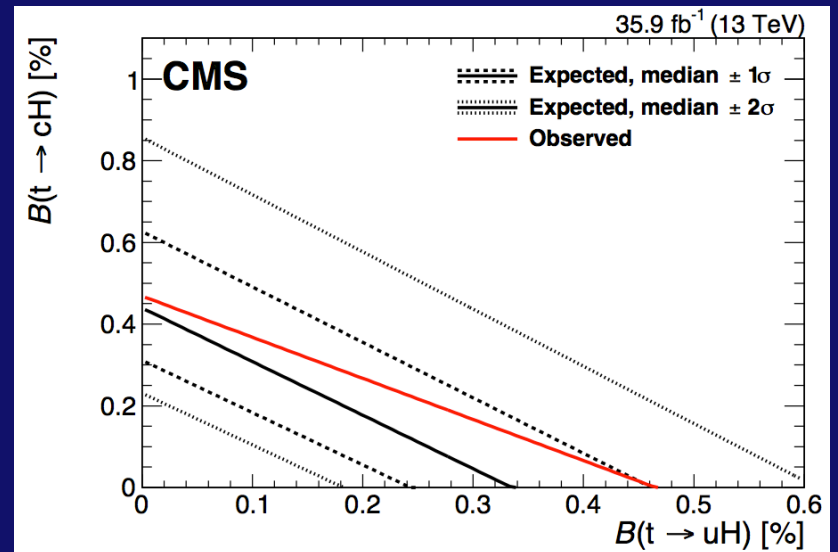
Search for  $t\bar{t}H$  production in multilepton final states at  $\sqrt{s} = 13$  TeV, CMS PAS HIG-15-008  
Search for associated production of Higgs bosons and top quarks in multilepton final states at  $\sqrt{s}=13$  TeV, CMS PAS HIG-16-022

Presented at QUARKS 2016, St Petersburg, Russia, ICNFP 2016, Crete, Greece, Bormio 2017, Italy and PASCOS 2017, Madrid, Spain



*Search for the flavor-changing interactions of the top quark with the Higgs boson in  $H \rightarrow b\bar{b}$  channel at  $\sqrt{s}=13$  TeV, CMS PAS TOP-17-003*

Presented it at Top 2017, Braga, Portugal



# Faculty of Physics: Particle physics II

## Research responsibilities:

1. **Co-convenership of CMS Higgs ZZ sub-group (Sep 2015 - Aug 2017)**
  - **Measurement of H(125) properties** (mass, width, production modes, fiducial/differential cross-sections)
  - **Searches for BSM phenomena** (search for anomalous couplings of H(125), search for add. scalar resonances)
2. **Co-convenership of CMS Higgs Future sub-group (Sep 2017 - )**
3. **Co-convenership of LHC Higgs XS WG for fiducial, differential and simple, template cross-sections (2015 - present)**
4. **Other: CMS Phase II upgrade** (HGCal detector R&D, physics performance of 4l measurements for HL-LHC )

## Publications and conferences:

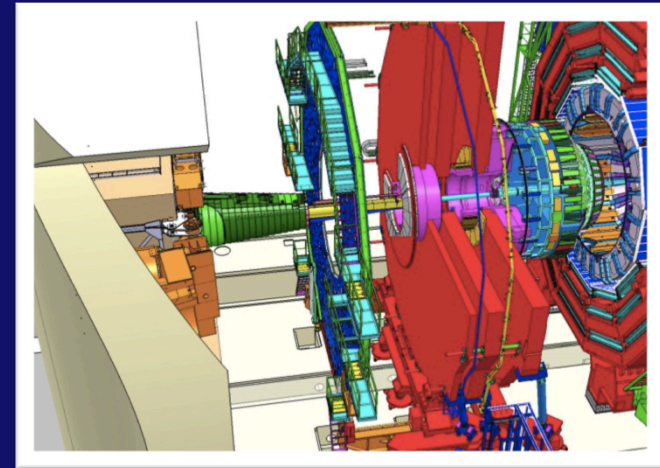
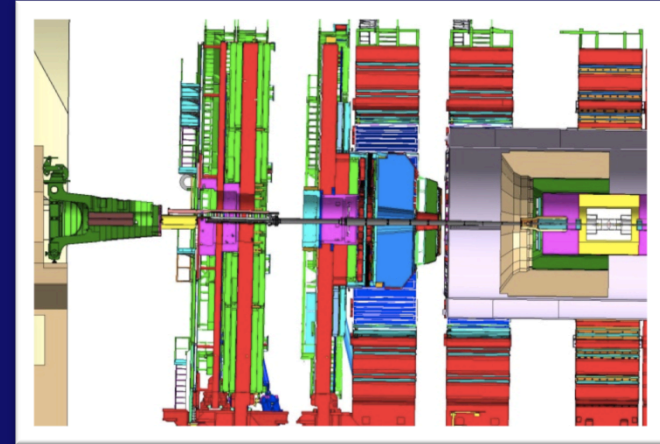
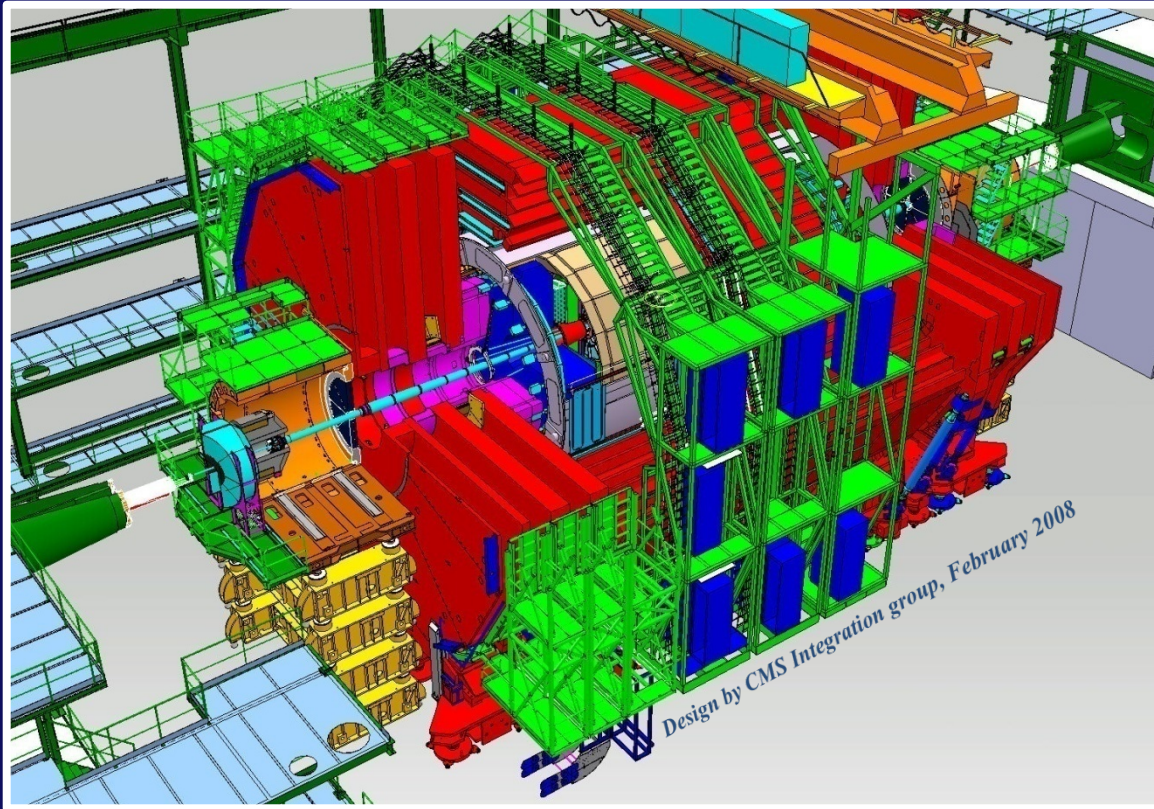
1. Phenomenology of Higgs physics: **Phys. Rev. D 87 (2013) 5, 055006, Phys. Rev. D 89 (2014) 3, 034002.**
2. CMS publications and int. conferences: **13 papers, 4 PAS-only publications, 14 conferences/workshops**
3. **2014-2016: Research and teaching assistantship, University of Belgrade (student + master student)**  
2016-present: Imperial College London (PhD student)

## Research activities and involvements as Master and PhD student:

- **ROOT developments within CERN EP-SFT group:** Multidimensional kernel estimation, CERN-STUDENTS-Note-2015-224
- **Master thesis: “Study of four-lepton production in  $pp \rightarrow ZZ/ZZ^*/Z\gamma^* \rightarrow 4l$  processes”**, defended at University of Belgrade
  - Results are part of publication: **SMP-16-001 (Phys. Lett. B, 763), PAS HIG-16-033, and HIG-16-041 (submitted to JHEP).**

# Engineering contribution to CMS (since 2004)

# CMS Detector - Organisation, planning and control of the installation

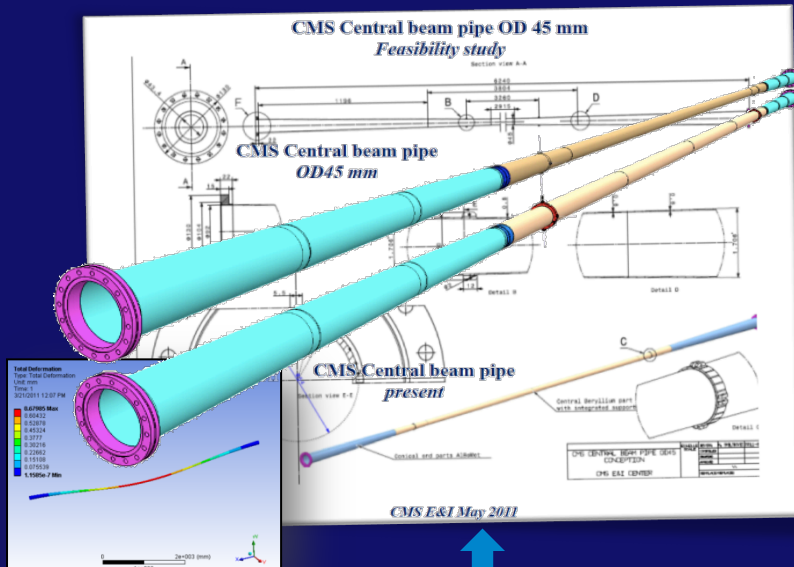


Proposal to convert different CAD files in to the CATIA system

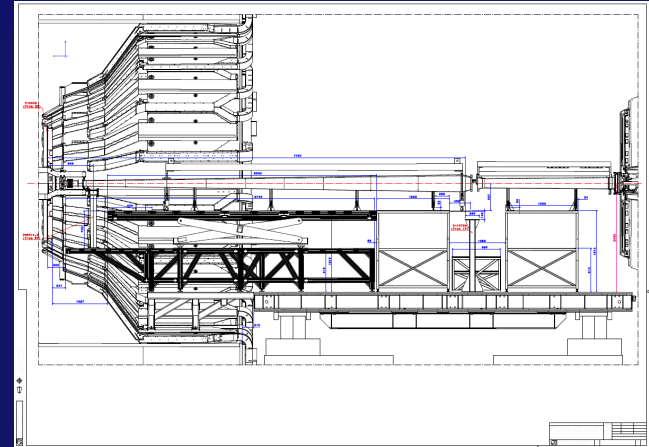
DMU, Fitting and kinematic simulation modules, automatic transfer of the survey data are used in planning and control of different sequences of installation.

Request to organize many scenarios and configurations using existing models, introduce Data base and functional files organization.

# New CMS central beam pipe



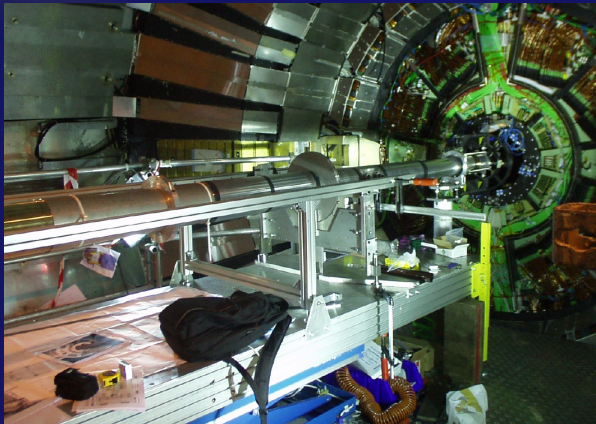
# CMS Beam pipe Installation



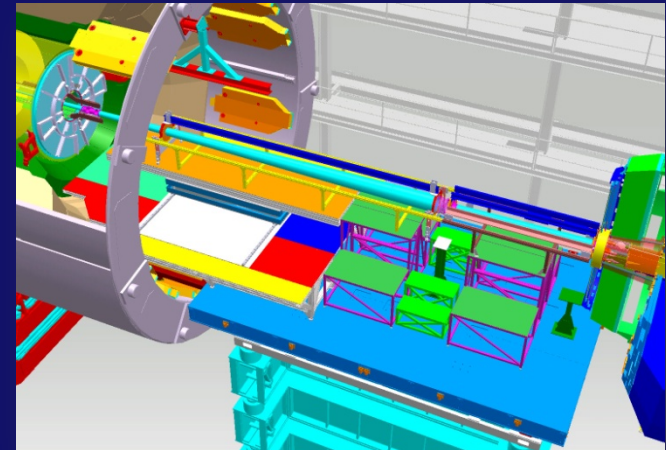
Installation drawings



# PLM



Existing tools and procedures



Sequence of the installation

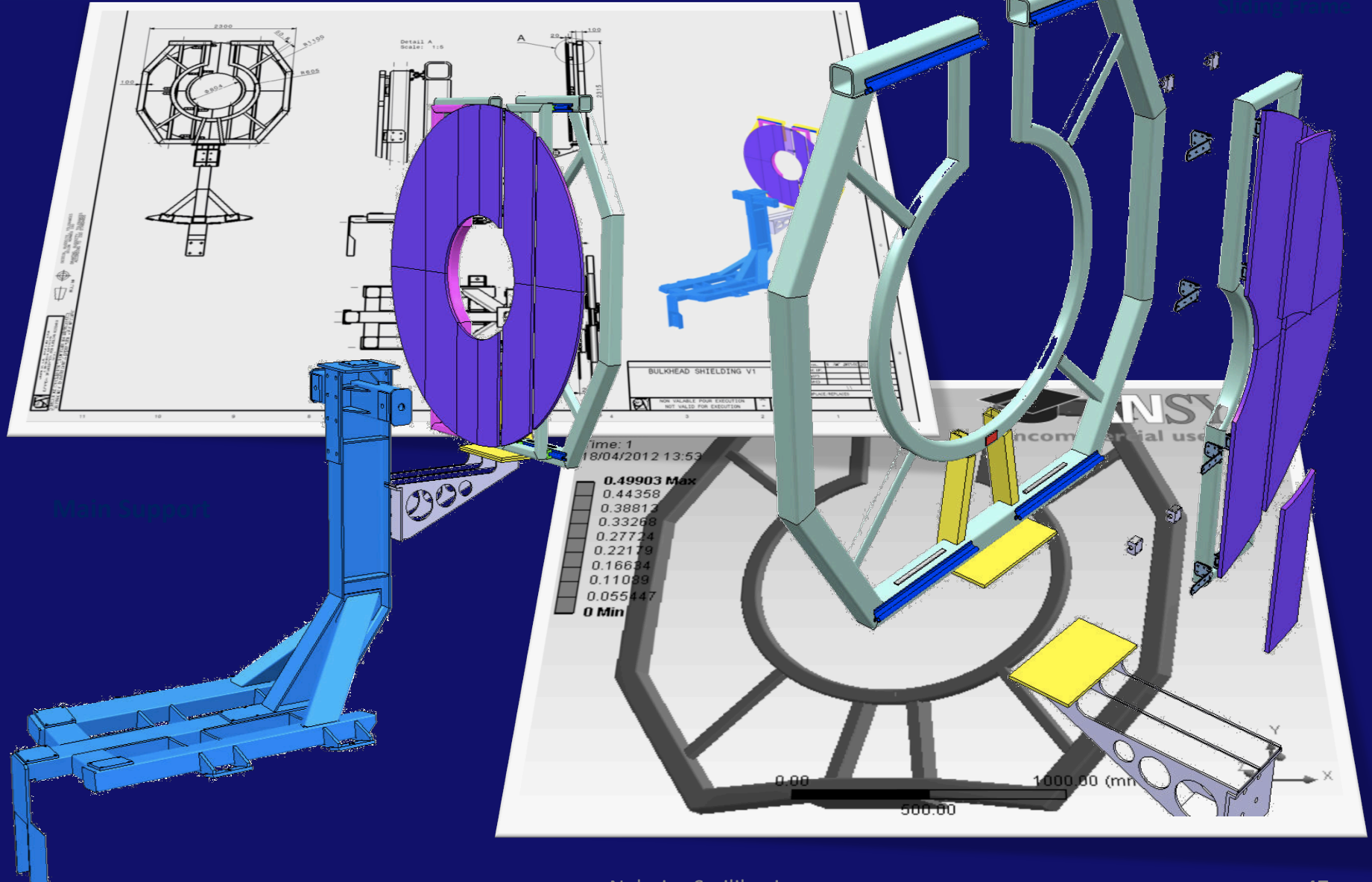


Process to design and reinstall the new CMS Central beam pipe, starting from conceptual design, inside same team, using stored data and respecting proven process from the first installation.

# Bulkhead Shielding

*Conceptual design*

Modeling, drawings and simulations



# UPGRADE of CMS

Planned contribution to:

1. ECAL BARREL
2. HG-ECAL
3. Physics



# VINČA Institute:

**A group of HEP physicists**  
(four PhD physicists and two students)  
**participating in CLIC**

Publications since 2012: **14 papers, 20 conference papers.**

## University of Belgrade:

Faculty of Physics + Institute of Physics:

### NA61/SHINE group

- **3 members** – Faculty of Physics, University of Belgrade;
- **Task1:** full responsibility for Time Of Flight (TOF) detector:
  - Developing software;
  - Hardware maintenance;
  - Calibration of detector;
  - Data analysis.
- **Task2:** 2 PhD thesis in progress – production of  $K_0$ 's in proton-proton interactions in last 5 years;
- **published 9 papers.**

NEW PROJECT  
IN INSTITUTE OF PHYSICS - BELGRADE

**“VERROCCHIO “ CENTER**

New educational, research and innovation  
center supported by the Government of Serbia

Agreement on financial support signed  
yesterday, 15 November 2017.

# Institute of Physics - Belgrade (IPB): **Verrocchio Center**

How to tap human creativity efficiently and on a global scale? We seek to address this challenge by creating a new kind of educational institution to catalyze this process.

The Verrocchio Center will be a novel project-centered, interdisciplinary and ambitious education and innovation environment complementary to that of a standard university. The new center will be incubated in a competitive research surrounding, on the Danube campus of Institute of Physics Belgrade (IPB). Verrocchio will network with similar facilities around the world and work towards developing a new educational paradigm for post-industrial society.

Verrocchio will work with IPB strategic partners (**CERN, INFN and DESY**) towards realizing long-term global technological goals coming out of and related to High Energy Physics. In the process, Verrocchio will delineate specific technological niches in which Serbia can meaningfully and measurably contribute to this effort. **Verrocchio will also work with Serbia's growing IT sector to develop, organize and host scientific and technological challenges and train the next generation of technological entrepreneurs and innovators.**

When it gets completed during the 10-year period, it is expected that the Verrocchio project will strengthen collaboration of IPB with its strategic partners, as well as enable and bring participation of Serbian scientists and engineers to a high level not only within these three, but with other European institutions.

## **Funding**

- The Government of Serbia has made "Verrocchio" a priority project, agreeing to contribute **5 M euro** towards covering all building and basic infrastructure costs.
- IPB, as host institution, has agreed to guarantee project sustainability during a 10-year implementation period. **Total IPB contribution to Verrocchio is estimated at 7 M euro.**

SERBIA at CERN  
in statistics

# Serbia at CERN

Since Serbia's accession as an Associate member state (2012), new 53 users have been registered amounting in the total to over 80 users.

- Five (6) fellowships obtained (three out of five physicists employed in Serbian institutions);
- two LD positions obtained (none from Serbian institutions);
- Industrial return improved in last three years and looks very good;
- several educational programmes realized with CERN.



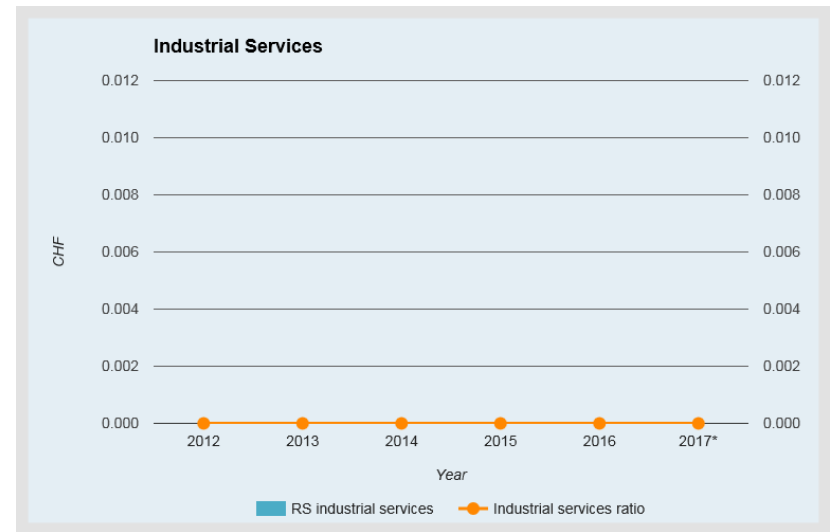
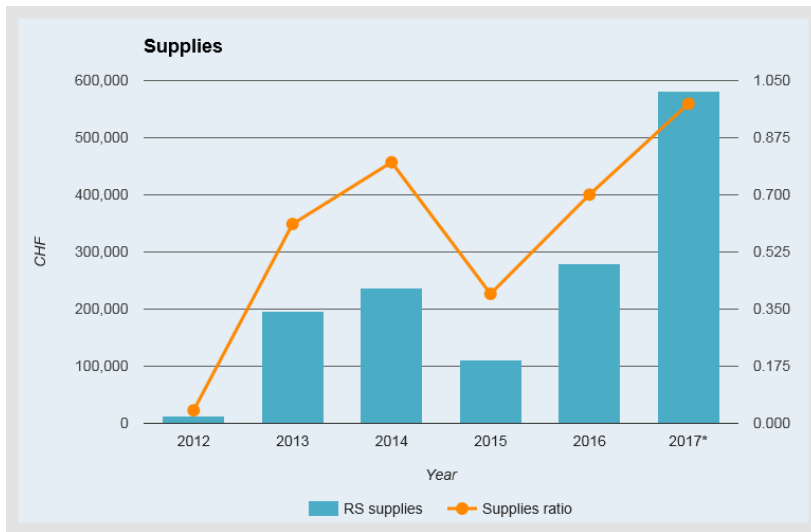
**Cooperation between  
CERN and Serbian Industries  
2017**

	I	II	III = II/I
	CHF	CHF	%
2012	1,091,804,300	1,000,000	.09%
2013	1,092,816,950	1,000,000	.09%
2014	1,103,322,899	1,000,000	.09%
2015	1,062,202,700	1,000,000	.09%
2016	1,127,444,450	1,317,000	.12%
2017*	1,142,179,450	1,935,850	.17%

IV	V
CHF	CHF
352,236,775	130,558,377
351,567,741	166,390,502
329,242,703	159,408,925
297,504,934	126,378,183
342,222,700	147,272,122
350,757,259	71,564,341

VI	VII
CHF	CHF
13,184	–
196,477	–
236,492	–
111,177	–
280,160	–
582,178	–

VIII = (VI/IV) / III	IX = (VII/V) / III
CHF	CHF
.04 (0.89)	0 (0.4)
.61 (0.91)	0 (0.4)
.8 (0.91)	0 (0.4)
.4 (0.9)	0 (0.4)
.7 (0.9)	0 (0.4)
.98 (0.9)	0 (0.4)



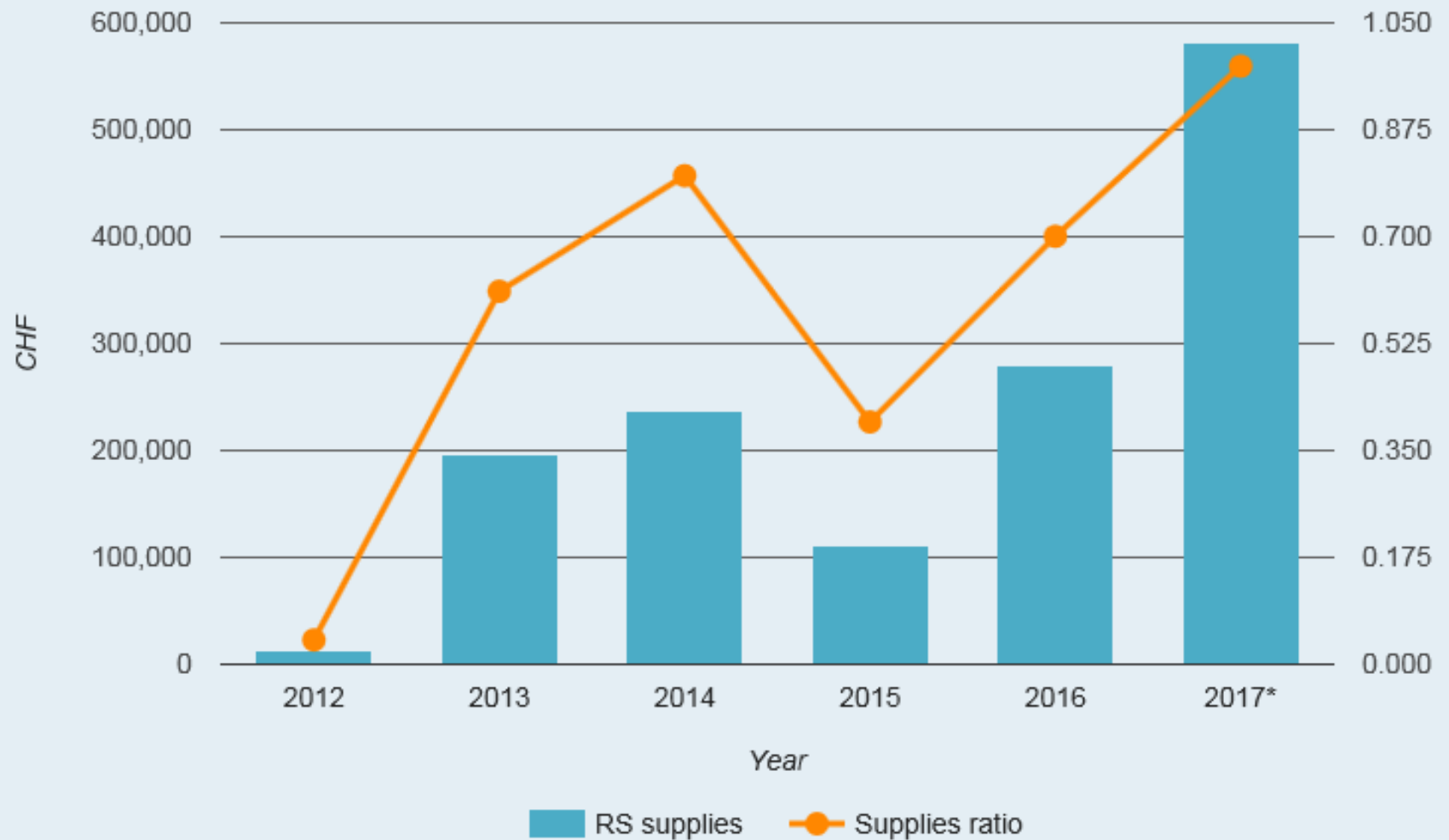
\* Provisional figures for the year



# Industry, Procurement & Knowledge Transfer



## Supplies



\* Provisional figures for the year

Supplier name	Country	City	Country of origin percentage	CERN budget (CHF)	Teams budget (CHF)
ATB SEVER DOO	RS	SUBOTICA	100%	348,364	–
VCF TP EX: GTM TP LYON ***DUPLICATE - SEE VCF-03***	FR	BRON CEDEX	10%	176,909	–
PROMEK	RS	VELIKA PLANA	100%	32,243	–
DANICA STOJILJKOVIC	RS	NOVI BEOGRAD - BEOGRAD	100%	5,000	–
UNP	RS	VRNJACKA BANJA	100%	3,800	–

Supplier name	City	CERN budget (CHF)	Teams budget (CHF)
ATB SEVER DOO	SUBOTICA	348,364	–
PROMEK	VELIKA PLANA	32,243	–
DANICA STOJILJKOVIC	NOVI BEOGRAD - BEOGRAD	5,000	–
UNP	VRNJACKA BANJA	4,422	–
PETNICA SCIENCE CENTER	VALJEVO	3,000	–

FINANCIAL SUPPORT

## The only Funding Agency:

The Ministry of Education, Science  
and Technological Development  
of the Republic of Serbia

- New call for national projects expected.
- The Ministry of Education, Science and Technological Development regularly provides the financial support for M&O for all LHC and ISOLDE experiments.

However,

there is no improvement and progress in financial support for the work and activities of Serbian users at CERN in comparison with the last RECFA visit in October 2012.

Perhaps another letter by RECFA to the Ministry or to the government could help.

Thanks