A person is paragliding over a vast valley. The paraglider's canopy is bright green and blue. Below, a wide river flows through a lush green landscape, with a city visible in the distance under a blue sky with light clouds.

Ideas and technologies for a next generation facility for medical research and therapy with ions

Yiota Foka

GSI

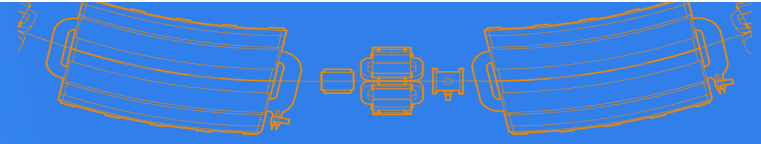
on behalf of the IONS2018 Organizers

ESI, Archamps

19 June, 2018



Organisation



Social events [link](#), CERN Visits [link](#), Transportation [link](#)

Programme Committee

- M. Cirilli (CERN, Switzerland)
- M. Dosanjh (CERN/ENLIGHT, Switzerland)
- Y. Foka (GSI & FAIR, Germany)
- C. Graeff (GSI & FAIR, Germany)
- M. Pullia (CNAO, Italy)
- L. Rinolfi (ESI, France)
- M. Vretenar (CERN, Switzerland)

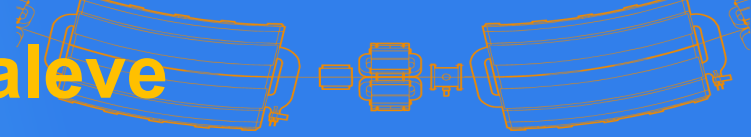
Organizing Committee

- V. Brunner (CERN, Switzerland)
- Y. Foka (GSI & FAIR, Germany)
- B. Holland (ESI, France)
- M. Janik (WUT, Poland)
- A. Katanaeva (UB, Spain & SPbSU, Russia)
- L. Rinolfi (ESI, France)
- M. Vretenar (CERN, Switzerland)





Tuesday Dinner at Saleve



18:30 End of Session

Free time at Hotels

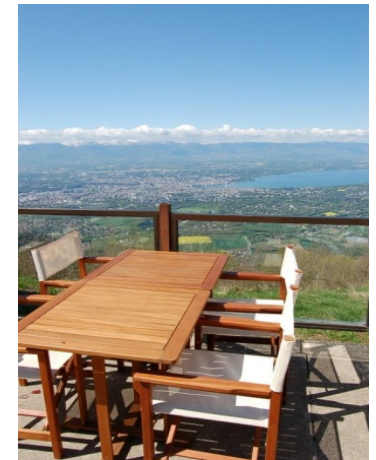
19:30 Bus Departure from ESI

GROUP PHOTO

3

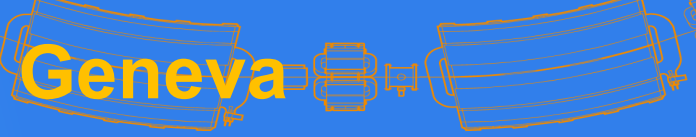
20:00 Dinner Restaurant Le Panoramique

22:00 Bus Departure from Restaurant to Hotels





Wednesday Dinner in Geneva



18:30 End of Session

may leave laptops at ESI

Bus Departure from ESI

Explore Old Town

20:00 Dinner at Greek Restaurant Emilios

22:00 Bus Departure back to Hotels

pick up laptops from ESI

World-cup: big screen at Plainpalais
Careful with pickpockets !



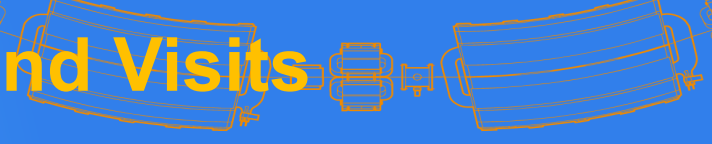
Chania IONS2017



Happy to welcome you in Crete next time !



Thursday Transport and Visits



Please bring your luggage at ESI in the morning

13:00 End of Session

Bus Departure from ESI to CERN

Public Transport from CERN to Airport

14:30 CERN Visits

- ALICE
- Lier

Confirmations: contact Valerie

Public Transport from CERN to Airport

Early flights, individual transport: contact Valerie

Material in conference folders, transport schedules posted at registration

Workshop on Ions

for Cancer Therapy, Space Research and Material Science

SPACE
RESEARCH
WORKSHOP
ON IONS FOR
CANCER THERAPY
MATERIAL
SCIENCE



**Chania,
Crete, Greece**

**26 - 30
August
2017**

Workshop Main Topics

28-30 of August at Great Arsenali

Particle therapy status

- Centres worldwide
- Treatment planning and imaging novel methods
- Challenges, new R&D directions

Space research and dosimetry

Nanotechnology, electronics and material research

Modelling and benchmarking of experiments

Novel accelerators and training

Public Events

26 of August - science fair at Neorio Moro

27 of August - public talks at Great Arsenali

30 of August - coffee with scientists at Neorio Moro

<https://indico.cern.ch/e/ions2017/>

International Advisory Committee

Ebernette Auffray (CERN, Switzerland)
Philip Burrows (University of Oxford, UK)
Marco Durante (TIFPA, INFN, Italy)
Paolo Giubellino (GSI & FAIR, Germany)
Apostolos Karantanas (Medical School, University of Crete, Greece)
Vladimir Kikelidze (JINR, Russia)
Panos Razis (University of Cyprus, Cyprus)
Boris Sharov (ITEP, Russia)
George Stavrakakis (Technical University of Crete, Greece)
Thomas Stoehiker (GSI & FAIR, Germany)

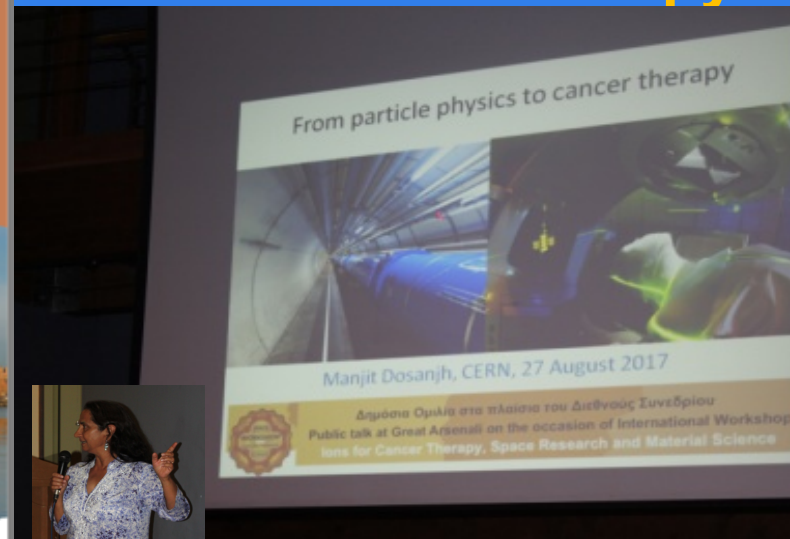
Organizing Committee

Y. Foka (GSI, Germany) - chair
C. Balas (TUC, Greece)
E. Dimovasili (CERN, Switzerland and UCY, Cyprus)
C. Graeff (GSI, Germany)
N. Kalithrakas (TUC, Greece)
R. Pleskac (GSI, Germany)
E. Tsesmelis (CERN, Switzerland and Oxford, UK)
M. Vretenar (CERN, Switzerland)
M. Zervakis (TUC, Greece)

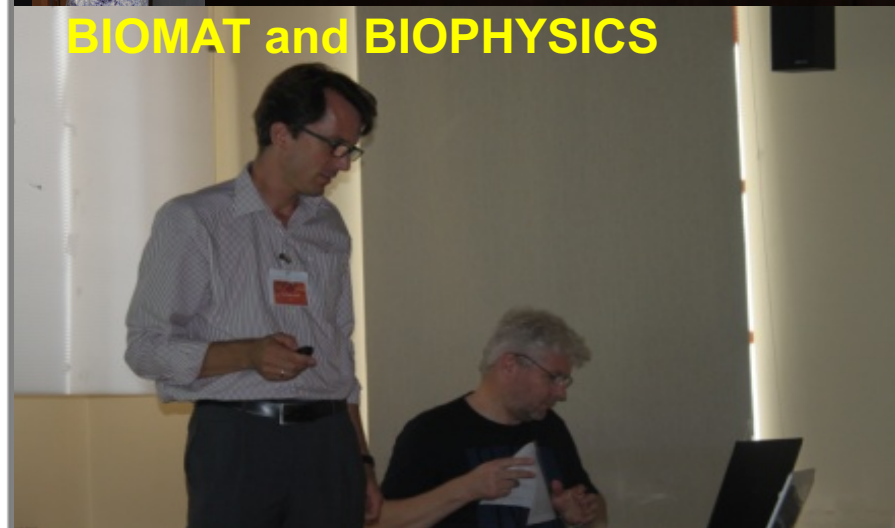
Web Assistants

E. Andronov (SPbSU, Russia)
K. Foka Sandoval (EPFL, Switzerland)
L. Graczykowski (WUT, Poland)
M. Janik (WUT, Poland)
A. Katanaeva (UB, Spain and SPbSU, Russia)
D. Shukhobodskaja (SPbSU, Russia)

Ions for
cancer therapy

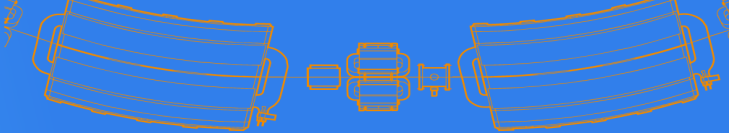


BIOMAT and BIOPHYSICS



Birth of IONS2017

Archamps, 19 June 2018



Highlight pioneering work at GSI

Publicize to students

- new research facilities**
- new directions in education**
- new job opportunities**



Venue

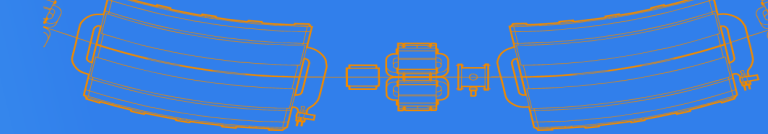


GSI/FAIR



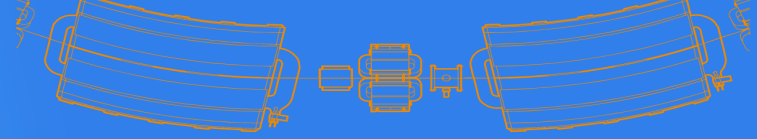
Chania technical university





[more photos](#)



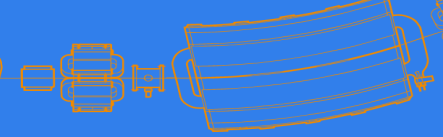


“The first of a series” !



[and
some
more
photos](#)

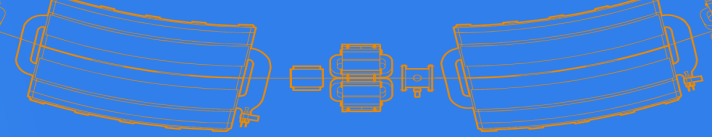




Opportunities for ion accelerators in medicine and industry	Maurizio Vretenar	14:00 - 14:30
Carbon linac developments in TERA and ADAM	Alberto Degiovanni	14:30 - 15:15
Medical applications of high frequency high gradient structures	Walter Wuensch	15:15 - 15:45
Linacs in heavy ion beam therapy facilities	Bernhard Schlitt	15:45 - 16:15
Coffee Break		
<u>Programme on-line</u>		
The CNAO accelerator and experience with ion therapy	Marco Pullia	16:15 - 16:45
		16:45 - 17:15
	Maurizio Vretenar	17:15 - 17:30
	Radek Pleskac	17:30 - 17:45
	Alexander Golubev	17:45 - 18:00
	Alexander Golubev et al.	18:00 - 19:00
Outcome of the Workshop	Maurizio Vretenar	19:00 - 19:10
Closing	Yiota Foka	



IONS2017 outcome



Workshop on Ions for Cancer Therapy, Space Research and Material Science

26-30 August 2017



Ideas and technologies for a next generation facility for medical research and therapy with ions ESL, Archamps, France

19-21 June 2018

Europe/Paris timezone

- Home
- Organization
- Scientific Programme
- Posters
 - Workshop Poster
 - Public Event 26.08
 - Public Event 27.08
 - Public Event 30.08
- Public Events
- Conclusions of the Workshop
- Published articles
- Agenda
 - Timetable
 - Locations
- Scientific Focus and Vision
- Dates and Announcements
- Registration
 - Registration Form
 - Registration Fees
 - Details of Payments
- Participant List
- My Contributions
- Practical Information
 - Venue
 - Accommodation
 - Social Events
 - Workshop Excursion

Scientific Programme [link](#)

Benefits for Society, Science for Health

Key speakers: Costas Bolas (Technical University of Crete), Karan Kaler (University of Calgary), Christina Kourkoumelli (National and Kapodistrian University of Athens), Cristina Montesi (INFN), Nektarios Papadogiannis (Centre for Plasma Physics and Lasers, T.E.C.), Suzanne Sheehy (University of Oxford)

Particle Therapy: Projects and Centers

Key speakers: Oana Actis (PSI), Evangelia Dimovasili (University of Cyprus), Grigori Fedorov (Saint Petersburg State University), Arnold Pompos (University of Texas), Marco Palla (Fondazione CNAO), Josep Seco (DKFZ Heidelberg), Thomas Stoeckler (Max-Planck-Institute Jena)

Treatment Planning and Imaging

Key speakers: George Dedes (LMU Munich), Christian Graeff (GSI), Wioletta Kozłowska (Medical University of Vienna), Dieter Roelrich (University of Begeji), Martin Schanz (GSI)

Radiation Studies and Space Research

Key speakers: Michael Campbell (GSI), Chiara La Tessa (University of Trento), Laure Sabatier (CEA), Christoph Schuy (GSI)

Accelerators for Medicine and Industry

Key speakers: Vretenar (GSI)

Biomedicine

Key speakers:

Published articles

Some publications on the Chania workshop may be found here:

- on 22 Issue of Accelerating News ARIES, see link <http://accelerating-news-arc.web.cern.ch/content/accelerating-health-and-space-research>
- on November issue of ALICE Matters, see link <http://alicematters.web.cern.ch/?q=content/node/1062>
- on December issue of CERN Courier, see <http://cerncourier.com/cws/archive/cern/57>, Crete workshop takes stock of hadron therapy
- on December issue of GSI Kurier 51-2017, see <http://www.gsi.de/kurier>, Workshop on hadron therapy, space research and materials science held in Greece

Home

Organization

Workshop Poster

Objectives and Scientific Programme

Agenda

Timetable

Registration

Registration Form

Participant List

My Contributions

Practical Information

Venue

Accommodation

Objectives and Scientific Programme [link](#)

The Conclusions (see [here](#)) and lively discussions of the first workshop "Ions for Cancer Therapy, Space Research and Material Science", that took place in Chania, Crete, 28th to 30th August 2017, underlined the need for a next generation research and therapy facility with ions in Europe.

Conclusions

Outcome Chania Workshop
M. Vretenar, conclusions and thoughts, 04.09.17

1. **Proton therapy** is rapidly progressing, thanks to easy commercial availability (cost for single-room center based on SC cyclotrons starting from 30-40 MEUR, down from 100-200 MEUR a few years ago. For comparison, conventional X-ray systems are at about 3 MEUR. There are several vendors on the market (ProBeam from Varian, Proteus from IBA) offering complete turnkey centers equipped with one or more gantries. Other vendors are Mevion (rotating SC cyclotron) and Hitachi (synchrotron). The number of facilities is rapidly increasing; it is a new instrument for doctors and leads to emulation between countries (case of Norway). Research is oriented towards delivery systems and optimizing treatment; nobody questions the accelerator.
2. While there is a lack of data for proton therapy and the diagnostics and delivery tools are still being developed, there is no evidence for a different **effectiveness** between X-rays and protons. The difference is in the quality of life (damage to healthy tissues, secondary cancer), and this is why usually protons are used for children. Example a 18-yo that was cured 10 years ago for a skull cancer. Only slightly visible effects, while X-rays would have damaged the bones and his face appearance. Quality of life studies are being started for children, but there is no interest from the doctors. Doctors remain reluctant to send patients to faraway proton therapy centers.
3. Instead, there is a clear indication that **carbon ions** have a strong potential. The damage to DNA cells cannot be repaired; they are effective with radio-resistant tumors (low oxygen) and might reduce metastasis that are the main cause of mortality (more than solid tumors or collateral damage). So far, 2/3 of cases treated at the multi-particle facilities (CNAO, HIT, etc.) are with carbon.
4. There is a need of clinical data, with carbon but as well comparing carbon and other ions. The community needs a flexible (and expensive, costs of the order of 200 MEUR) **research facility** that can make multiple ions, with the options of tests on cells, on animals and on patients, to compare carbon with other ions and to optimize doses and treatment. Options to explore is replacing p with He and C with O. A similar facility is planned in Dallas (Southwest University), and there are plans in India. A research facility should be planned in Europe, possibly with the support of the EC and using parts of the BioER proposal.
5. In parallel, there is clear need for a **compact carbon accelerator** at a cost < 100 MEUR. Should be an accelerator optimized for treatment with 1% charge-to-mass particles that could allow acceleration of fully stripped carbon or helium. There are 4 accelerator options: synchrotron, cyclotron, FFAG and linac. IBA is developing within an industrial consortium a cyclotron solution based on Cyclone C400, for the hadrontherapy center in Caen; it is complex but well advanced. Synchrotrons can allow only a minimum progress from the HIT-CNAO design. The FFAG (PAMELA) design





Workshop
 Location Archamps, France
 Venue: European Scientific Institute (ESI)
 Dates: 19-21 June 2018

Ideas and technologies for a next-generation facility for medical research and therapy with ions



MAIN TOPICS:

- ▶ EXISTING FACILITIES
- ▶ CURRENT INITIATIVES
- ▶ NEW TECHNOLOGIES
- ▶ DESIGN PARAMETERS
- ▶ TECHNICAL OPTIONS

<https://indico.cern.ch/e/ions2018>

photo credit: PIMMS2 Photos from Medical Machine Study

ORGANIZATION

International Advisory Committee

U. Amaldi (TERA, Italy)
 F. Bordry (CERN, Switzerland)
 J. Debus (PET, Germany)
 M. Durante (TIFPA, INFN, Italy)
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 R. Miralbell (HUG, Switzerland)
 S. Rossi (CNAO, Italy)
 H. Specht (Univ. of Heidelberg, Germany)
 E. Tsesmelis (CERN, Switzerland)
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 A. Zern (MedAustron, Austria)

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 Y. Foka (GSI & FAIR, Germany)
 C. Graeff (GSI & FAIR, Germany)
 M. Pulia (CNAO, Italy)
 L. Ribold (ESI, France)
 M. Vretenar (CERN, Switzerland)

Organizing Committee

V. Brunner (CERN, Switzerland)
 Y. Foka (GSI & FAIR, Germany)
 B. Holand (ESI, France)
 M. Janik (WUT, Poland)
 A. Katanaeva (IIB, Spain & SPSSU, Russia)
 L. Ribold (ESI, France)
 M. Vretenar (CERN, Switzerland)



Details by Maurizio



Cheerful optimism !
 Strong interest and push to advance !

**Convergence
 and Right Timing !**

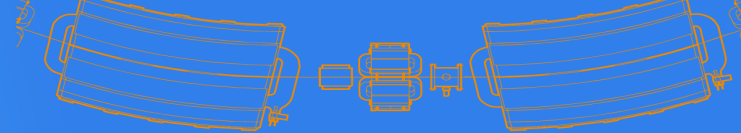
**Join efforts and expertise
 Open design for community**



Archamps, 19 June 2018

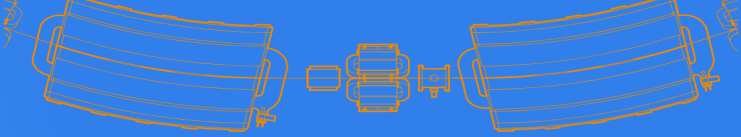


ESI support



Acknowledgements to:
Marie Gauthier
Bob Holland
Luis Rinolfi





Fruitful workshop, concrete outcome, offer to society.



- Home
- Organization
- Workshop Poster
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 - Registration Form
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 - My Contributions
- Practical Information
 - Venue
 - Accommodation
 - Social Events
 - CERN visits
- Workshop transportation
- Coming to CERN
 - Free shuttle CERN - Airport - CERN
- Information related to Pope visit
- Previous edition
- How to upload your presentation
- Contact
 - ions.2018@cern.ch

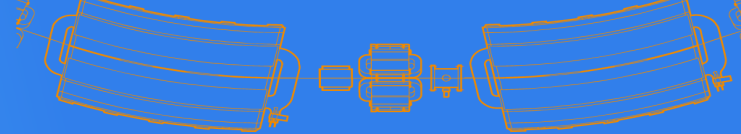
Agenda

Tue 19 June 2018		
	Programme Committee	
	M. Cirilli (CERN, Switzerland)	
	M. Dosanjh (CERN/ENLIGHT, Switzerland)	
09:00	Y. Foka (GSI & FAIR, Germany)	
	C. Graeff (GSI & FAIR, Germany)	
	M. Pullia (CNAO, Italy)	
10:00	L. Rinolfi (ESI, France)	
	M. Vretenar (CERN, Switzerland)	
11:00	ESI, Archamps	10:30 - 11:15
	Meeting point with the Bus at CERN Building 33, Main Reception	
	ESI, Archamps	11:15 - 11:30
	Bus Stop at the Geneva airport	
	ESI, Archamps	11:30 - 11:40
	Trip to ESI Archamps	
	ESI, Archamps	11:40 - 12:00
12:00	Buffet lunch	

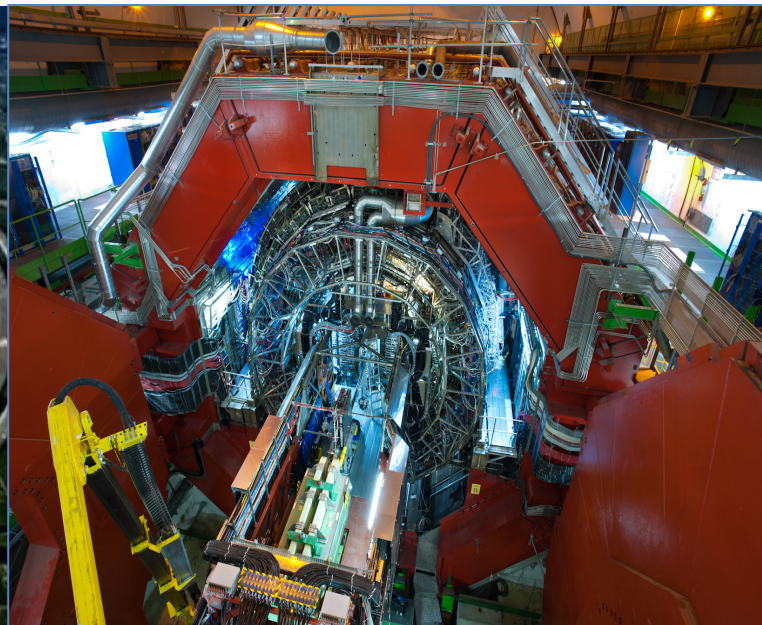
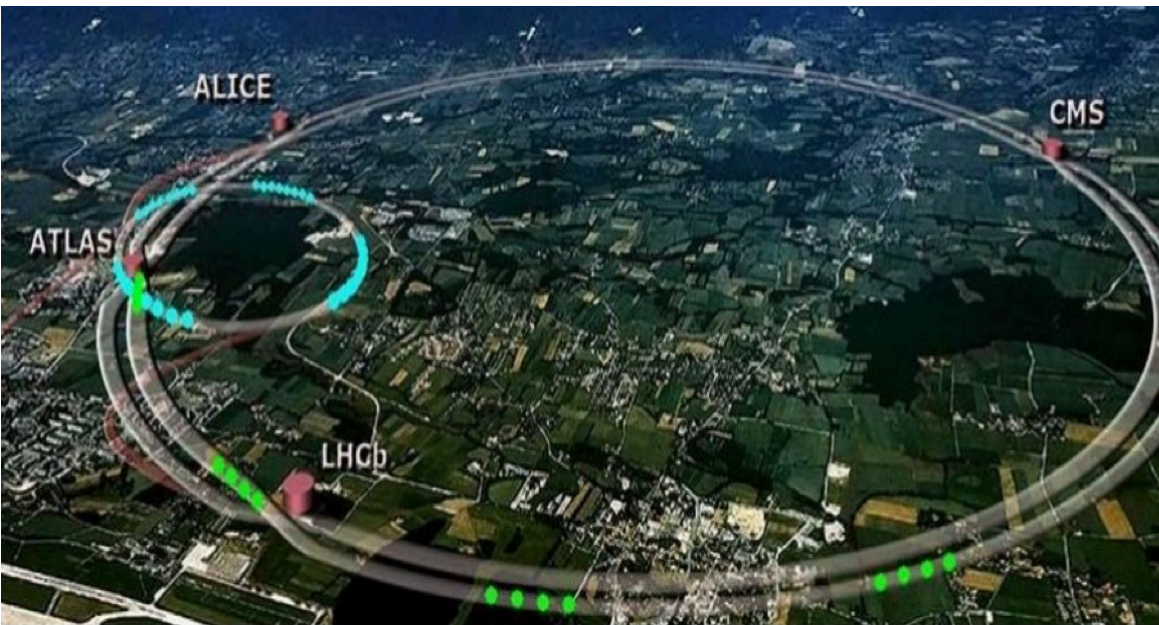
- ## International Advisory Committee
- U. Amaldi (TERA, Italy)
 - F. Bordry (CERN, Switzerland)
 - J. Debus (HIT, Germany)
 - M. Durante (TIFPA, INFN, Italy)
 - P. Giubellino (GSI & FAIR, Germany)
 - R. Miralbell (HUG, Switzerland)
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 - H. Specht (Univ. of Heidelberg, Germany)
 - E. Tsesmelis (CERN, Switzerland)
 - U. Weinrich (GSI & FAIR, Germany)
 - A. Zens (MedAustron, Austria)

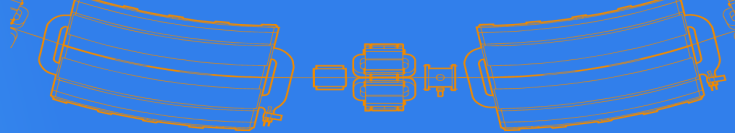
Please upload on Indico!
Instructions on [link](#).





Introductory Material. ... “Do it Yourself” visit ...

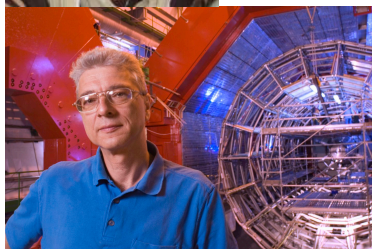




ALICE Public web Pages



Despina Chatziphotiadou
Outreach coordinator

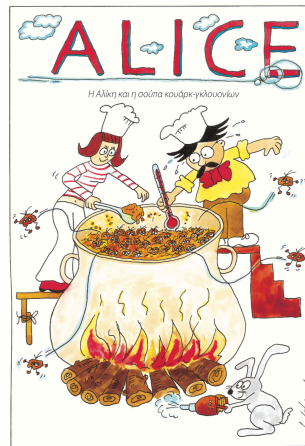


Jurgen Schukraft
First spoke-person



Served as
Deputy physics coordinator
Data Quality Monitoring and
Event Display coordinator
Outreach coordinator

Introduction for beginners

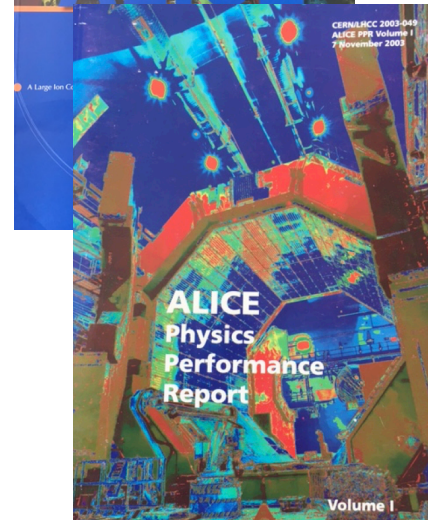
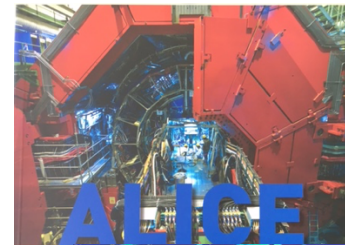


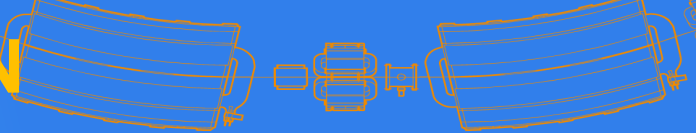
[ALICE Cartoon](#)

[Flying over ALICE](#)

[ALICE Virtual Tour](#)

[ALICE Video](#)





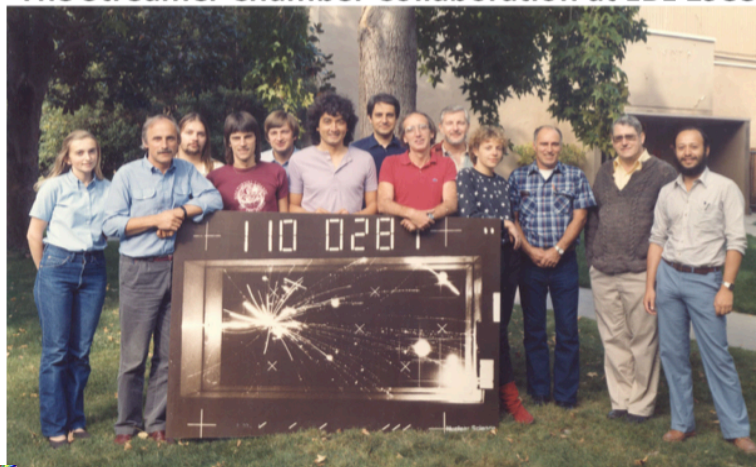
Berkley 1939



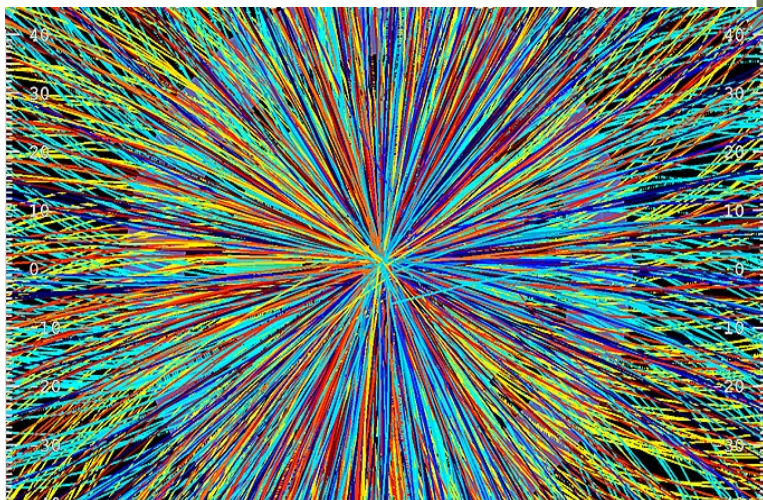
First direct irradiation of a patient, on the new 60-inch cyclotron

Berkley 1983

The Streamer Chamber Collaboration at LBL 1983



First PbPb event in ALICE

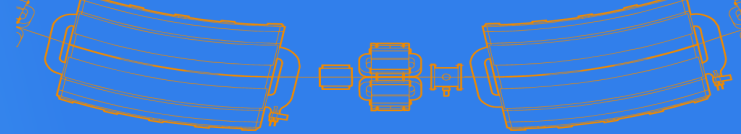


2000: CERN Press Release

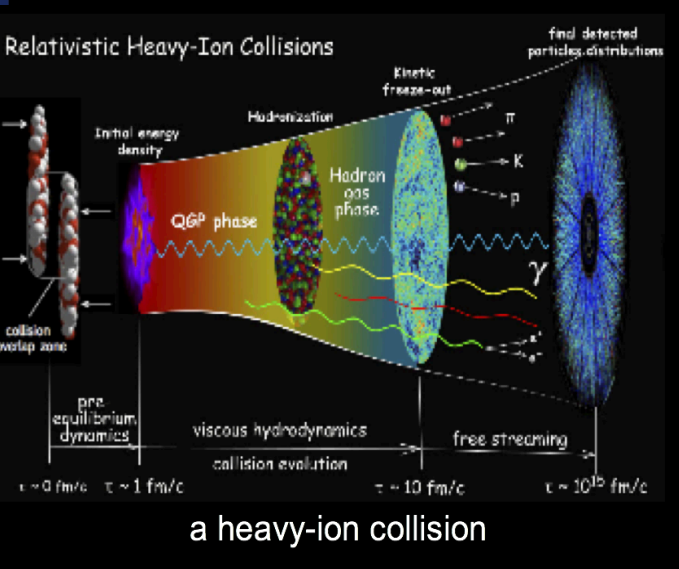
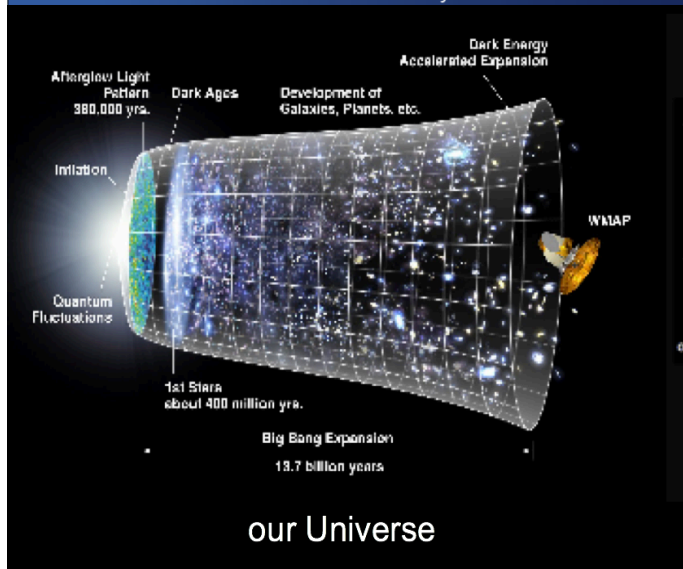
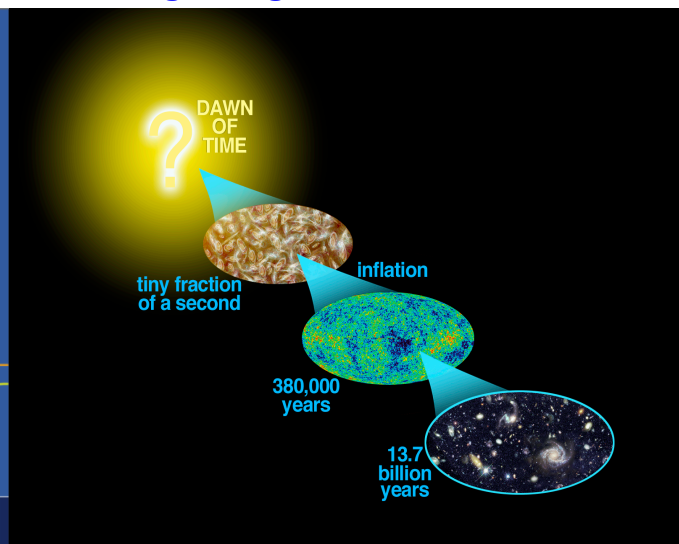
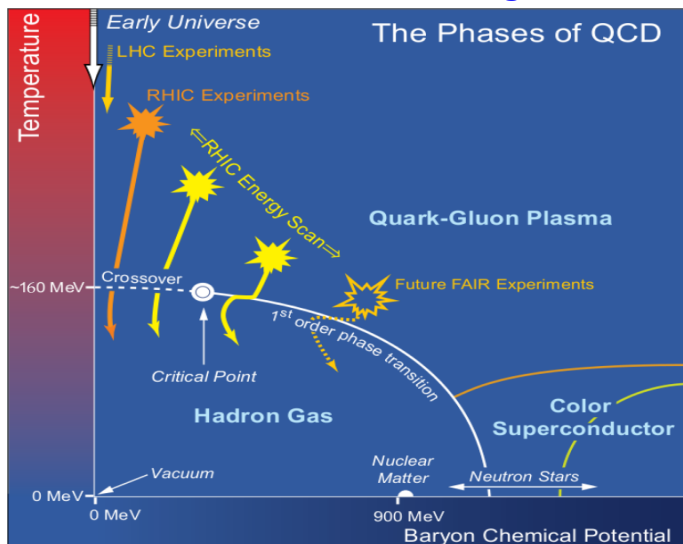
2016: 30 Years of HI, what next?

successful GSI/CERN collaboration!



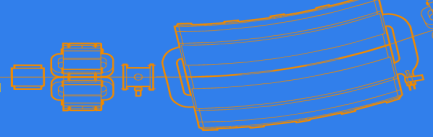


Analogies of Little and Big Bang See for instance [here](#)



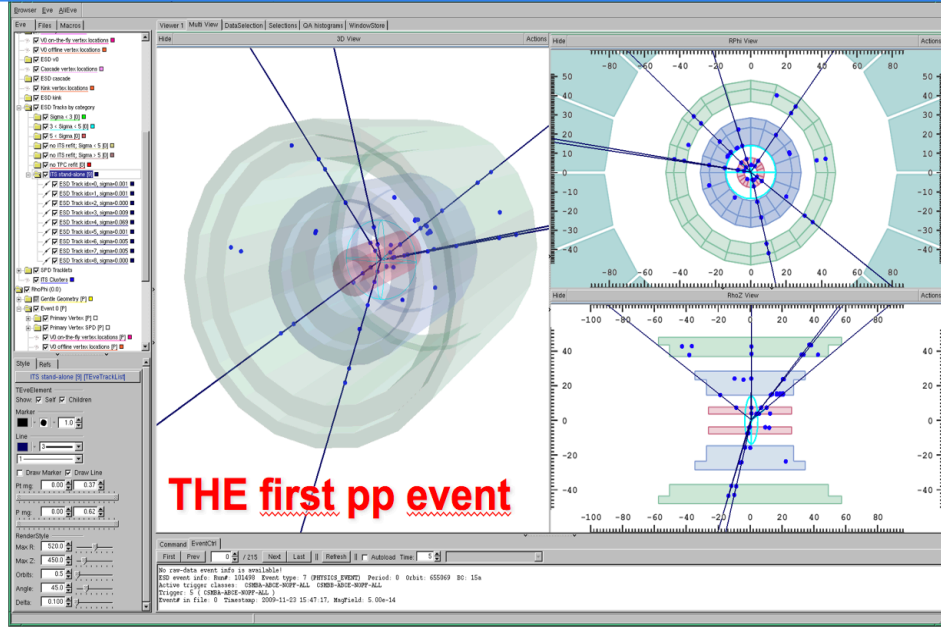


First LHC collisions in ALICE



First paper at LHC on multiplicity measurement

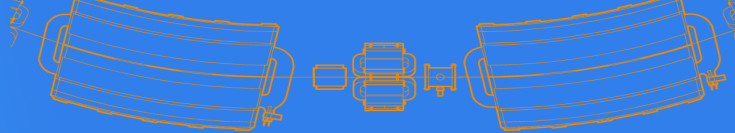
Published on Monday, 14 December 2009 16:00



At 17:21 the beams were dumped and the run closed with 284 events

At 17:28 the first mails with the first online reconstructed event were sent to the institutes

On 23rd November 2009, during the early commissioning of the CERN Large Hadron Collider (LHC), two counter-rotating proton bunches were circulated for the first time concurrently in the machine, at the LHC injection energy of 450 GeV per beam, allowing all LHC experiments to report first collision candidates.



QM2018 Venice

Understanding pp collisions

strangeness

baryon production mechanisms

Probes of HI Collisions

- Summary

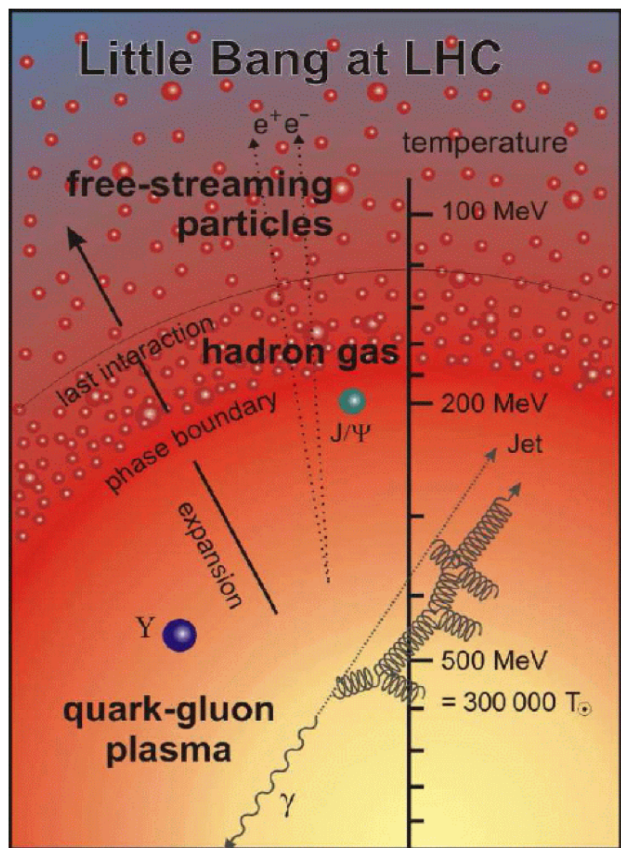
Global bulk event properties

- multiplicities, energy density, temperature
 $\epsilon \sim 15 \text{ GeV/fm}^3$ $T = 300 \text{ MeV}$
- space-time evolution of the emitting source:
HBT: $V \sim 5000 \text{ fm}^3$ $\tau \sim 10 \text{ fm/c}$
- degrees of freedom as a function of T :
hadron spectra and ratios
 $\mu_\beta = 1 \text{ MeV}$, $T \sim 155\text{-}164 \text{ MeV}$
- early state collective effects
 $\langle \beta \rangle \approx 0.65$, $\eta/s \sim 0.2$
- direct thermal photos
 $T_0 = 300\text{-}500 \text{ MeV}$

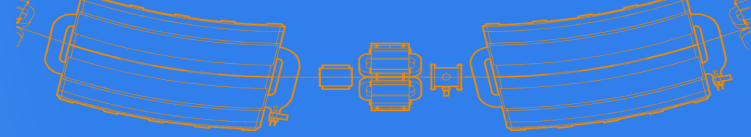
Medium induced effects

- parton energy loss:
high p_T spectra,
open charm and open beauty
transport coefficients, v_2 and R_{AA}
- deconfinement:
charmonium and bottomonium spectroscopy

**Era of precision measurements
Towards Standard Model of Little Bang**



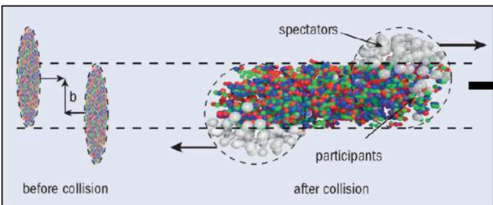
soft
↓
hard probes



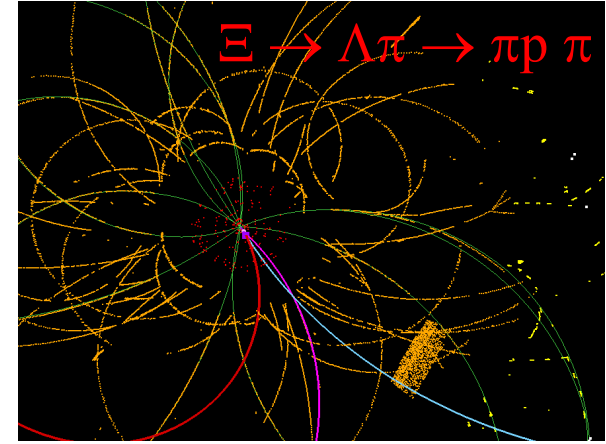
New Year CERN DG 2018



ALICE



Heavy Ion collisions: conditions of high density and temperature of nuclear matter \rightarrow formation of a plasma of deconfined quarks and gluons (QGP).

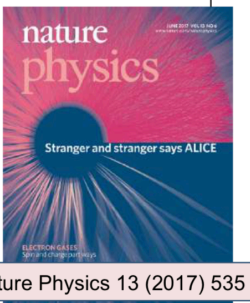


J. Rafelski, Arizona Strangeness QGP September 22, 2011, SQM2011 page 2

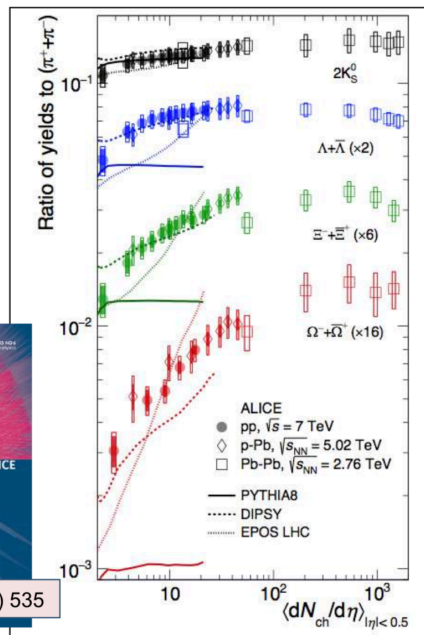
Enhanced production of strange particles historically considered to be one of the manifestations of QGP formation

First observed at CERN in the 90's (WA97, NA57, NA49). Later at RHIC and by ALICE

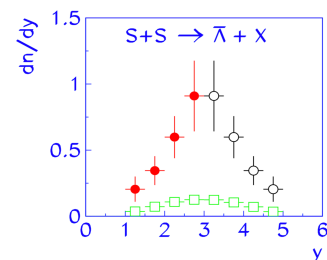
Now observed by ALICE also in high-multiplicity pp interactions \rightarrow Is this due to QGP formation in "small systems" (pp, p-Pb) at high multiplicity (already hinted by particle correlations, so-called "ridge")? Observation not reproduced by pp MC models \rightarrow opens new directions of (joint) theoretical and experimental studies in pp and HI



Nature Physics 13 (2017) 535



Central Rapidity Fireball and QGP

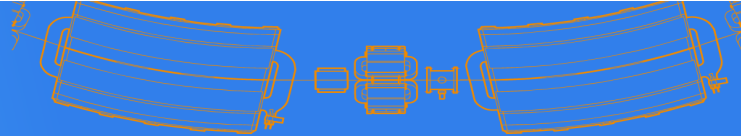


First antibaryon enhancement result, 1990-94, SPS-NA35II EXCESS $\bar{\Lambda}$ emitted from a central well localized source. Background (squares) from multiplicity scaled NN reactions. From Yiota Foka, PhD Thesis, Geneva University 1994.



Conclusion: by early 1990's we have convincing evidence of QGP formation at SPS energy heavy ion collisions including S-S.

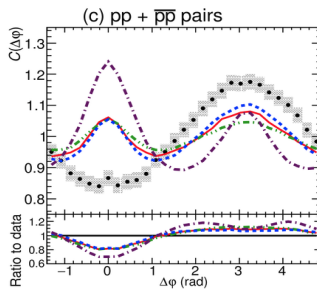
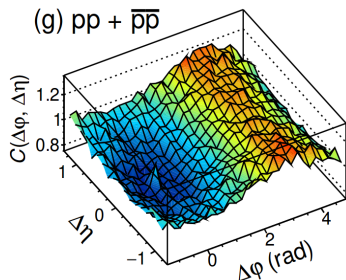




Baryon production mechanisms to be understood



MJ Thesis,
arXiv: 1612.08975 (EPJC)



ALICE PID studies: Baryons, protons, in minimum pp events

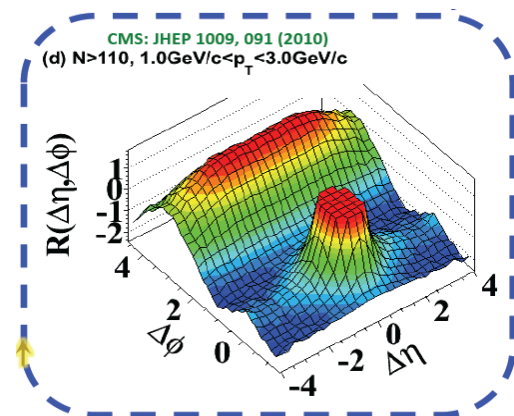
Understanding biological effects

Radiation-induced DNA damage

Credits: T. Nomiya, NIRS Japan

Radiation can kill cancer cells by damaging their DNA. X-rays can hit or miss the DNA. Protons are slightly more lethal to cancer cells than X-rays. Carbon ions are around 2-3 times as damaging as X-rays.

First discovery at LHC: CMS “Ridge” in high multiplicity pp

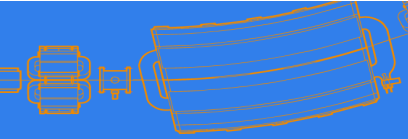


Re-analysis of ALEPH ee
and HERA ep data
to understand
where such patterns appear.

Understanding fundamental interactions !



Next generation of scientists



<http://physicsmasterclasses.org>

In 2018

14 000 students

52 countries

225 institutes

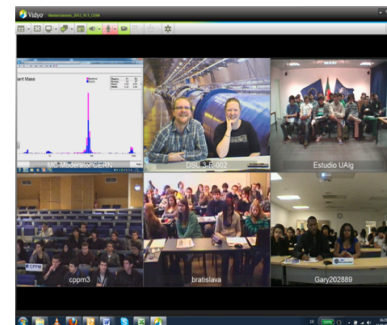
Discussion on implementing Masterclass for Therapy

Every year, during the months of February-March school-children (15-19 year old) are invited to an institute of their area.

They are exposed to the world of high-energy physics

Hands-on measurements with real LHC data

International video conference (3-5 institutes) moderated by CERN or Fermilab



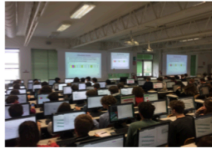
INTERNATIONAL MASTERCLASSES



Hands on Particle Physics

INTRODUCTION

International Masterclasses¹ are a successful tool to engage young people with particle physics. High school students are offered the chance to become scientists for one day and perform a tailor-made physics analysis involving real LHC data under the supervision of physicists. In this way students experience methods and tools used in research and an appreciation for fundamental science is created.



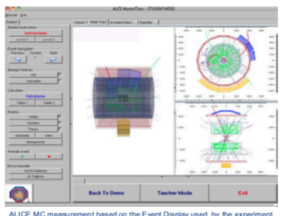
CONCEPT

- High school students (15-19 years old) are invited to a university or research lab
- Introductory talks (standard model, detectors, accelerators)
- Hands-on: measurement with LHC data (ALICE, ATLAS, CMS, LHCb)
- International videoconference (3-5 groups + moderators at CERN / Fermilab)
- Organized by IPOG²



MEASUREMENTS

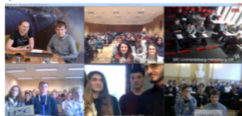
Measurements³ with data from ALICE, ATLAS, CMS, and LHCb have been developed for International Masterclasses. Students are introduced to basic concepts of particle identification and event classification. They work with event displays and tools also used by scientists. The basic idea of each measurement is a question related to particle physics. The results lead students to new and fundamental insights in this field. Tasks for students include for example revealing the structure of the proton, rediscovering the Z boson, the search for the Higgs particle or signatures of quark-gluon plasma. All material is free to use for any educational purpose.



ALICE MC measurement based on the E-vent Display used by the experiment.

VIDEOCONFERENCE

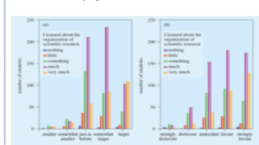
At the end of their Masterclass, students connect to a videoconference with CERN or Fermilab and groups from other countries. Moderators combine students' results and discuss them with participants. In addition, the videoconference includes a Q&A session and a Quiz.



Videoconference with moderators at CERN (top left) and 5 groups.

EVALUATION

Evaluations have shown that students enjoy Masterclasses. The appreciation is independent of gender and pre-knowledge. Three-quarter of the participants reported that they learned much or very much about the organization of scientific research. In addition, students increase their general interest in physics and wish to have more modern physics at school⁴.



After a whole day of particle physics students' motivation is raised.

PARTICIPATION

Since its beginning in 2005, the program has steadily grown⁵. In 2018, more than 220 universities and research labs in 52 countries participated with 14,000 students getting their hands on real data from the LHC. The worldwide participation reflects the international collaboration in particle physics.



World map (left) and map of Europe (right) showing in green countries participating in International Masterclasses.





Fundamental Research
and Benefit to Society

Thank you !

*successful take off !
and
successful landing !*