



HiLumi
HL-LHC PROJECT



IPAC20



EPS

Superconducting magnets and accelerators: technology for extending our knowledge

talk for the **EPS-AG/IPAC'20 Rolf Wideröe Prize**

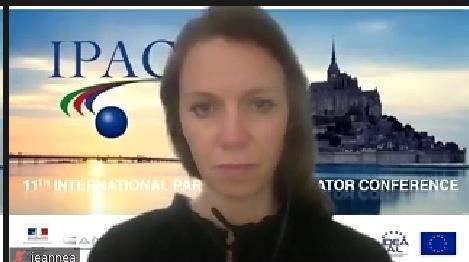
Lucio Rossi

CERN, High Luminosity LHC Project Leader
(on leave from University of Milano)

IPAC2020 – Thursday 14 May - EPS-AG/IPAC'20 prize award session



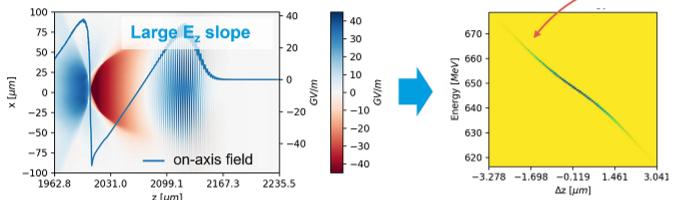






Energy spread in plasma accelerators

General overview



- Large correlated energy spread.
- Main source of energy spread (typically 1-10%).

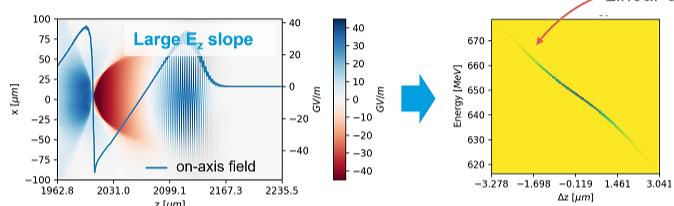
- Energy chirp can be mitigated through **beam loading** (beam can flatten E_z if peak current is large enough). [S. Van der Meer, 1985; T. Katsouleas, 1987]
- Several alternative **chirp compensation** [G. Manahan, 2017; R. Brinkmann, 2017] and **beam stretching** [A. Maier, 2011] schemes have also been proposed but not yet demonstrated. **Plasma dechirper** only with RF beams [D'Arcy et al, 2019; V. Shpakov et al, 2019; Wu et al, 2019]

See talk by R. D'Arcy (MC3)



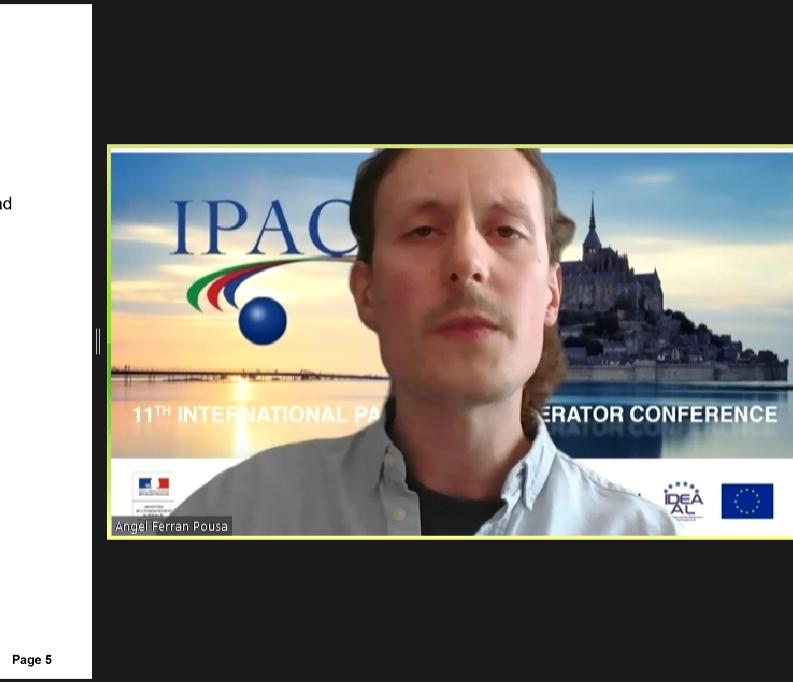
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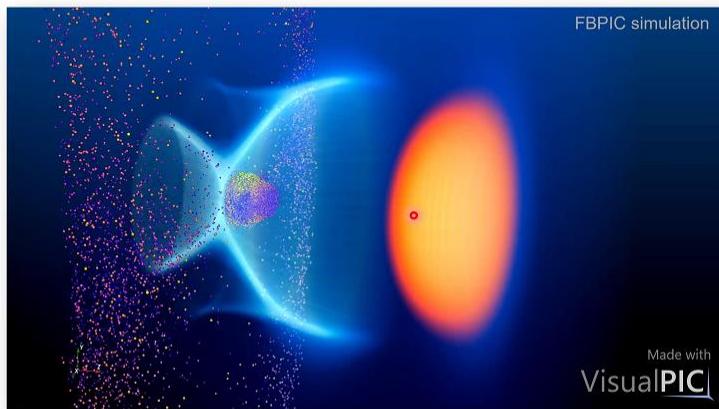
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Improved understanding of energy spread sources

Differences in path length due to betatron motion

- Usually subtle effects become relevant in plasma accelerators due to ultra-strong ($> \text{MT/m}$) focusing fields.



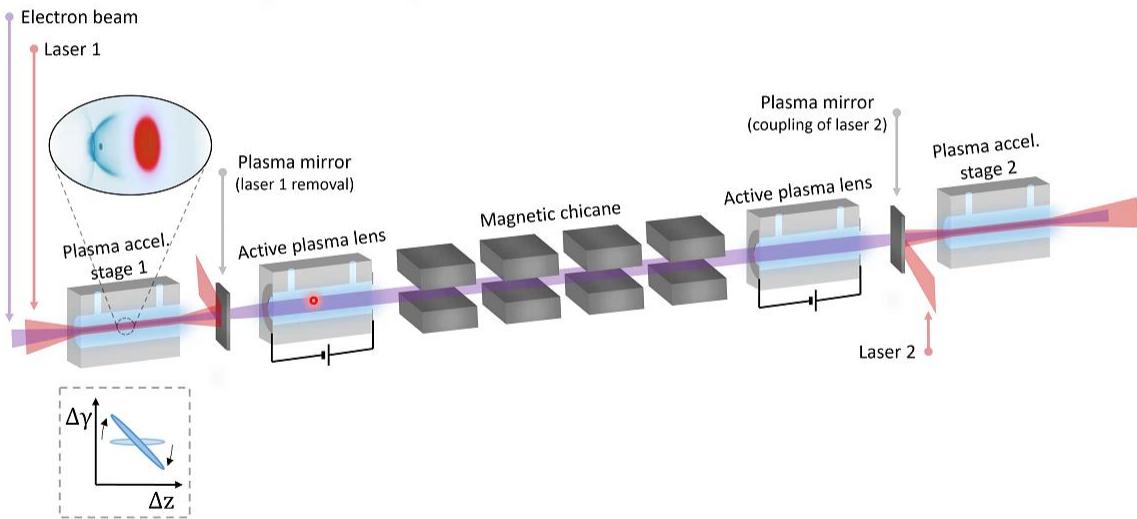
DESY | Multistage plasma-acceleration concept for ultra-low energy spread beams | Ángel Ferran Pousa, 14/05/20

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New plasma-acceleration concept

Acceleration in two stages with a magnetic chicane



DESY | Multistage plasma-acceleration concept for ultra-low energy spread beams | Angel Ferran Pouso, 14/05/20

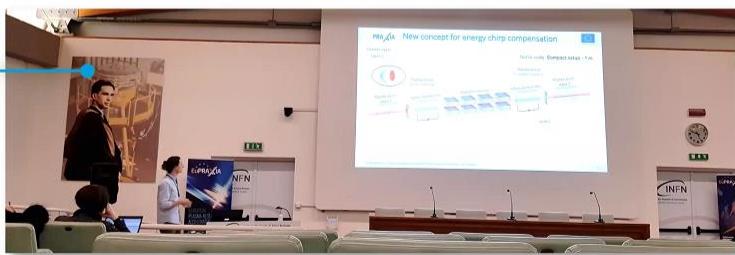
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Thank you!

Special thanks to:

- EPS-AG/IPAC'20 Accelerator Prizes Selection Committee, chaired by Gianluigi Arduini (CERN).
- My supervisors R. Assmann (DESY), F. Grüner (Uni Hamburg) and A. Martinez de la Ossa (DESY).
- R. Brinkmann (DESY), with whom I had the pleasure to work with while developing these concepts.
- All my colleagues from the MPY-1 group at DESY and EuPRAXIA collaborators.
- My family and girlfriend.



First public presentation of multistage concept in Frascati, under the close supervision of Touschek.





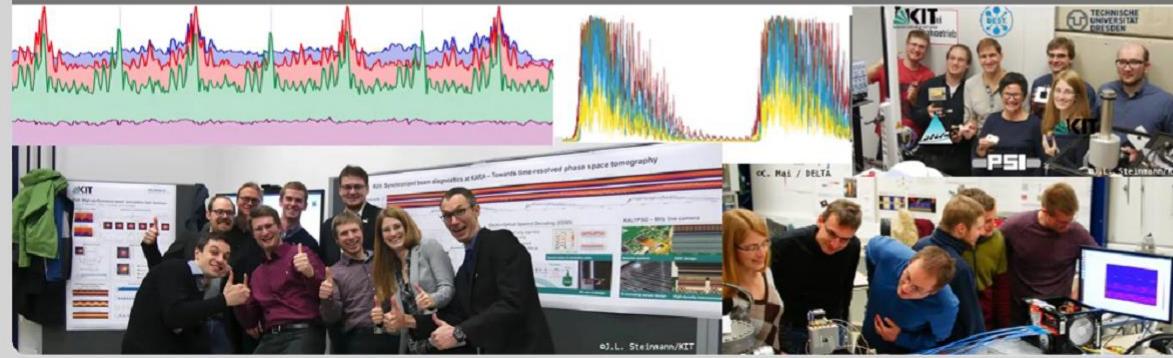


Diagnostics of short electron bunches with THz detectors in particle accelerators

Johannes L. Steinmann*

Institute for Beam Physics and Technology (IBPT)

*on leave to Argonne National Laboratory, Lemont, IL, USA

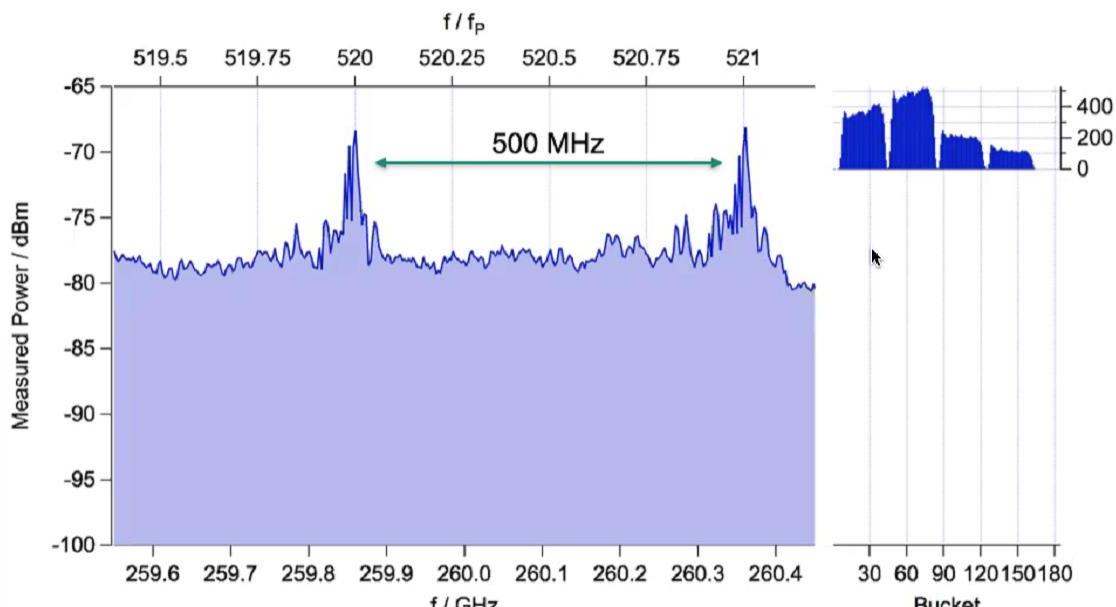


www.kit.edu

KIT – The Research University in the Helmholtz Association



Spectra of Different Filling Patterns



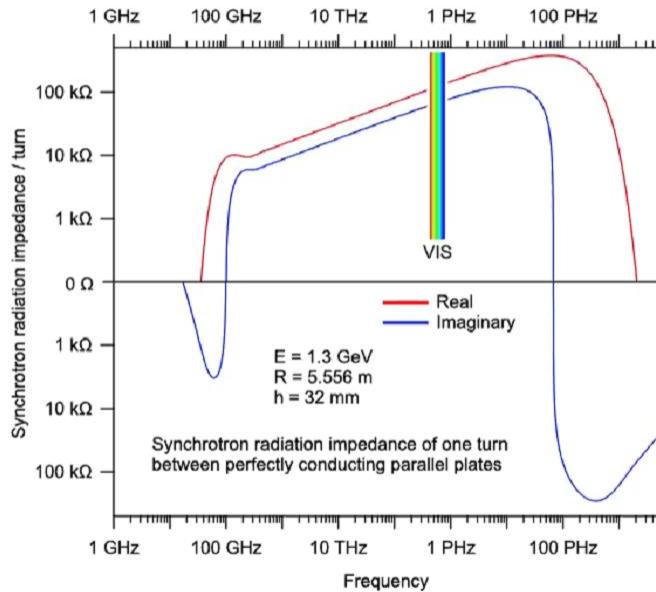
Published in: J.L. Steinmann et al., "Frequency comb spectrum of periodic patterned signals", *Phys. Rev. Lett.* 117(17), 174802 (2016)

"Superradiant" frequencies were first observed at the Canadian Light Source: B. E. Billingshurst, et al., "Observation of superradiant synchrotron radiation in the terahertz region", *Phys. Rev. ST Accel. Beams* 16, 060702 (2013), DOI: 10.1103/PhysRevSTAB.16.060702



Theory: Microbunching Instability

- Low frequencies shielded by vacuum chamber
- "parallel plates"-impedance
- Real part = energy loss



Equations taken from:

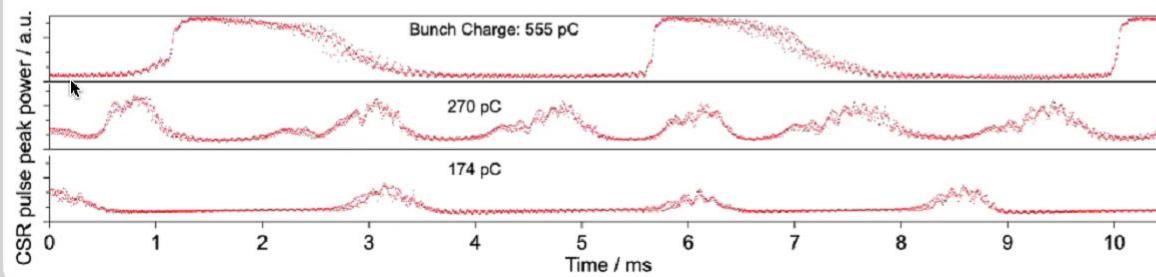
Low frequencies: T. Agoh. „Steady fields of coherent synchrotron radiation in a rectangular pipe“. In: Phys. Rev. ST Accel. Beams 12 DOI: 10.1103/PhysRevSTAB.12.094402
High frequencies: R. Li and C.-Y. Tsai. „CSR Impedance for Non-Ultrarelativistic Beams“, IPAC 2015. DOI: 10.18429/JACoW-IPAC2015-MOPMN004



Bunch-by-bunch and turn-by-turn diagnostics

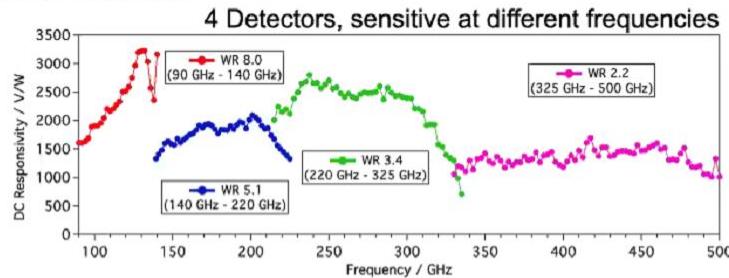


- Fast THz detectors can resolve single pulses
- Observing bunches over multiple revolutions
- Microbunching instability leads to bursts of radiation
- Charge dependent behavior



Requirements for fast THz-Spectrometer

- Able to resolve single bunches (500 MHz / 2 ns), no averaging
 - Not possible with interferometer
- Long-term recording (seconds) for analysis of bunch dynamics
 - Not possible with oscilloscopes
- KAPTURE readout system: DAQ developed at the KIT
- Based on frequency selective detectors



Many thanks to M. Caselle, M. Weber and their team at IPE/KIT for developing this amazing readout system and adapting it to my needs

M. Caselle, et al., "An ultra-fast data acquisition system for coherent synchrotron radiation with terahertz detectors", J. Inst, 9, (2014), DOI: 10.1088/1748-0221/9/01/c01024

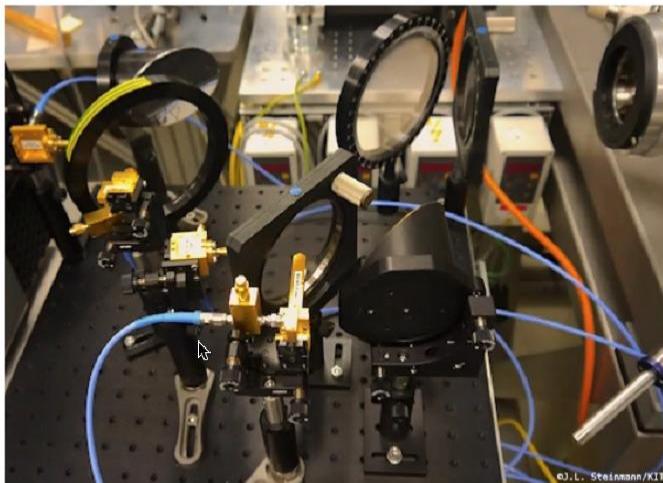
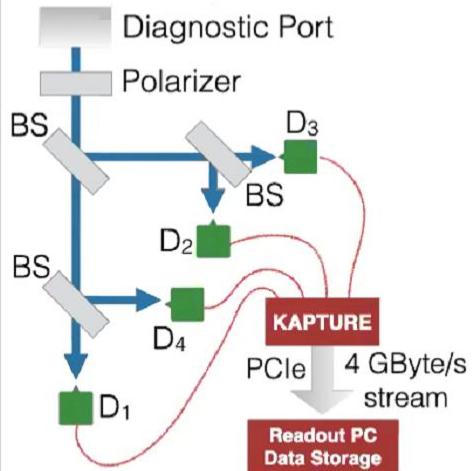
M. Caselle, et al., "A Picosecond Sampling Electronic 'KAPTURE' for Terahertz Synchrotron Radiation", IBIC (2014), <http://jacow.org/IBIC2014/papers/moczb1.pdf>

M. Caselle, et al., "Commissioning of an Ultra-fast Data Acquisition System for Coherent Synchrotron Radiation Detection", IPAC (2014), DOI: JACOW-IPAC2014-THPME113

M. Caselle, et al., "KAPTURE-2. A picosecond sampling system for individual THz pulses with high repetition rate", J. Inst, 12, (2017), DOI: 10.1088/1748-0221/12/01/C01040

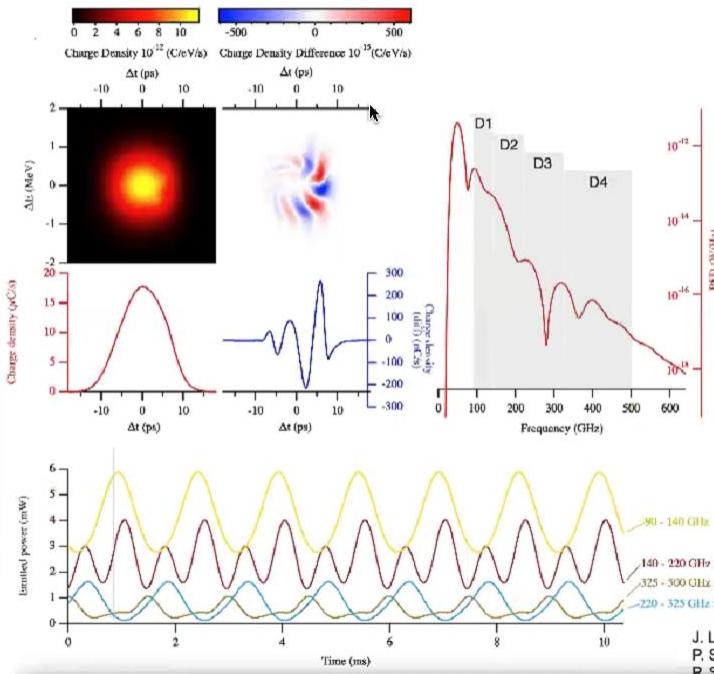


Single-Shot 4-Channel Spectrometer

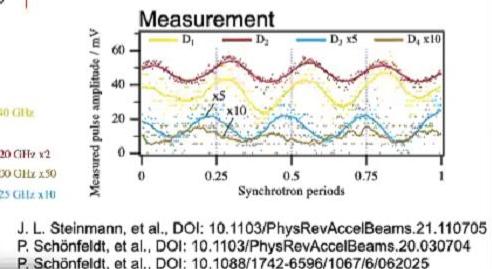


J. L. Steinmann, et al., "4-Channel Single Shot and Turn-by-Turn Spectral Measurements of Bursting CSR", DOI: 10.18429/JACoW-IPAC2017-MOPAB056
J. L. Steinmann, et al., "Continuous bunch-by-bunch spectroscopic investigation of the microbunching instability", DOI: 10.1103/PhysRevAccelBeams.21.110705

Simulation with Inovesa



- Vlasov-Fokker-Planck solver
- Developed at KIT
- Open source: github.com/inovesa
- Longitudinal phase space
 - Longitudinal bunch profile
 - Emitted CSR spectrum
 - Detector range
 - Power evolution
- Compare to measurement
- Improve physics model

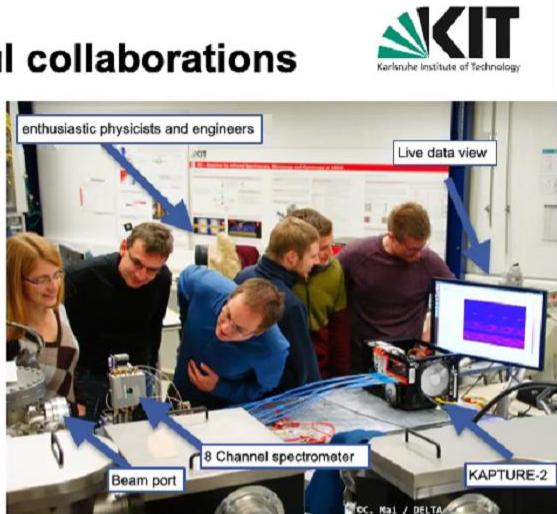


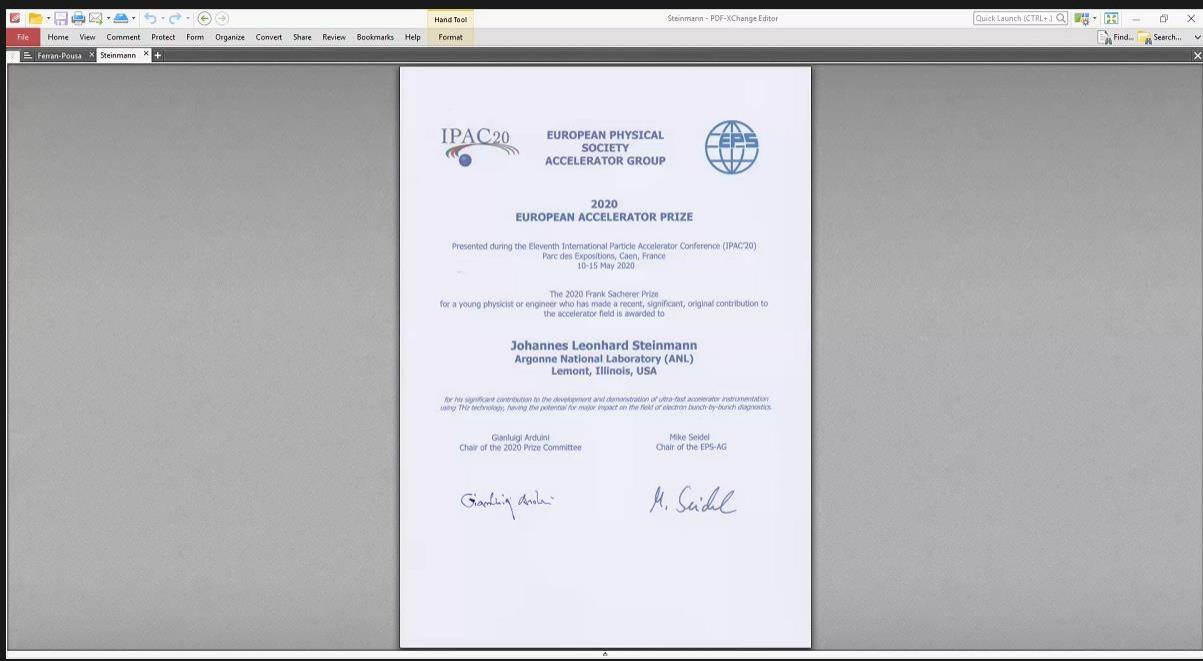
Johannes Steinmann

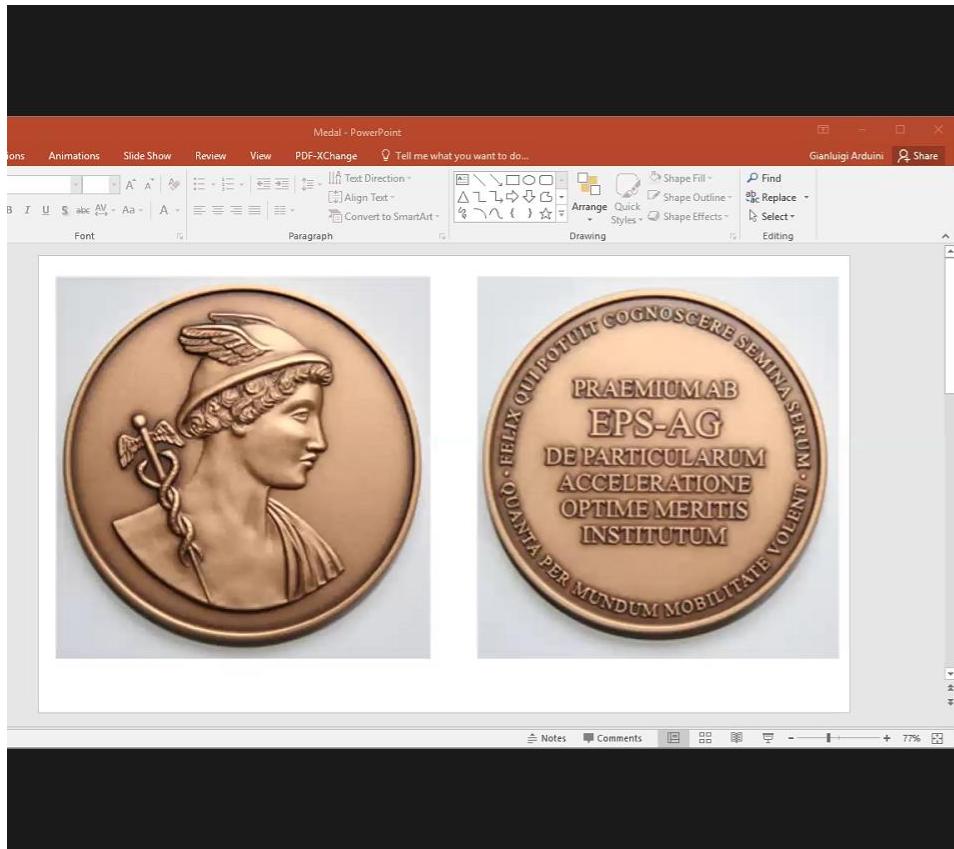
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INTERNATIONAL PARTICLE ACCELERATOR CONFERENCE

Thank you for all the wonderful collaborations



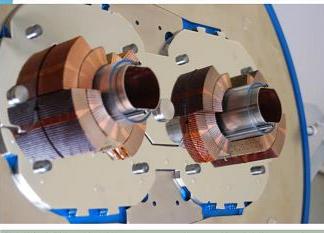




Superconducting Magnets Collider: Hall of Fame

DIPOLE MAGNETS

LHC has been the summit of > 40 y developments with SC Nb-Ti magnets. Magnet design soon converged to Cos9



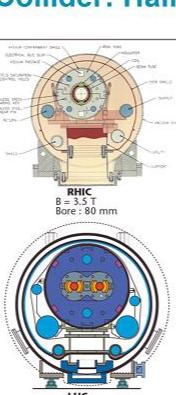
LHC Dipole Cross section: Cos9 layout



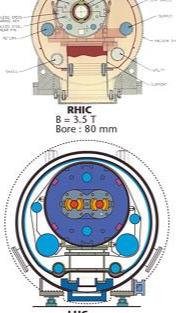
HERA
B = 4.7 T
BORE : 75 mm



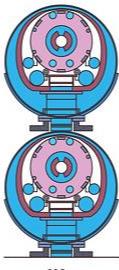
TEVATRON
B = 4.5 T
Bore : 76 mm



RHIC
B = 3.5 T
Bore : 80 mm



LHC
B = 8.3 T
Bore : 36 mm



SSC
B = 6.6 T
Bore : 50-50 mm

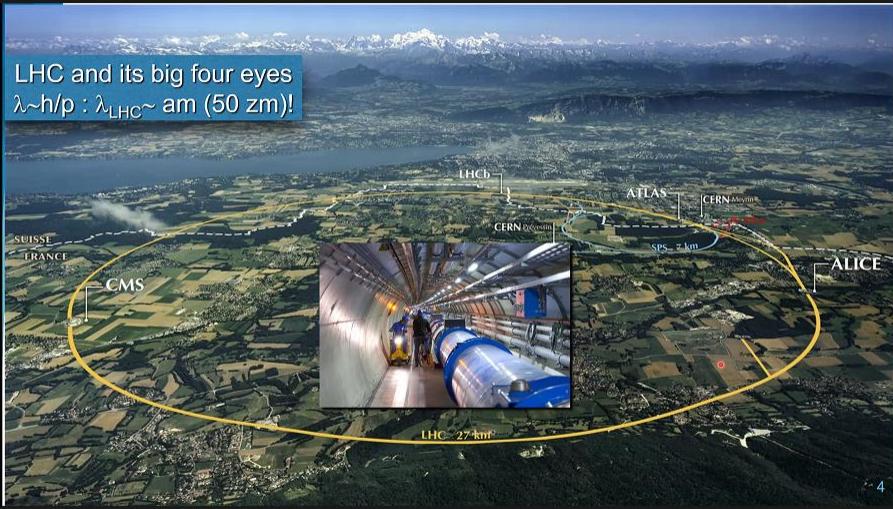
CERN-HE-109-BRIC-2020/09/20

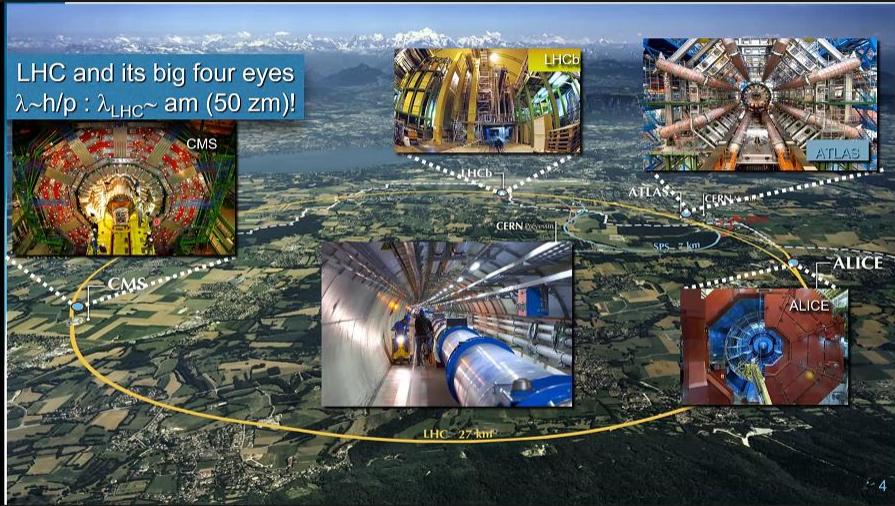
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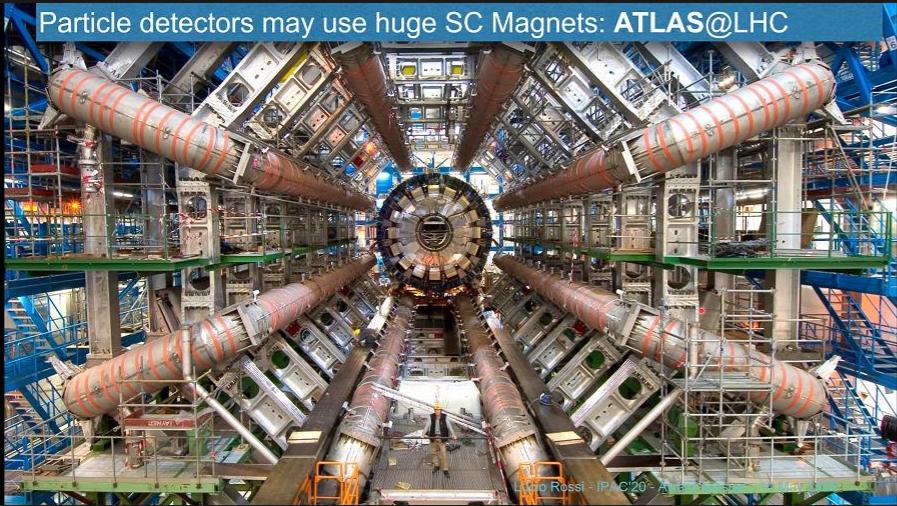
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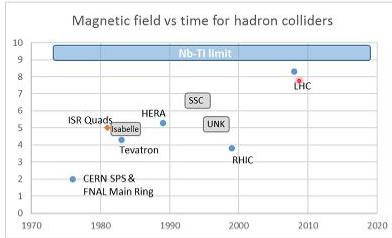






Hadron Colliders are ruled by: $E_{beam} = 0.3 R * B$ (TeV; km; T)

< 10 y to double field: 2 T MR → 4 T Tevatron
> 20 y to double again in SC: → 8 T of LHC



Consideration on LHC

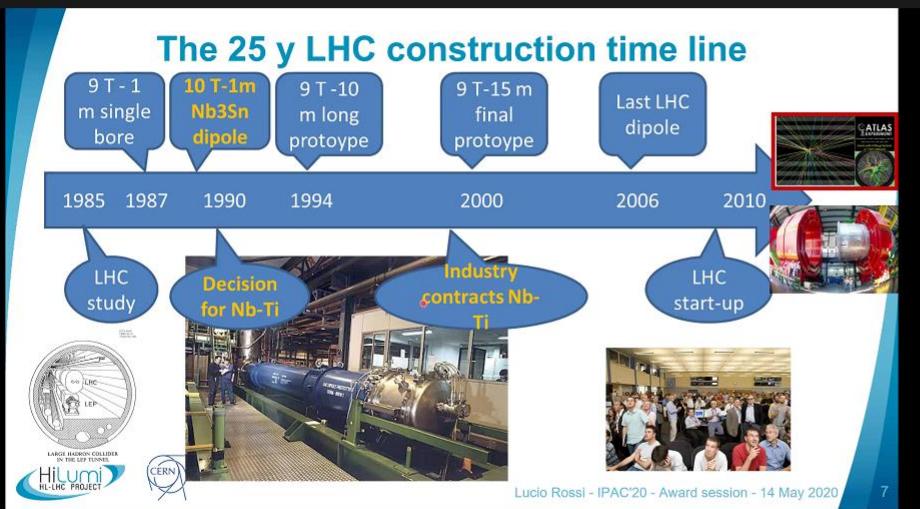
- Designed for 8.33 T (14 TeV c.o.m.) with margin to go to 9 T (15 TeV c.o.m)
- Today operating at **7.75 T** (13 TeV)
- **8.33 T in 2021 possibly**
- **9 T may be in 2026/2030 with HiLumi but very difficult (trade off with loss of lumi)**

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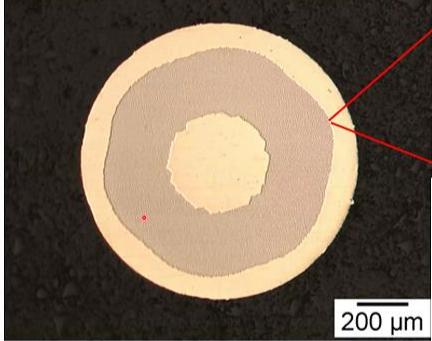
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The key factor: superconductor (but not the only factor!)



Developing SC is the key in SC accelerators. LHC is indebted to SSC

The perfection of LHC superconductor is such that we basically «forget» the SC effects and is the base of the repeatability and optimal performance of the collider

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Accelerator Magnets Basic Design

e.m. Forces support - Protection following a quench

Principle

e.m. forces NOT SELF-SUPPORTING

J_{overall} ≈ 500 A/mm² ! e.m. forces are not kept by conductors but tend to tear apart the winding.

Reality

Protection: $P = \rho J^2$

$J = 1000 \text{ A/mm}^2 \text{ in Cu}$
 $\Rightarrow P = 100 \text{ W/cm}^3 @ 4 \text{ K}$
 $= 10 \text{ kW/cm}^3 @ 300 \text{ K}$
 100 ms to cut down current in the LHC magnets (10 ms in HiLumiLHC)

HiLumi PRO

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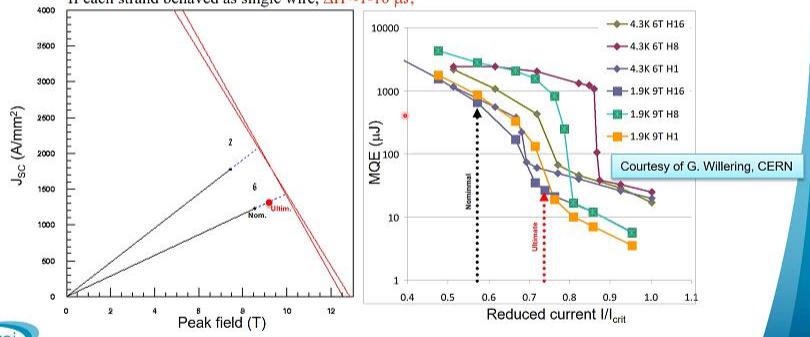
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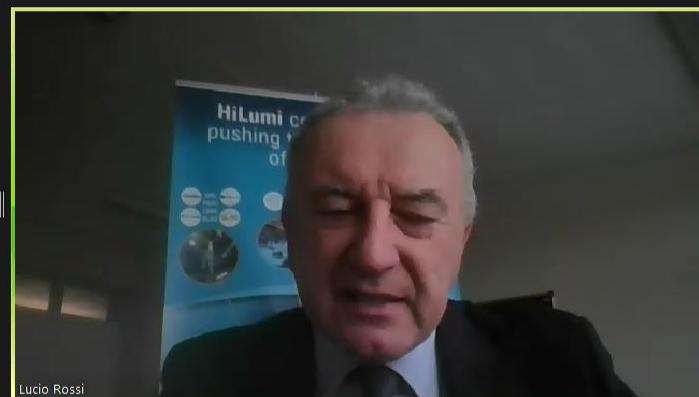
Huge forces, and little margin: also stability at LHC is a problem! TRAINING!

If there is no stabiliser, only NbTi, we see that $l \approx 1 \mu\text{m} \Rightarrow \Delta H \sim 1 \text{ nJ}$ only !!

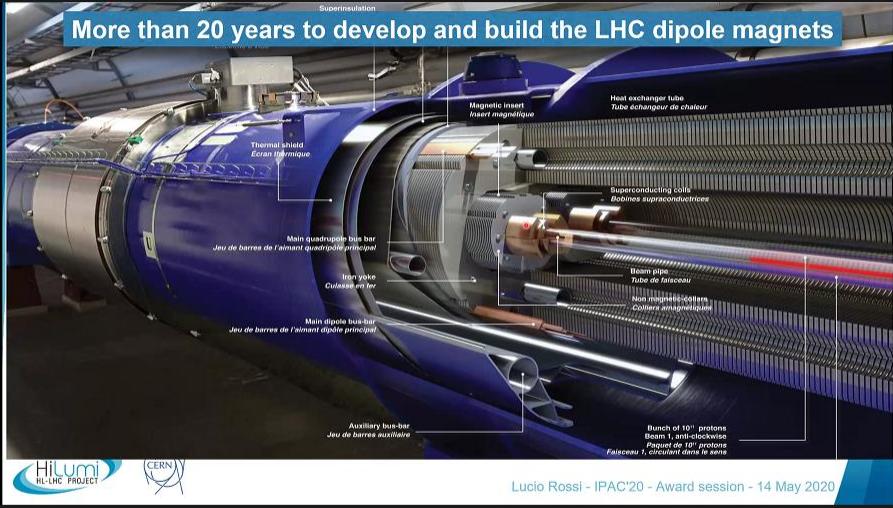
If each strand behaved as single wire, $\Delta H \sim 1-10 \mu\text{J}$



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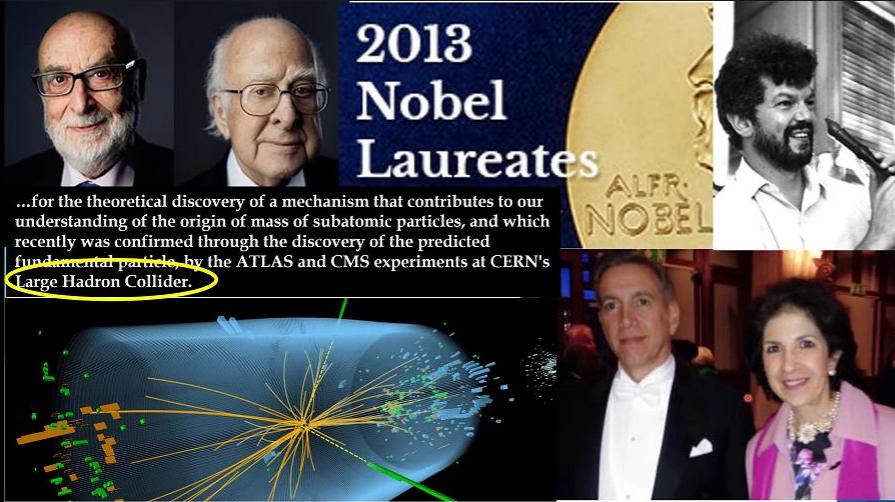


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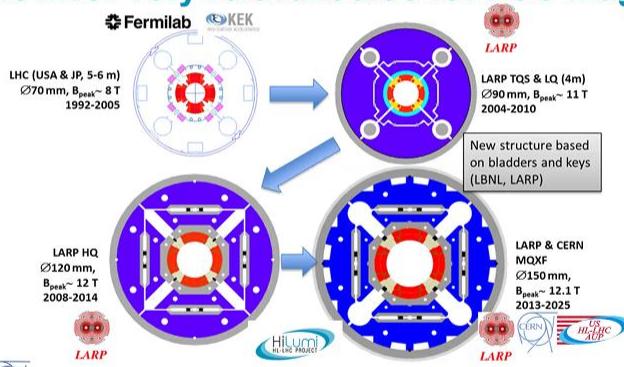


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New IT quadrupole. Increase in field but also in size wrt LHC. Very relevant also for FCC magnets



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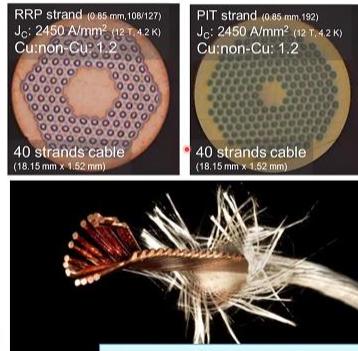
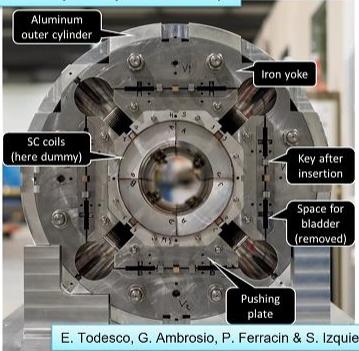
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New structure to accomodate brittleness of the Nb₃Sn superconductor

Key&Bladder system by LBNL, S. Caspi



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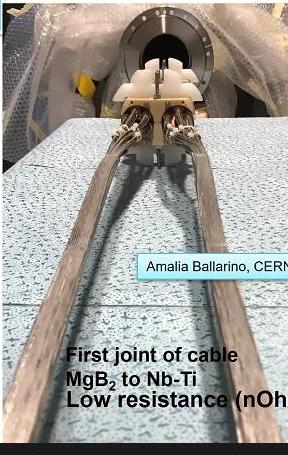
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SC Links inside flexible cryostat: first 60 m long prototype 20 kA cable tested at CERN

First long length of 20 kA
MgB₂ cable (IT Quad circuit)



First joint of cable
MgB₂ to Nb-Ti
Low resistance (nOhms!)



Many magnets designed and manufactured via collaboration

KEK-JAPAN

D1 – KEK

Q4 MQYY – CEA Saclay (QUACO)

Nested orbit correctors – CIEMAT Madrid

Superferric HO Correctors INFN-Milano LASA

Test @ 2.17 K (1h @134.4 A i.e. 108% nominal current)
No-training
3 natural quenches @241 A, i.e. 97% of short sample limit 4.2 K

HL-LHC WP3
E. Todesco et al.

Iron field map when both dipoles are simultaneously powered

CIEMAT Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

INFN Istituto Nazionale di Fisica Nucleare

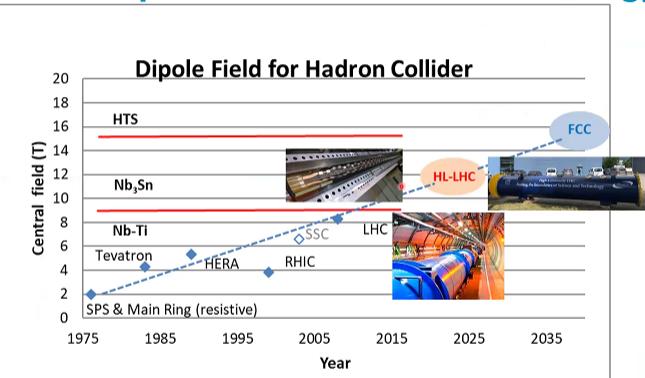
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CERN

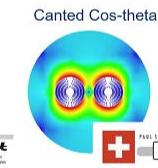
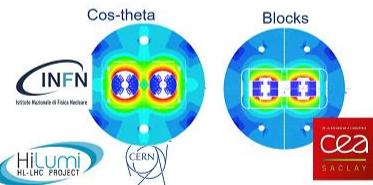
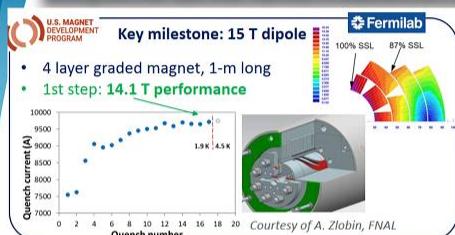
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With HiLumi we prepare the technology for a future leap in hadron collider technology...



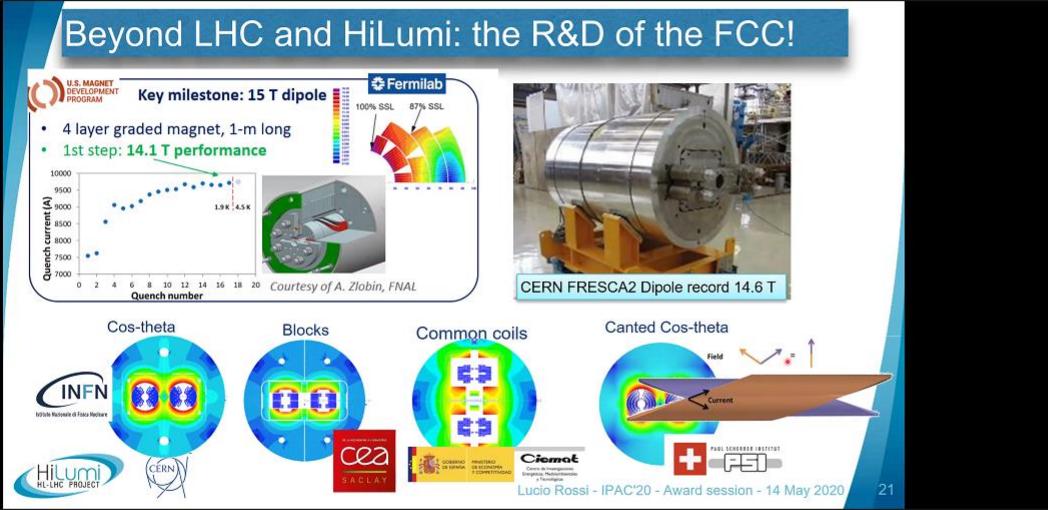
Beyond LHC and HiLumi: the R&D of the FCC!



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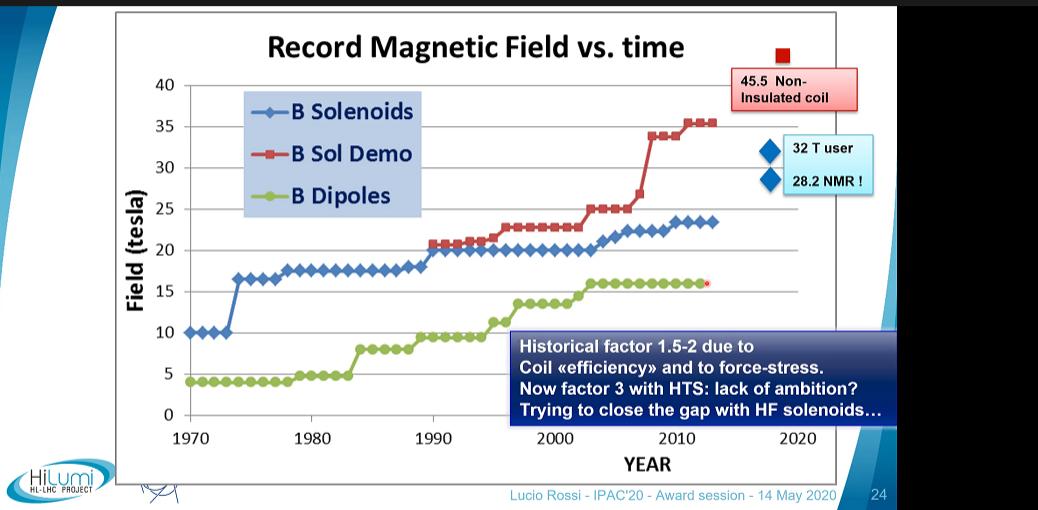


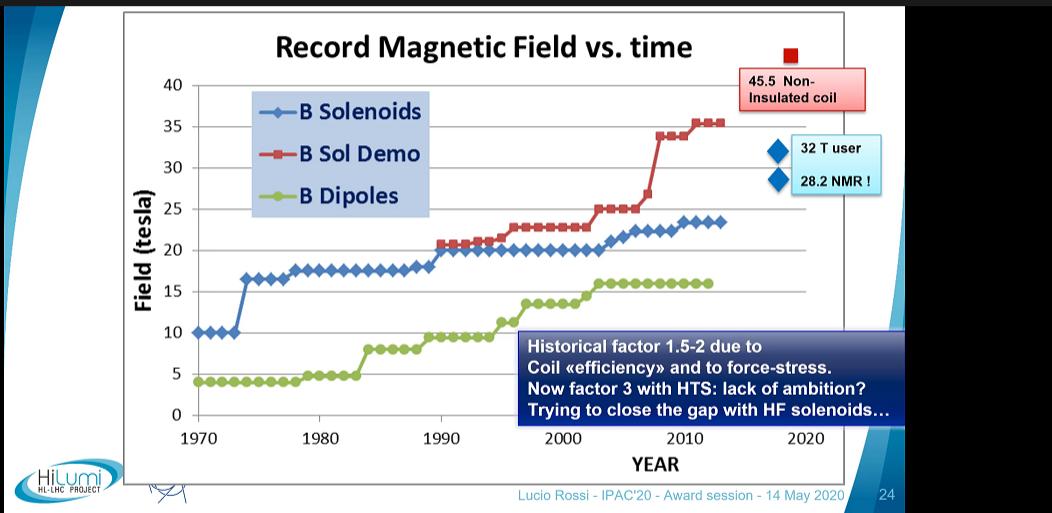
HTS Renaissance: many new activities from 2013 The dream of 20-25 tesla! (2 x HiLumiLHC!)

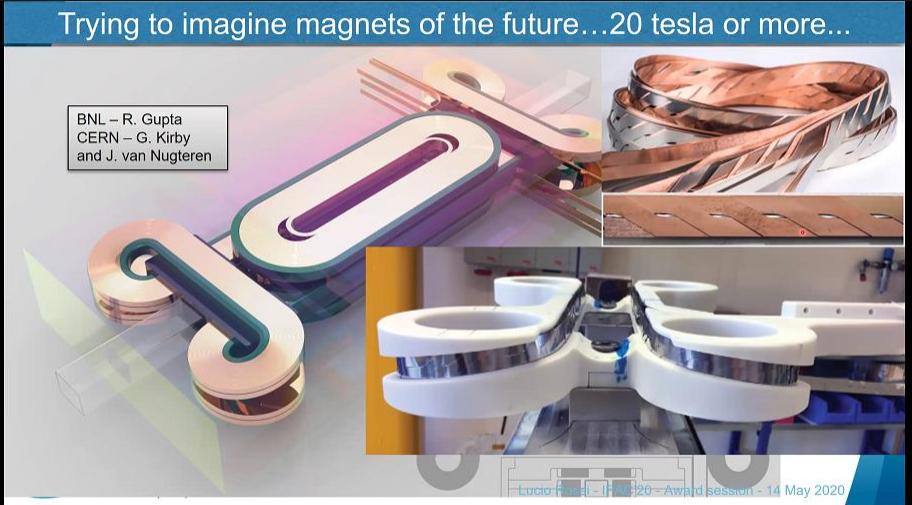


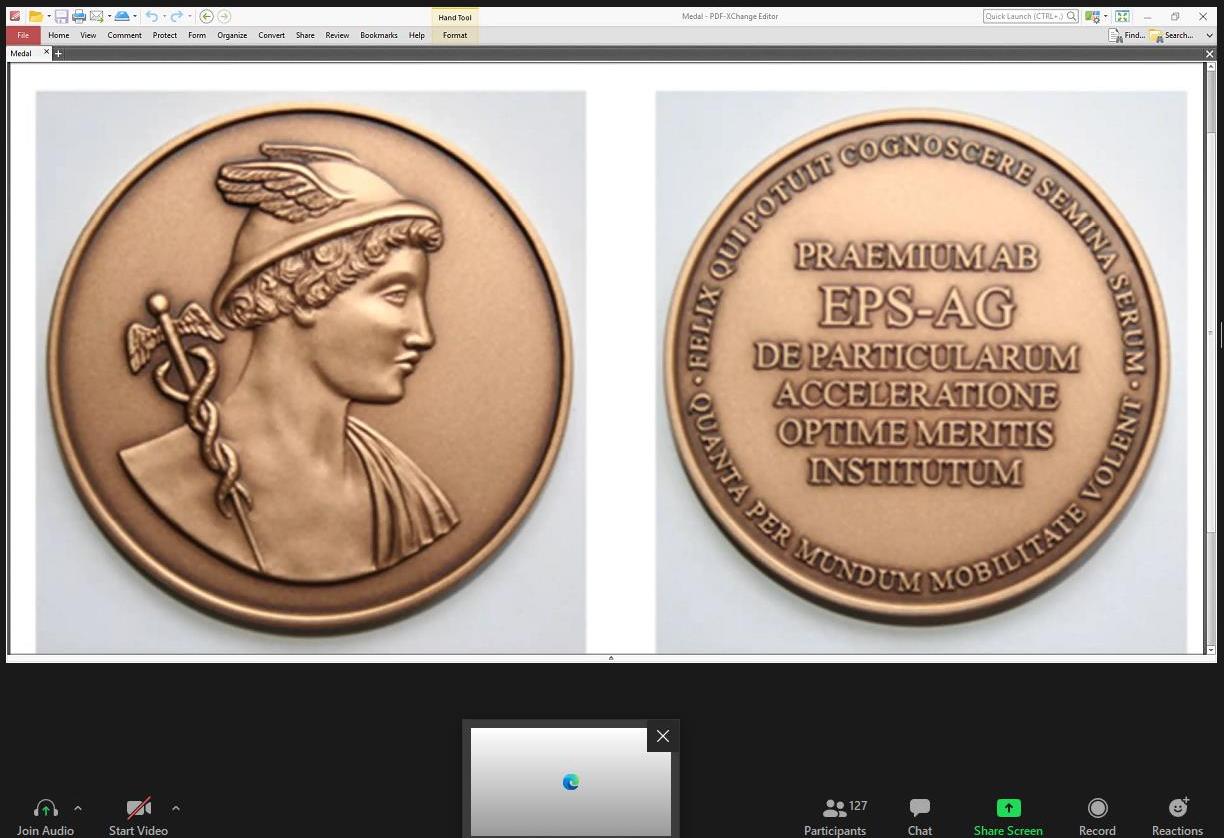
HTS Renaissance: many new activities from 2013 The dream of 20-25 tesla! (2 x HilumiLHC!)











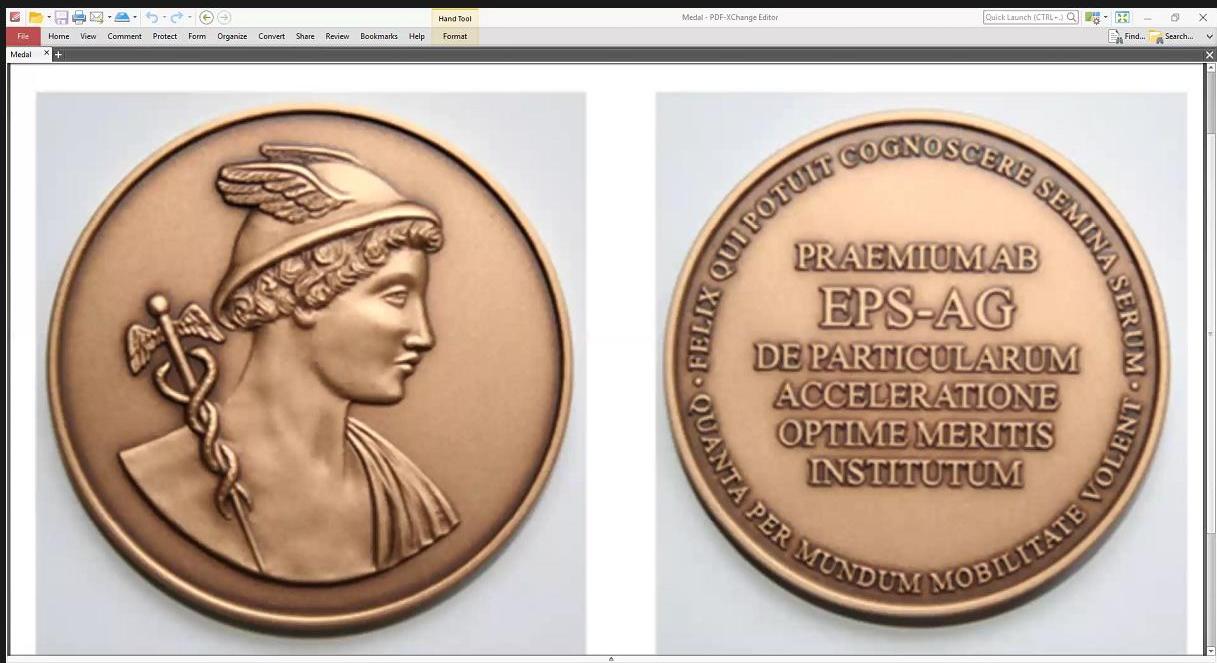
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11th INTERNATIONAL PARTICLE ACCELERATOR CONFERENCE
Mike Seidel

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Gianluigi Arduini

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Ralph Assmann

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2020 Accelerator Awards

Thanks to Gianluigi Arduini and Prize Committee

Touschek Prize
to A. Ferran Pousa, DESY



Frank Sacherer Prize
to J. Steinemann, KIT

Rolf Wideröe Prize
to Lucio Rossi,
CERN





The Scientific Programme Committee: Selection of Speakers

Main Classifications	European Coordinators	American and Asian "Deputies"
1. Circular and Linear Colliders	Frank Zimmermann, CERN	Fulvia Pilat, ORNL
2. Photon Sources and Electron Accelerators	Marie-Emmanuelle Couprie, SOLEIL	Todd Satogata, JLAB
3. Novel Particle Sources and Acceleration Techniques	Sven Reiche, PSI	Heung-Sik Kang, PAL (KR)
4. Hadron Accelerators	Giovanni Bisoffi, INFN	Tadashi Koseki, KEK
5. Beam Dynamics and Electromagnetic Fields	Sara Casalbuoni, KIT	Tor Raubenheimer, SLAC
6. Beam Instrumentation, Controls, Feedback and Operational Aspects	Andreas Jansson, ESS	John Byrd, ANL
7. Accelerator Technology	Jim Clarke, STFC	Qin Qing, IHEP
8. Applications of Accelerators, Technology Transfer, Industrial Relations and Outreach	Maurizio Vretenar, CERN	Kuo-Tung Hsu, NSRRC





Ex-officio Members
Ralph Assmann, DESY
Mike Seidel, PSI

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The Scientific Programme Committee: Selection of Speakers

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IPAC20 OC Chair

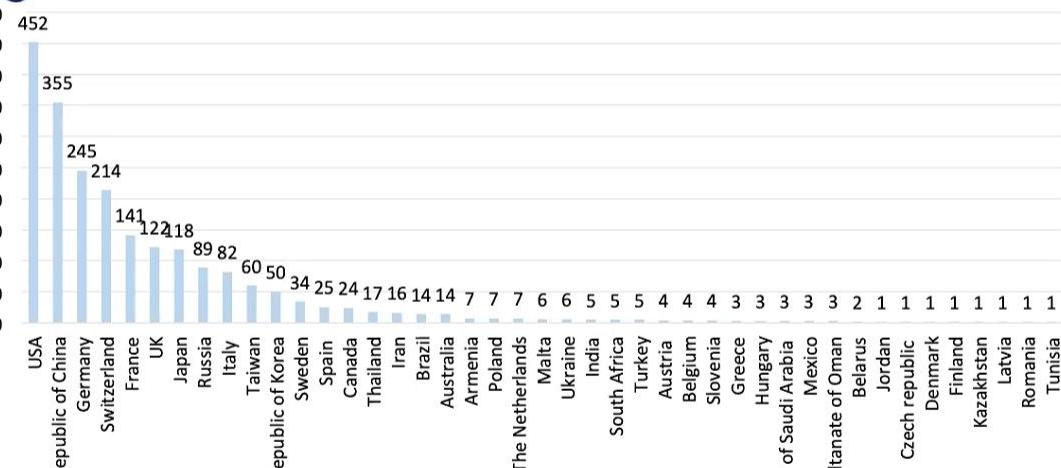
IPAC20 LOC Chair
Coordinator for the Session on Engagement
with Industry
WISE Session
Student training session
Peer reviewed proceedings
IPAC20 Scientific Secretary
Support IPAC20 SPC work





SPC/1, November 2018	SPC/2, May 2019
<ul style="list-style-type: none">Outline of program skeleton / synoptic table; review the main classification; concept of industrial session, WISEEstablish SAB; trigger submission of proposalsOC: visit venue; review preparationOC: decide on next venue in region	<ul style="list-style-type: none">Select invited oral presentations from proposals; balance aspects (themes, labs, countries ..)Plenary speakers; industrial session speakersFine tune slot distribution
SPC/3, January 2020	<p>During the conference, May 2020</p> <ul style="list-style-type: none">Evaluation of the posters during the student poster sessionIdentify publications <p>After the conference</p> <ul style="list-style-type: none">Provide feedback to the authors during the conference







Un Grand Merci ... to the Speakers





Un Grand Merci ... to the Speakers





Un Grand Merci ... to the Speakers





Un Grand Merci ... to the Speakers



What a diverse and promising group of 67 speakers... WOW

Shows strength, livelihood and dedication of our field!





The World Connected to IPAC'20



Note: Colleagues from China had problems to access IPAC'20 videos... To be solved in future!





Top 20 by Region (*Data from this Morning*)

Région	Region	Chargements
India		
+ France		6613
+ United States		6159
+ Germany		5810
+ United Kingdom		2959
+ Switzerland		1721
+ Japan		1623
+ Italy		1530
+ Sweden		1089
+ Canada		1076
+ Spain		763
+ India		705
+ Brazil		522

And the winner is: France





Top 20 by Region (Data from Monday)

Russia	490	Belgium	160
Republic of Korea	446	Slovenia	131
Hong Kong	390	Oman	130
Taiwan	294	Poland	122
Netherlands	293	Thailand	118
Australia	288	Denmark	85
		Ukraine	78

Welcome Oman!



Note: I assume some Chinese colleagues connected through Hongkong.



Some Statistics – Status this Morning

- **32,032** videos watched
- Each registered participant watched on average **11 videos**
- Each talk watched on average **470 times**
- **604** comments on 76 presentations
- **Keep watching:** Videos stay online another 10 days
- **Keep commenting:** Comments open until Saturday





Bringing IPAC'20 Online



Plus all the other members of the LOC, OC and SPC teams!





Bringing IPAC'20 Online



"What a challenge .. I like it ! Cheers"

Thank you!

Frederic Chautard, GANIL
Chair of the LOC

Master of Organization and Style.
Never giving up...





Bringing IPAC'20 Online



"a glass of "Pommeau", which is also a specialty from Normandy. It's a (secret !) mix of Calvados and apple juice for the aperitif time."





Bringing IPAC'20 Online



"Bon c'est pas local, ça vient de Rimouski au Quebec !!"

Thank you!

Laurent Fortin, GANIL

Implementing the machinery of
the virtual format in record time





Bringing IPAC'20 Online



"Instead of Calvados it's white wine for me ☺"

Thank you!

Adeline Jeanne, GANIL

Working miracles as Scientific
Secretary of IPAC'20 – making it
all possible. Nerves of steel!





Bringing IPAC'20 Online



"Yes, good idea in these tough times!"

Thank you!

Mike Seidel, PSI

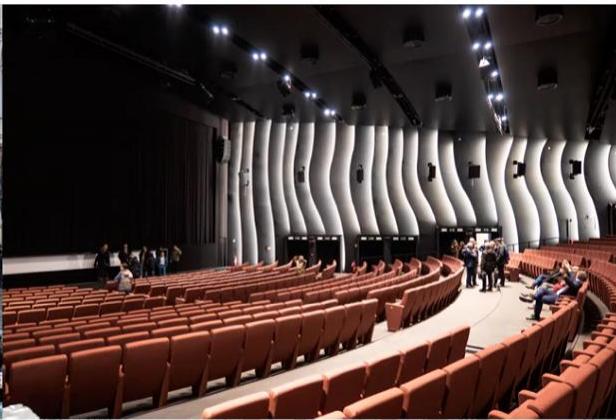
Guiding it all through good and
tough times with German
precision and Swiss calm...





Thanks to all

IPAC will be back in Europe in 2023 in Venice, Italy!





ipac20mercigrd.mp4 - VLC media player
Media Playback Audio Video Subtitle Tools View Help

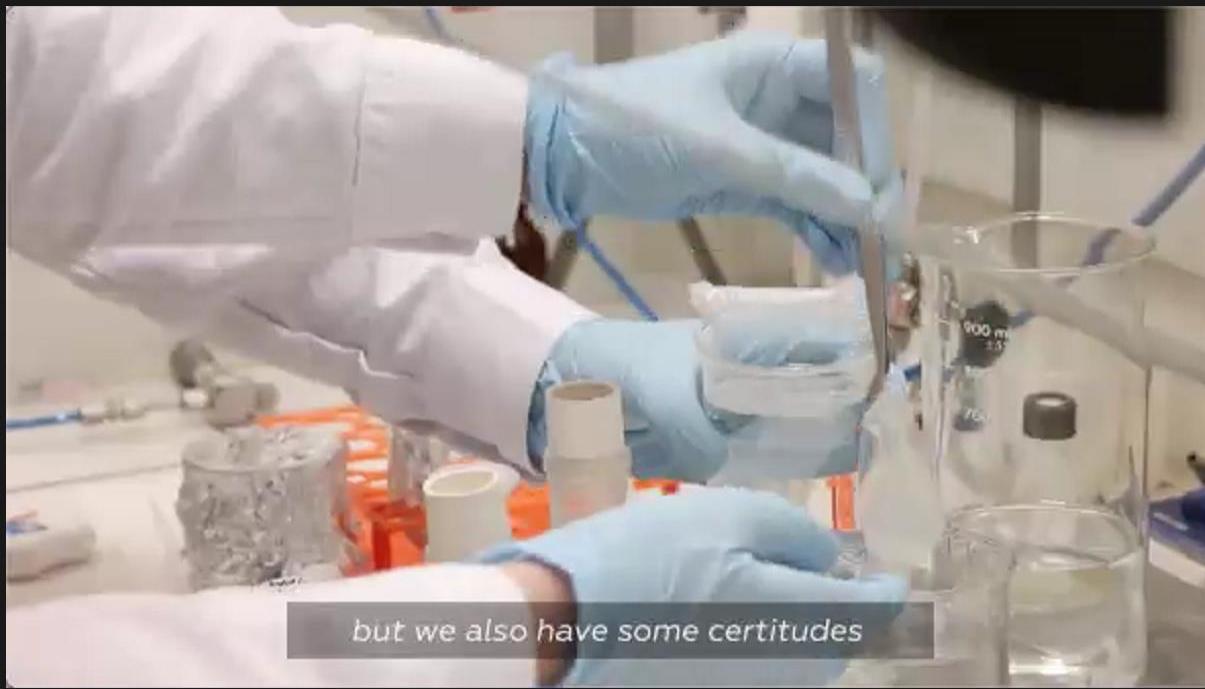












The image displays four separate video call frames from the "IPAC20 11th INTERNATIONAL PARTICLE ACCELERATOR CONFERENCE". Each frame features a different speaker against a background of the Mont Saint-Michel abbey at sunset. The frames are arranged vertically.

- Ralph Assmann:** A man with glasses and a dark suit, identified by a small red icon.
- Mike Seidel:** A man with glasses and a dark suit, identified by a small red icon.
- Frédéric Chautard:** A man with a beard and a dark suit, identified by a small red icon.
- Liu Lin:** A woman with glasses and a patterned top, identified by a small red icon.

The top of each frame includes the conference logo, the name "IPAC20", the subtitle "11th INTERNATIONAL PARTICLE ACCELERATOR CONFERENCE", and the flags of France, Germany, and the European Union. The bottom of each frame shows the speaker's name and a small red video icon.

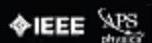






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23-28 May 2021



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www.ipac21.org







