The High Luminosity LHC Project at CERN

How to cooperate in CERN R&D activities and create innovative solutions

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On behalf of the HL-LHC Project

Slovenian Day – CERN – 9 October 2019

Outline

- The High Luminosity LHC Project
- The mechanism of Collaboration Agreements
- Two personal examples of R&D and innovation
- Conclusions

Large Hadron Collider

Discovery 2012, Nobel Prize in Physics 2013

The Nobel Prize in Physics 2013 was awarded jointly to François Englert and Peter W. Higgs *"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider".*

But…

- No evidence of New Physics so far…
- If New Physics at TeV scale its spectrum is heavy: need of high luminosity (3000 fb^{-1}) and a lot of energy
- Puzzles:
  - Why Higgs boson is so light? (naturalness or fine tuning?)
  - What is the origin of matter-antimatter asymmetry?
  - Why is Gravity so weak?
  - The 96% Dark Universe?
  - Other unknowns?
- LAST BUT NOT LEAST: LHC is ageing as well as the detectors
- Let me summarize as: we need to improve how we produce the phenomena that we want to study and how we look at them.
- Find the hidden details.

Goal of HL-LHC as fixed in 2010

From FP7 HiLumi LHC Design Study application

The main objective of HiLumi LHC Design Study is to determine a hardware configuration and a set of beam parameters that will allow the LHC to reach the following targets:

A peak luminosity of L_{peak} = **5×10^{34} $cm^{-2}s^{-1}$ with levelling**, allowing:

An integrated luminosity of **250 fb^{-1} per year**, enabling the goal of

L_{int} = 3000 fb^{-1} twelve years after the upgrade.

This luminosity is more than ten times the luminosity reach of the first 10 years of the LHC lifetime.

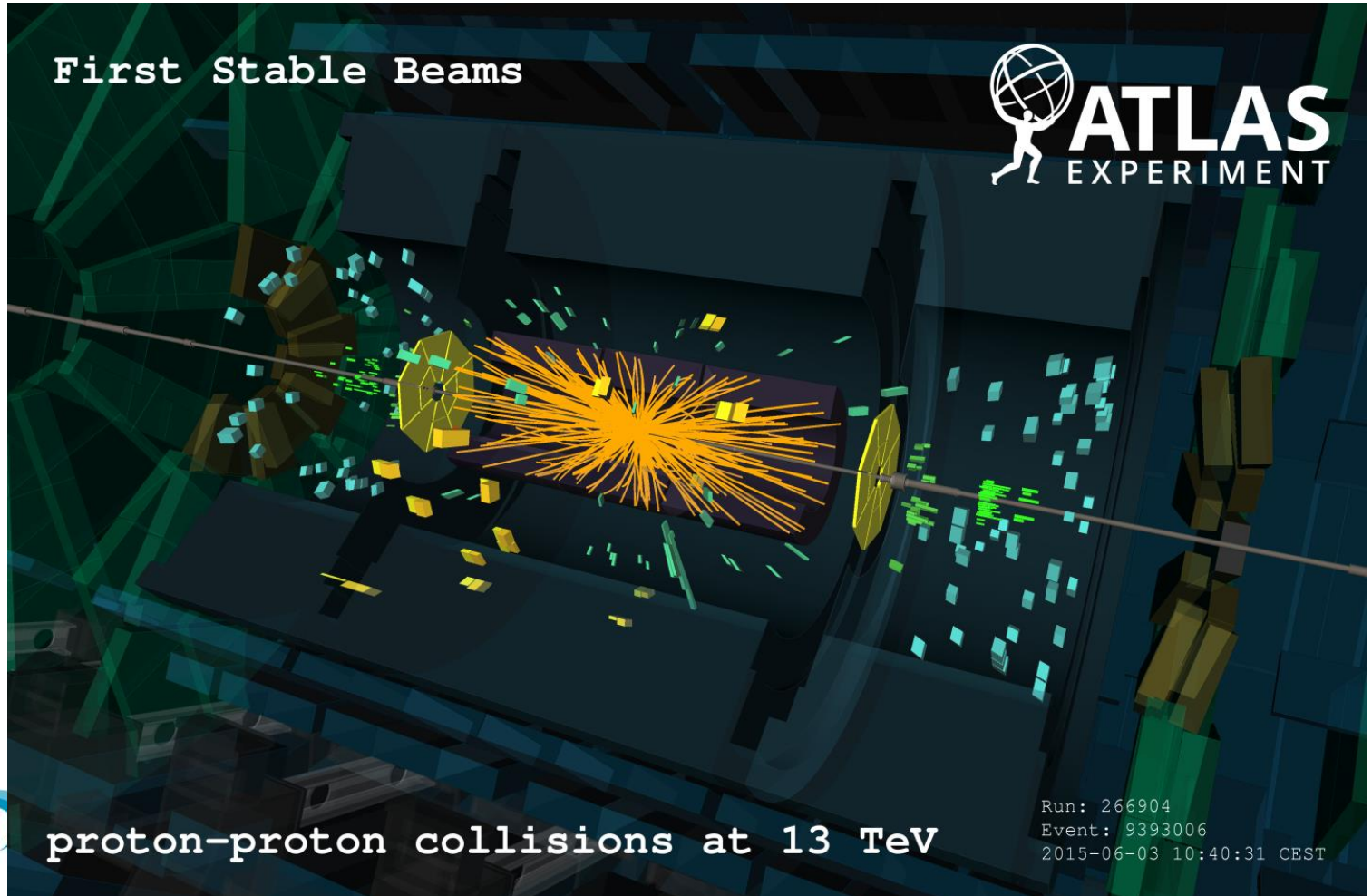
Ultimate performance established 2015-2016: with same hardware and same beam parameters: use of **engineering margins:**

$L_{peak\ ult} \cong 7.5\ 10^{34}$ $cm^{-2}s^{-1}$ and **Ultimate Integrated $L_{int\ ult} \sim 4000$ fb^{-1}**

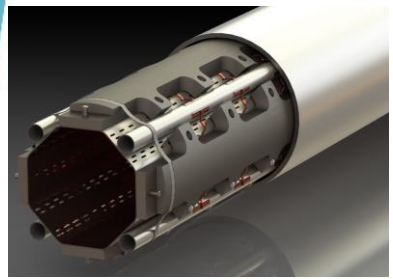
LHC should not be the limit, would Physics require more…

Project approved by CERN Council in June 2016

Collecting as many pictures as possible of phenomena



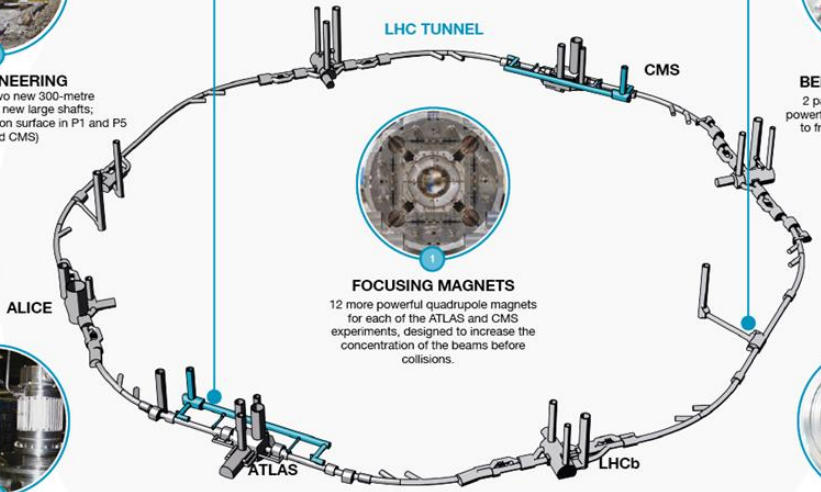
Technology landmarks



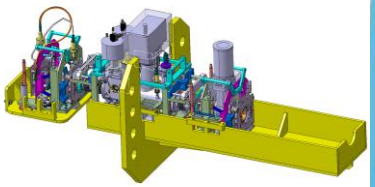
"CRAB" CAVITIES
8 superconducting "crab" cavities for each of the ATLAS and CMS experiments to tilt the beams before collisions.

CIVIL ENGINEERING
2 new caverns and two new 300-metre service galleries, two new large shafts; 10 new technical buildings on surface in P1 and P5 (ATLAS and CMS)

BENDING MAGNETS
2 pairs of shorter and more powerful dipole bending magnets to free up space for the new collimators.



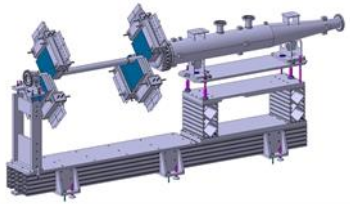
FOCUSING MAGNETS
12 more powerful quadrupole magnets for each of the ATLAS and CMS experiments, designed to increase the concentration of the beams before collisions.



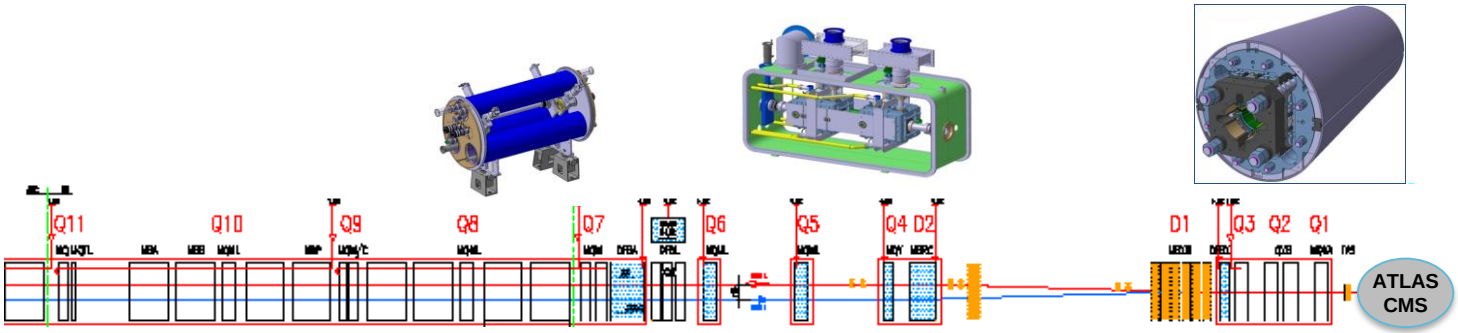
CRYOGENICS
2 new large 1.9 K helium refrigerators for HL-LHC near ATLAS and CMS

COLLIMATORS
15 to 20 new collimators and 60 replacement collimators to reinforce machine protection.

SUPERCONDUCTING LINKS
Electrical transmission lines based on a high-temperature superconductor to carry current to the magnets from the new service galleries to the LHC tunnel.



The largest HEP accelerator in construction



Dispersion Suppressor (DS) in P7

Modifications
1. In IP2: new DS collim. in C.Cryost.
2. In IP7 new DS collimation with 11 T

Cryogenics, Protection, Interface, Vacuum, Diagnostics, Inj/Extr… extension of infrastr.

Matching Section (MS)

Change/new lay-out
1. TAXN
2. D2
3. CC
4. Q4
5. Correctors
6. Q5
7. Q5@1.9K in P6
8. New collimators

Interaction Region (ITR)

Complete change and new lay-out
1. TAXS
2. Q1-Q2a-Q2b-Q3
3. D1
4. All correctors
5. Heavy shielding (W)

> 1.2 km of LHC !!

Participation with collaboration agreements

- CERN procures via tenders and procurement rules as explained
- In addition there is a mechanism for countries to provide in-kind contributions
  - A collaborating institute from a given country establishes a collaboration agreement with CERN
  - The institute provides part of the funding (generally 50% for member states)
  - The institutes takes on liability and procurement strategy

In-Kind contributions – Considerations

- In-kind contributions are necessary for:
  - Reducing the CERN financial cost.
  - Having NMS that are members of LHC experiments, to participate also to the **accelerator construction cost.**
- In-kinds are agreed with Collaborating Laboratories or Institutes, via Collaboration Agreements
- The in-kind contributions generate work for industry
  - Contributions are typically hardware deliverables built in institutes and industries (via tenders by the institutes)

In-kind contributions – Not only money!

In-kind contributions are necessary for HL-LHC also because:

- CERN has not enough personnel for design and follow up: **with no external collaborator we would delay the project or we would need to stop other key R&D.**
- That's why is critical that an Institute has **its own competent personnel** to make engineering and/or the construction follow up.

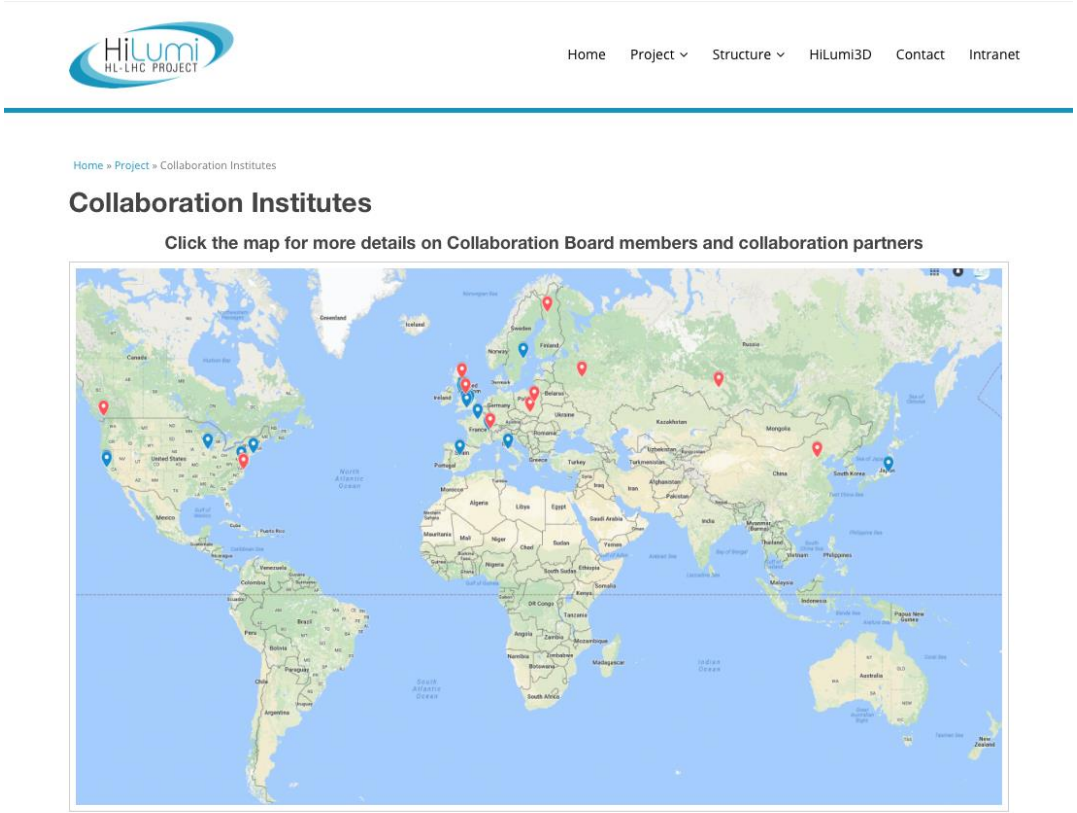
K-contracts for collaboration agreement

- CERN Procurement treats it as a contract awarded to a Research Institute/University
- If the payment is > 200 kCHF the Finance Committee authorization is required since it is a direct contract without formal tender.
- Industry are involved by the Collaborating Institute according to its own rule. CERN needs to qualify and approve the main «subcontract».
- The trend of the in-Kind contribution is monitored by the HL-LHC management via special «Steering committees» and by the HL-LHC Collaboration Board
- The 50% is not a hard threshold but we need to show to the FC that the gain for CERN is solid (w.r.t. to a tender).

A list of contributions

	COUNTRY	Institute	Title
R&D	France	CEA	Thermal Design of Superconducting High Field Magnets at CERN
	UK	Manchester	Beam instrumentation
	UK	Manchester	Cold powering: DFBX for String
	UK	ASTeC+Dundee	Laser treatment prototype (LESS)
Prototypes and BASELINE	Italy	INFN	High-order corrector magnets + prototypes
	Spain	CIEMAT	Nested orbit correctors + prototypes
	China	IHEP	D2 Correctors
	Sweden	Uppsala Univ.	Cold testing of corrector magnets and crab cavities
	Japan	KEK	D1 magnet model and cold mass
	Italy	INFN	D2 model + prototype+ Magnet
	USA	Several	Crab Cavities
	USA	Several	Triplet magnets
	Canada	TRIUMF	RFD Crab-cavities cryomodules
	Sweden	Uppsala Univ.	DFHM and DFHX 8+2 units
	UK	SOTO	DFM and DFX 8+2 units
	UK	ASTeC+Lancaster	DQW Crab-cavities cryomodules
	Serbia	Ministry	Magnets and CC jacks
	Russia	BINP	TAXS and TAXN
	Russia	BINP	Current leads matching section and inner triplets
	Russia	BINP	Low impedance collimators (12 units) + IR collimators (28 units)
	Russia	BINP	Solid State RF powering (replacing IOT)
	Russia	BINP	BPM Mechnics (20+28 units)
	Russia	Protvino	Ionisation chambers for SPS and LHC systems for HL-LHC beams (1000 units)
	Russia	MEPhI + JINR	HF-HOM and HOM Couplers and Filed Antennas
OPTIONS	UK	LIV+RHUL	Beam instrumentation EO-BPM
	UK	Liverpool	Beam Instr. For HEL
	UK	Dundee	Laser treatment final (LESS)
	Russia	BINP	LHC Dump System
	Russia	BINP	OPTION: Hollow e-lens
	Russia	PNPI/Protvino	OPTION: Crystal collimation for ions

Collaborating Institutes on HL-LHC WEB



"the sun never sets"

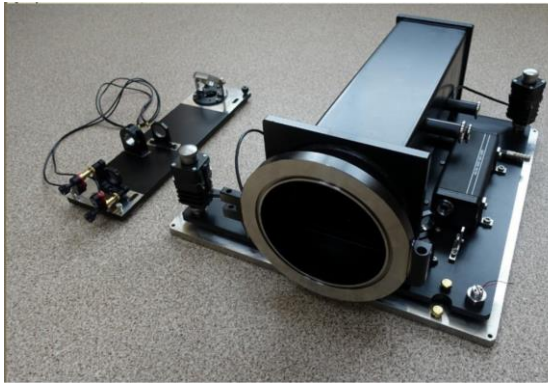
http://hilumilhc.web.cern.ch/about/collaboration-institutes

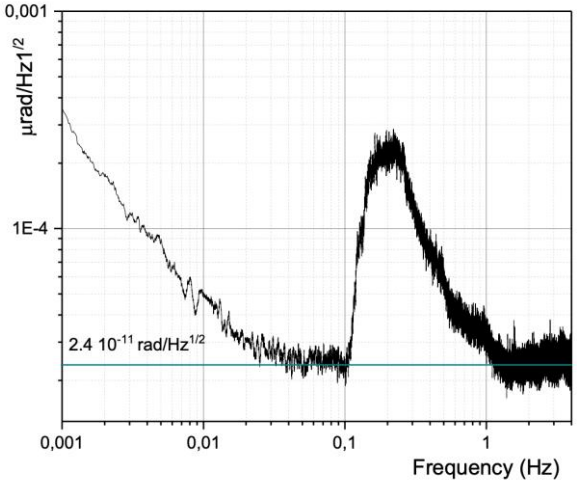
Other considerations

- An in-kind contribution makes sense only in case of a long term interest by an Institute
- Never a good idea to use it simply to maximize the short term return.
- However, it can turn out a very good long term investment!
- But must be supported by a genuine scientific and technological interest by a competent home team! **Without a competent home team is NOT possible to assign an in-kind contribution!**
- The interest of CERN is a networking model where the CERN resources are matched by local national resources and where the entire community align to the CERN scope providing also an invaluable intellectual contribution, beside increasing the validated industrial partners.
- **So collaborations and in-kinds are necessary for HL-LHC and also in this respect HL-LHC is a necessary «prototype» for FCC!**

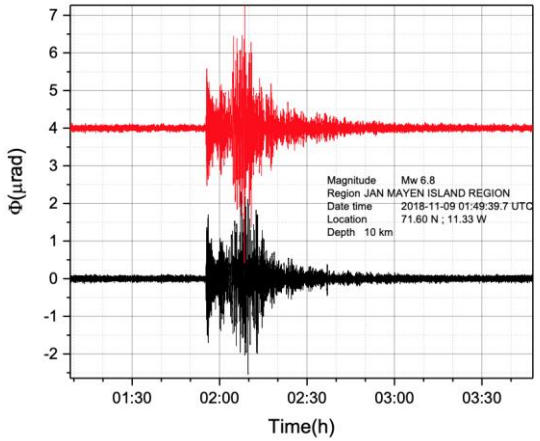
Before concluding: two very personal examples of R&D activities and innovative solutions

Development of high precision angular measurements





A precision of **$2.4 \cdot 10^{-11}$ rad/Hz$^{1/2}$** in the frequency range **$[10^{-3}, 12.4]$ Hz**



CERN-JINR collaboration

Now installed also at Virgo - a gravitational wave experiment

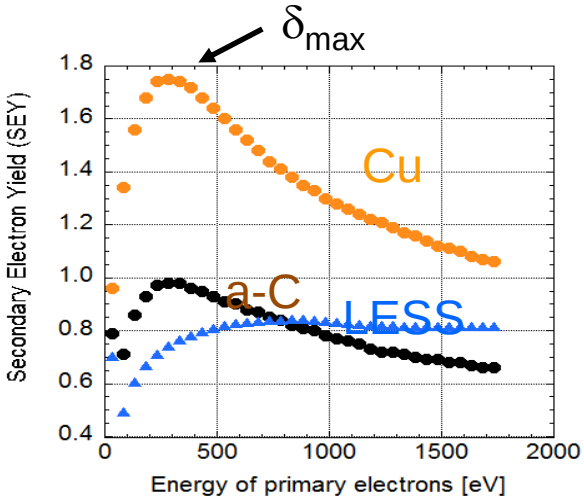
Sensor used at CERN could help gravitational-wave hunters

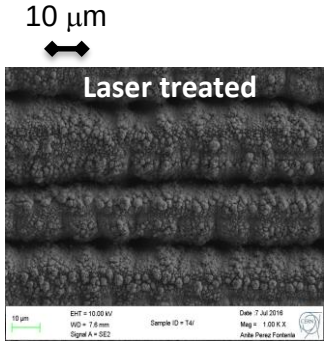
A new seismic device developed by CERN and JINR is now being tested at the Advanced Virgo detector

30 AUGUST, 2019 | By Ana Lopes

Aerial view of the Advanced Virgo detector, where a precision laser interferometer used at CERN was installed and is being tested (Image: Virgo collaboration)

Very high precision positioning system to bring laser light in a tiny pipe

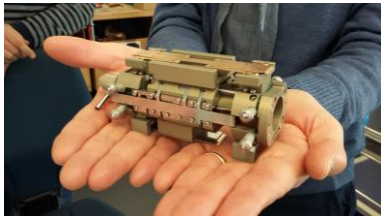


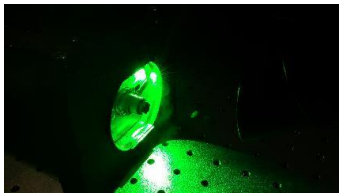


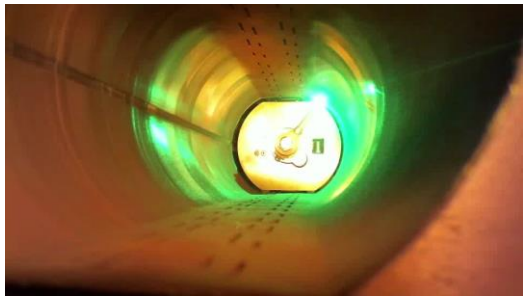
Lower SEY is a morphological effect

Fighting e-cloud effects that induce higher need of cryogenic power

LHC beam screen







7 μm precision in translation

CERN-Dundee Univ.-STFC and GE-IR

Thanks!
Questions?