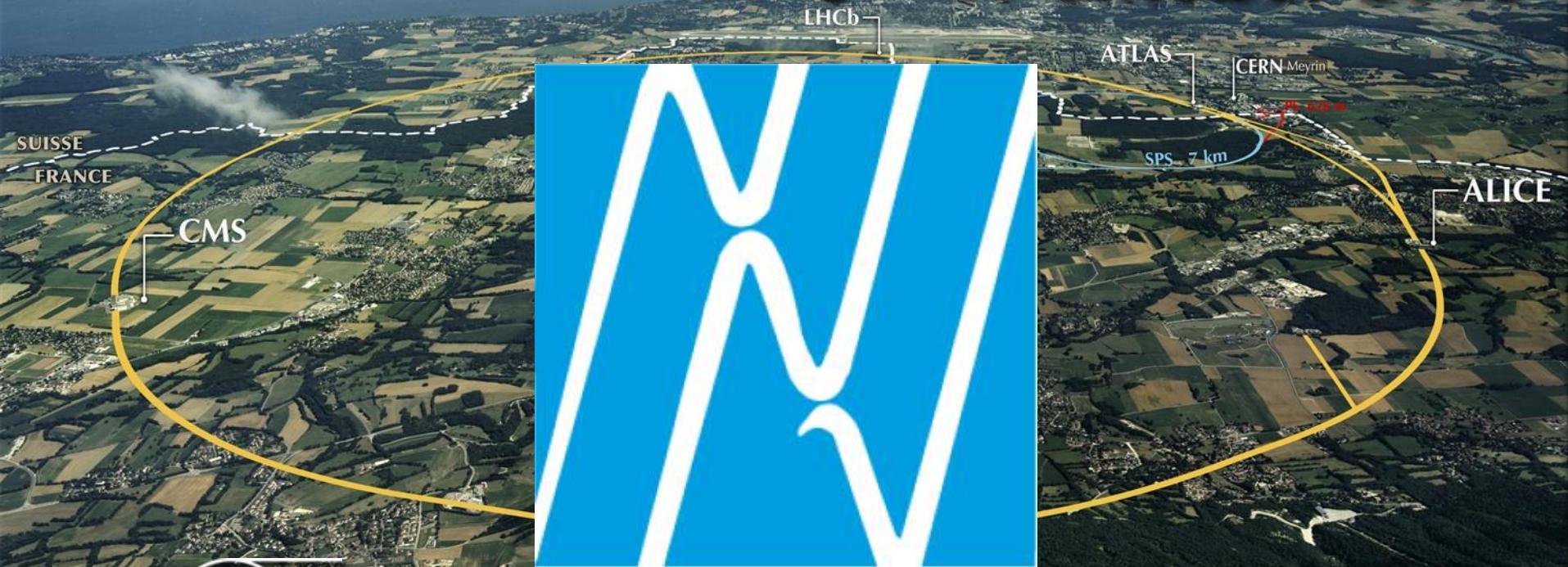


De LHC: Hoe werkt dat ?

NNV Profielwerkstukreis CERN

8 – 11 oktober 2019



Accelerating Science and Innovation
Jan Uythoven, CERN



Compact Muon Solenoid

- How does the accelerator work?
 - Magnets
 - Radio Frequency
 - ...
- Energy in the beam
- The future



Cern Control Centre





The LHC

A black and white photograph showing the interior of the Large Hadron Collider (LHC) tunnel. The perspective is looking down a long, narrow corridor. In the center of the corridor, a large, circular, multi-layered structure, likely a superconducting magnet or a detector component, is visible. The walls and ceiling are lined with complex machinery, pipes, and structural supports, creating a dense and industrial environment. The lighting is dramatic, with strong highlights and deep shadows, emphasizing the scale and complexity of the facility.

Very big

Very cold

Very high energy

The LHC

Two beams of trillions of protons race around the 27 km ring at 0.999999991 times the speed of light in opposite directions...

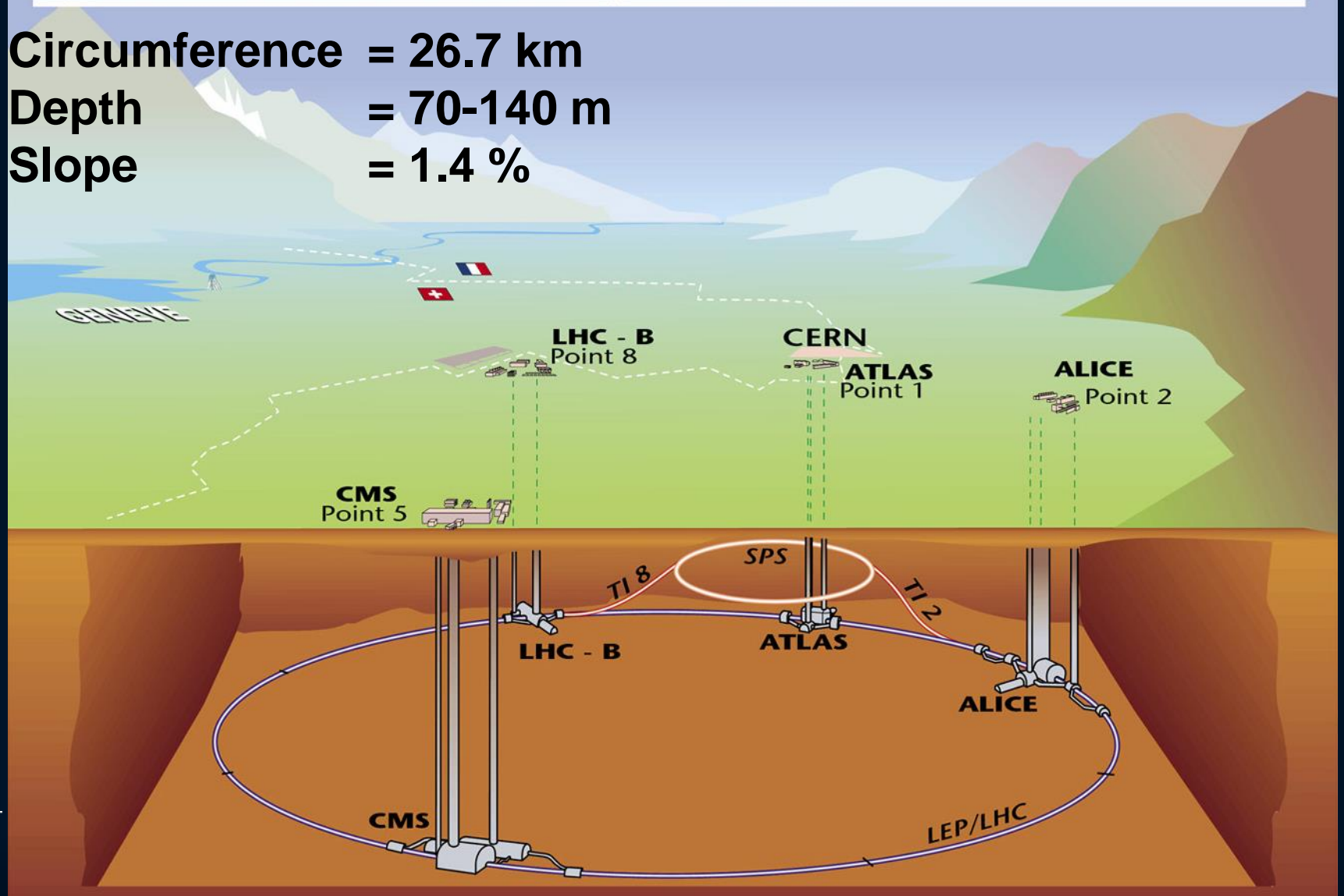


So a particle goes around the LHC 11'000 times per second !

LHC tunnel

Overall view of the LHC experiments.

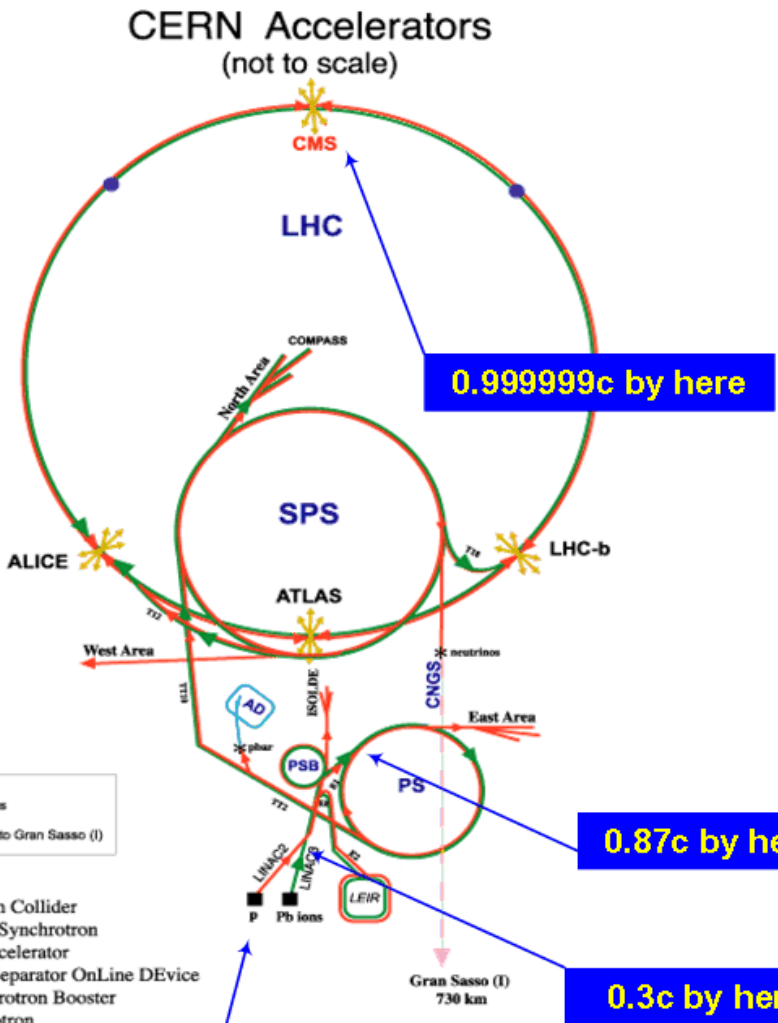
Circumference = 26.7 km
Depth = 70-140 m
Slope = 1.4 %



LHC Injector Chain

New Linac4 in 2020: H⁻

	Year	Top energy [GeV]	Length [m]
Linac	1979	0.05	30
PSB	1972	1.4	157
PS	1959	26.0	628
SPS	1976	450.0	6'911
LHC	2008	7000.0	26'657



LHC: Large Hadron Collider
 SPS: Super Proton Synchrotron
 AD: Antiproton Decelerator
 ISOLDE: Isotope Separator OnLine DEvice
 PSB: Proton Synchrotron Booster
 PS: Proton Synchrotron
 LINAC: LINear ACcelerator
 LEIR: Low Energy Ion Ring
 CNGS: Cern Neutrinos to Gran Sasso

Radolf LEY, PS Division, CERN, 02.09.96
 Revised and adapted by Antonella Del Zotto, ETT Div.,
 in collaboration with B. Desforges, SE Div., and
 D. Manglinski, PS Div. CERN, 23.05.01

Normal operation with protons, but every year few weeks of operation with heavy ions (Pb⁸²⁺)

Start the protons out here



Where do the Protons come from?



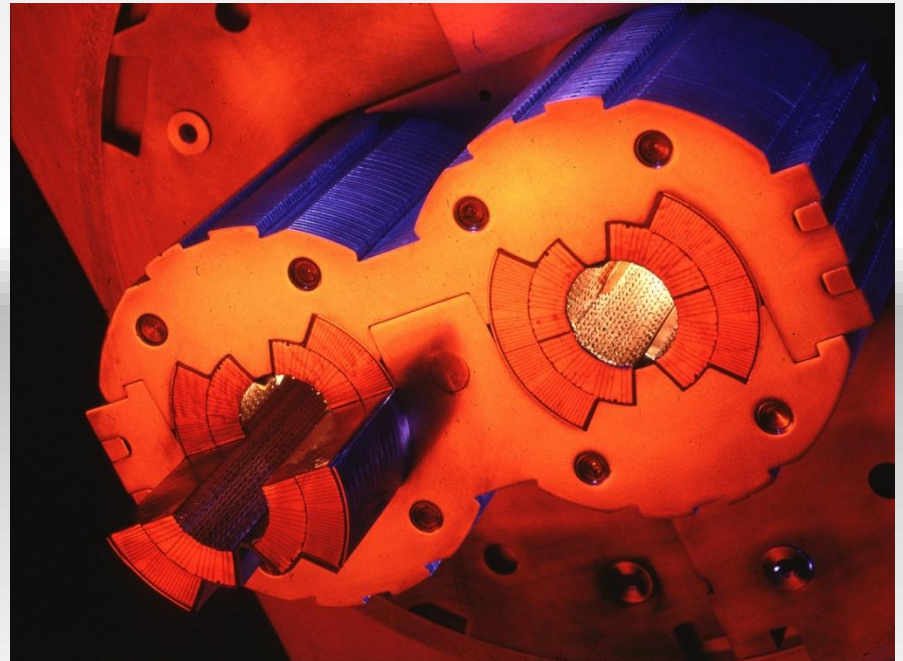
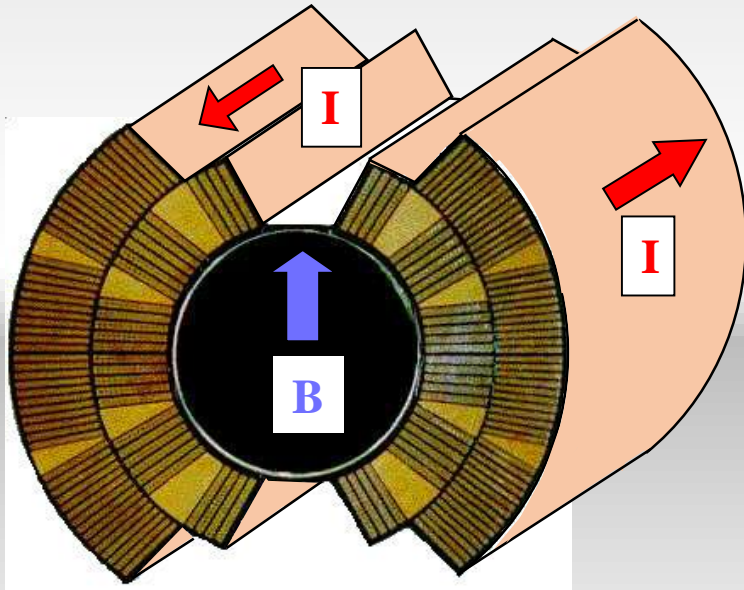
Basic ingredients of a particle accelerator

$$F = q \left[E + (v \times B) \right]$$

- **Magnetic field** to
 - Bend the beam around the circle (dipole magnets)
 - Keep the particles together (quadrupole magnets = lenses)
- **Electric field** to accelerate the particles
 - Very fast varying electric fields = Radio Frequency cavities

Dipole Magnets

- Bend the beam around the circle
- Number of dipoles 1232
- Dipole field at 450 GeV 0.535 T
- Dipole field at 7 TeV 8.33 T
- Bending radius 2803.95 m
- Main Dipole Length 14.3 m
- Openings (full aperture) 56 mm

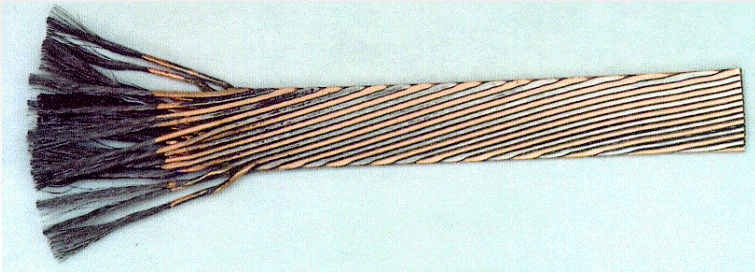


SUPERCONDUCTING!
Cooled with superfluid helium at 1.9 K

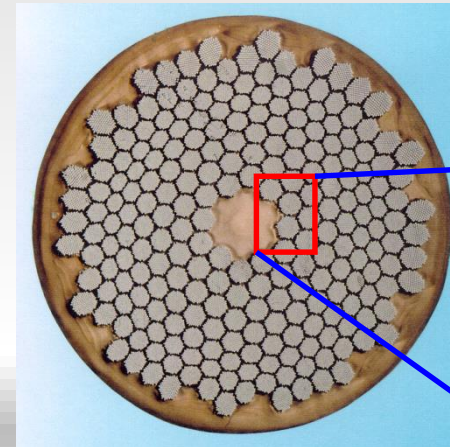
The superconductor

Niobium-titanium Rutherford cable

Cable



Strand

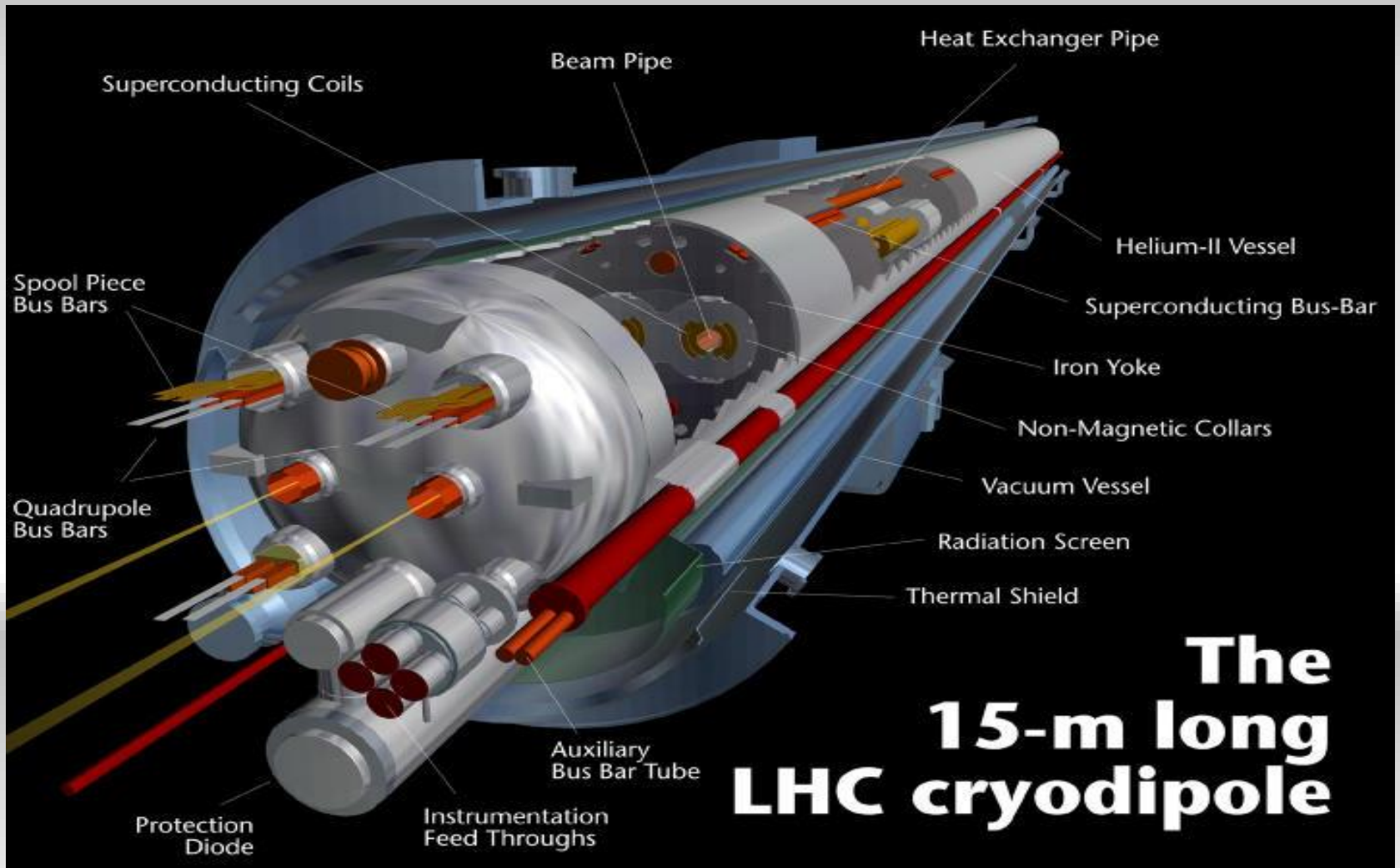


Filament



Used 1200 tonnes/7600 km of cable
Single cable carries current up to 12 kA

More than just some coils...



During construction: Dipoles all over

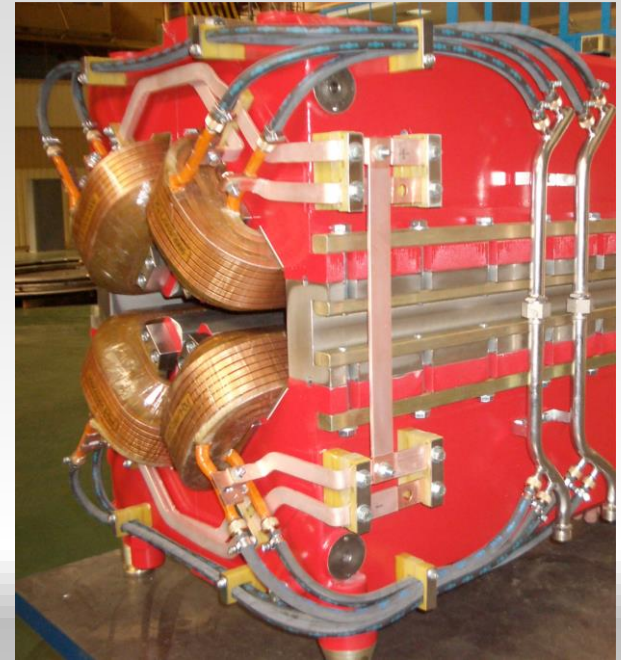
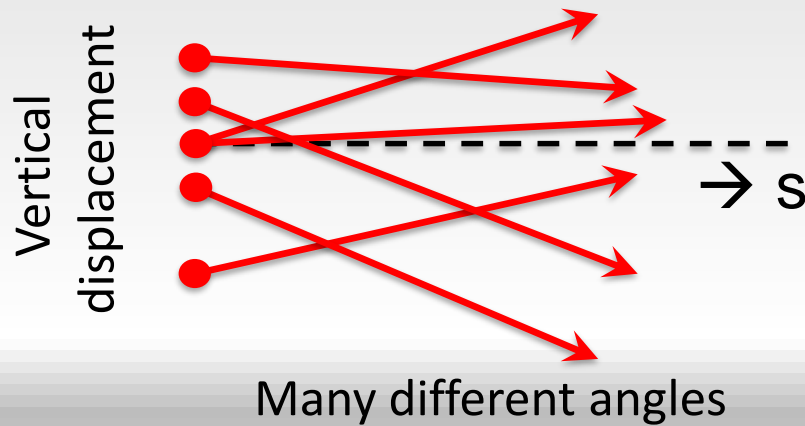


In the LHC tunnel



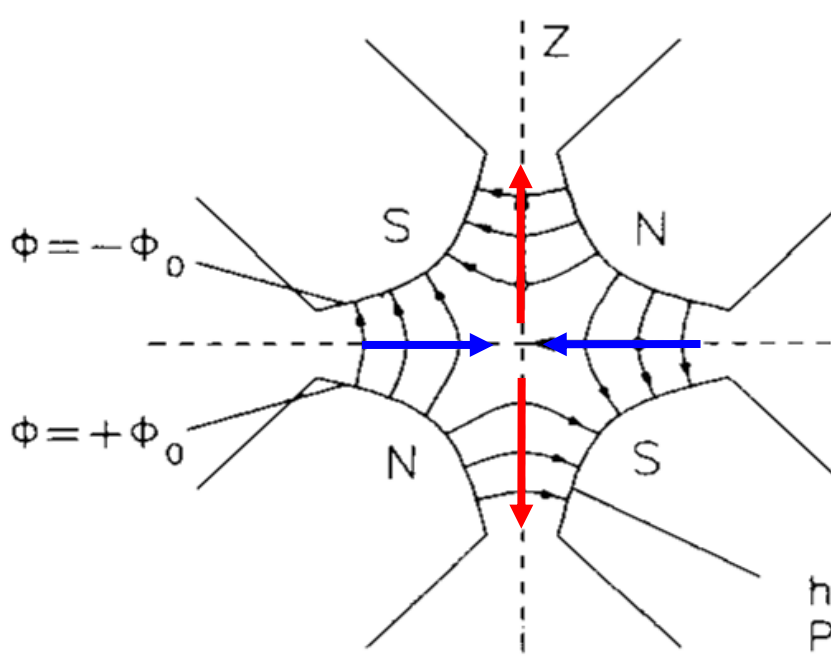
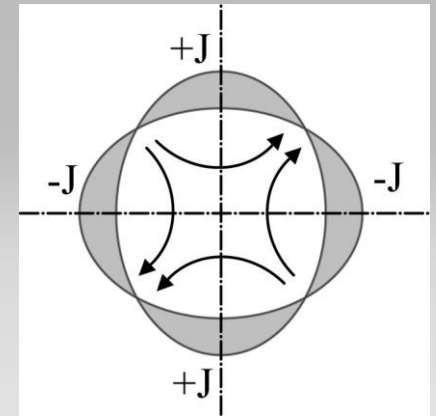
Beam is divergent

Many particles many initial conditions



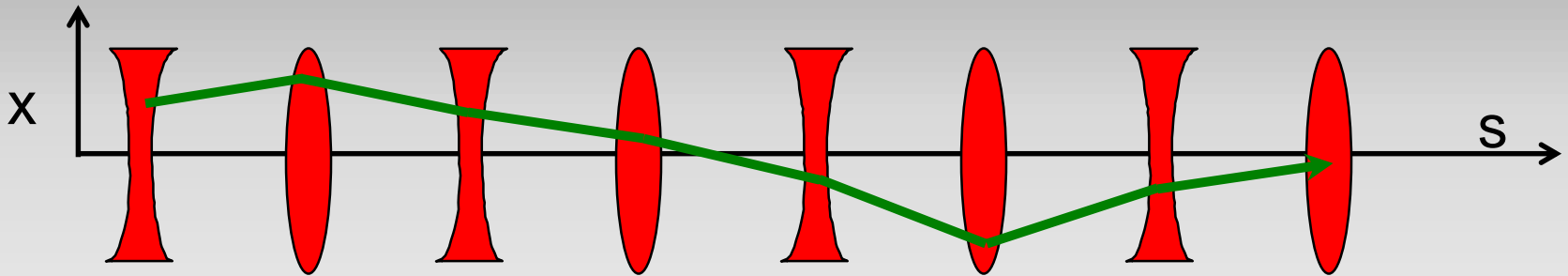
Quadrupole magnet

Quadrupole magnets



- A quadrupole magnet will focus in one plane and de-focus in the other.
- Convention: a “focusing” quadrupole focuses in the horizontal plane

Alternate gradient focusing



The general linear magnet lattice can be parameterized by a ‘**varying spring constant**’, $K=K(s)$.

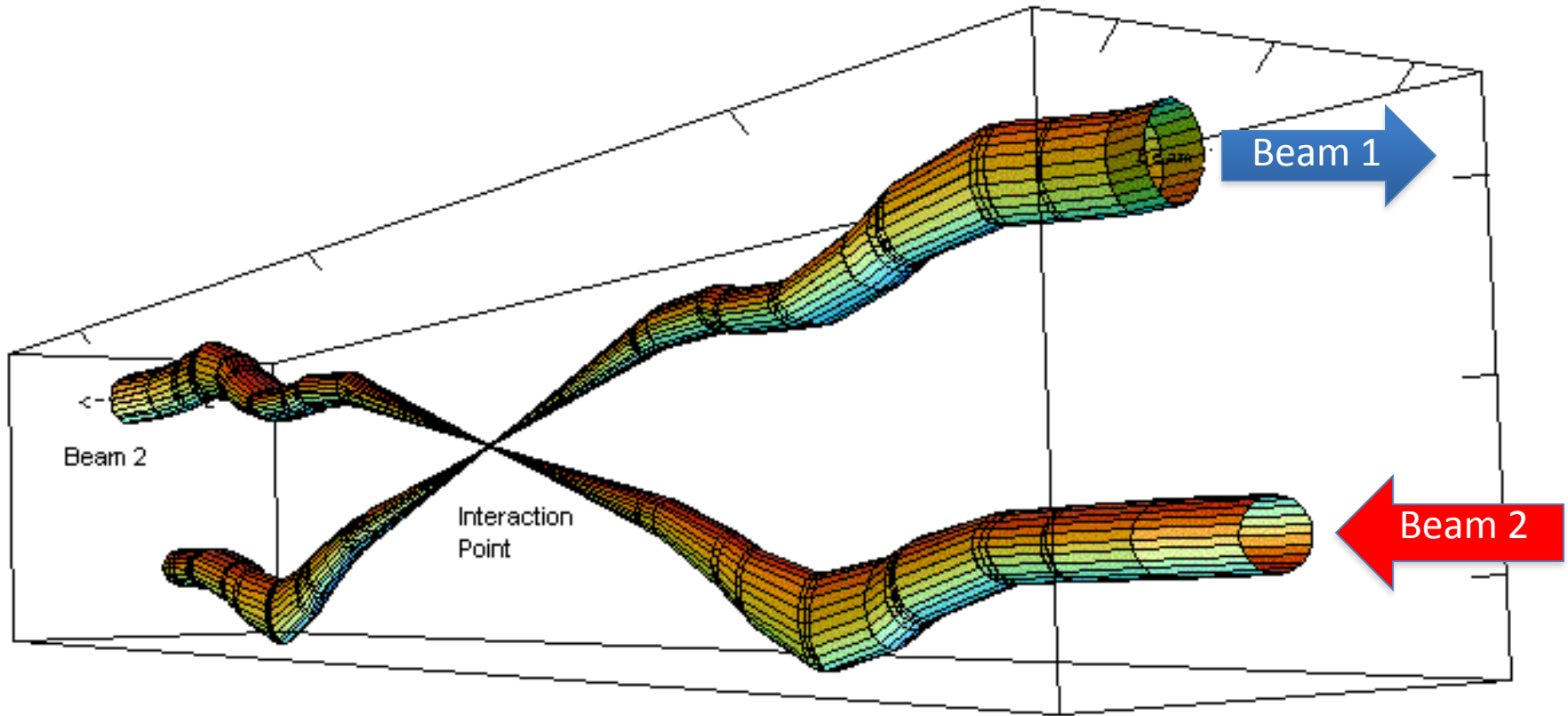
$K(s)$ describes the distribution of focusing strength along the lattice and is periodic.

$$\frac{d^2x}{ds^2} + K(s)x = 0$$

(and similarly for the vertical plane y)

This is Hill's equation.

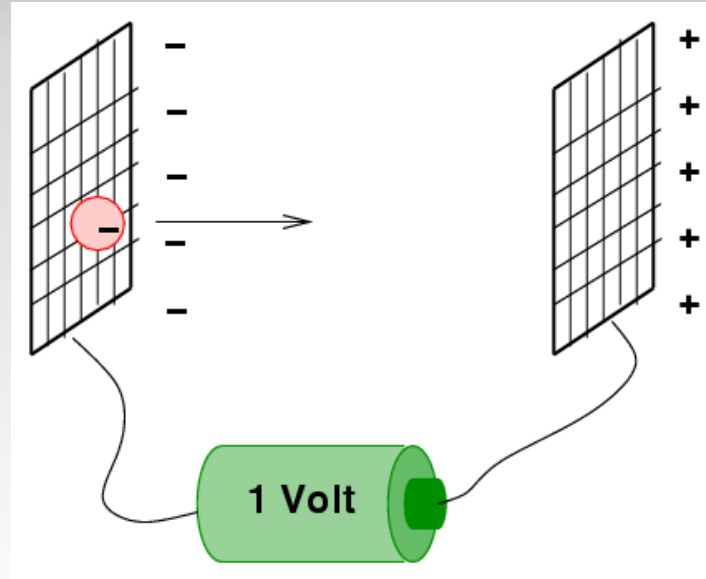
Squeeze



Relative beam sizes around IP1 (Atlas) in collision

Focus beam down to very small sizes in the experiments
using quadrupole magnets

Accelerating the Particles



LHC: beams with an energy of 6.5 TeV

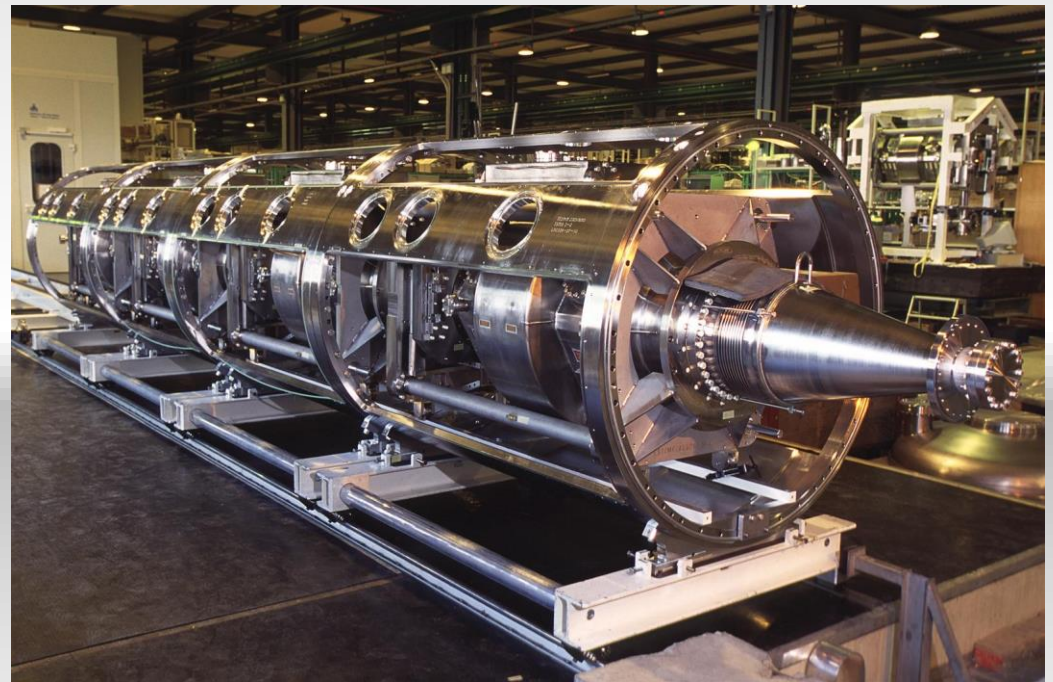
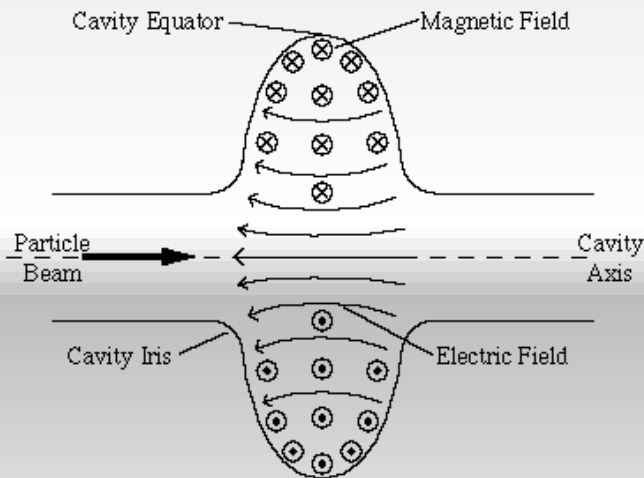
=

6 500 000 000 000 V

Tera Giga Mega kilo

Radio Frequency Cavities

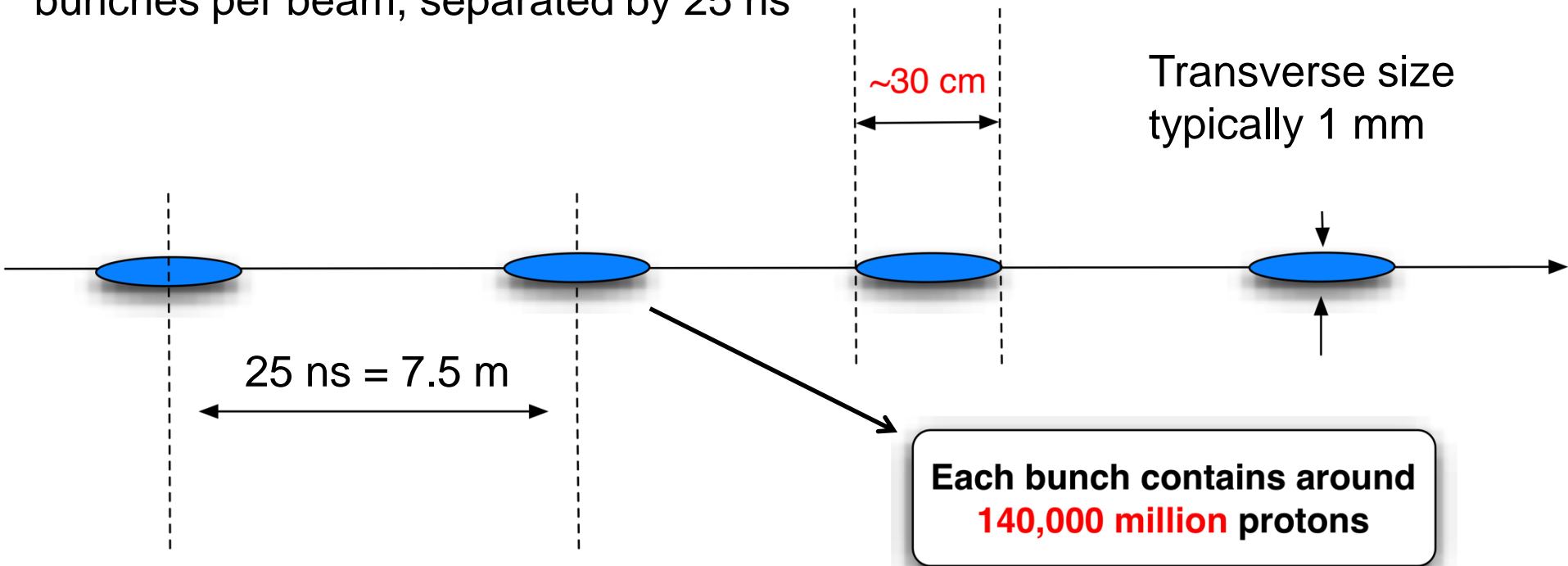
- RF = Oscillation of field at 400 MHz (Radio Frequency)
- Use the Electrical Field at each passage
- 4 cavities/module - 2 modules/beam - 16 MV (5.5 MV/m)
- Superconducting to reduce Beam Impedance



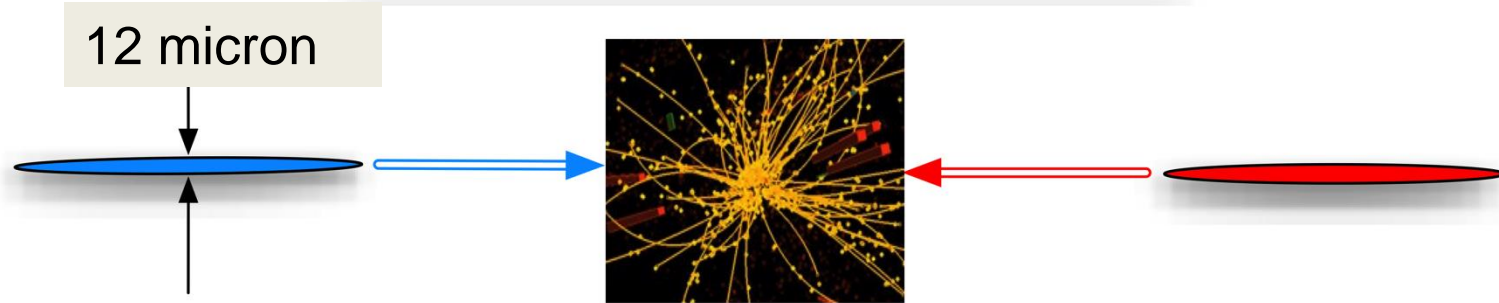
4 Cavity RF Module

Lots of bunches

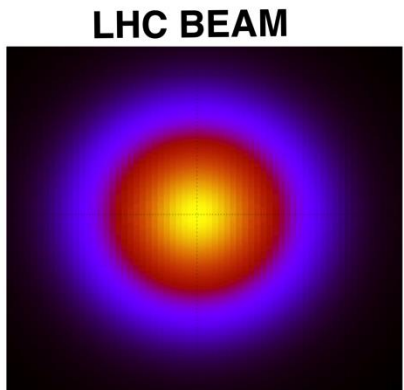
In 2017 the LHC operated with 2300 bunches per beam, separated by 25 ns

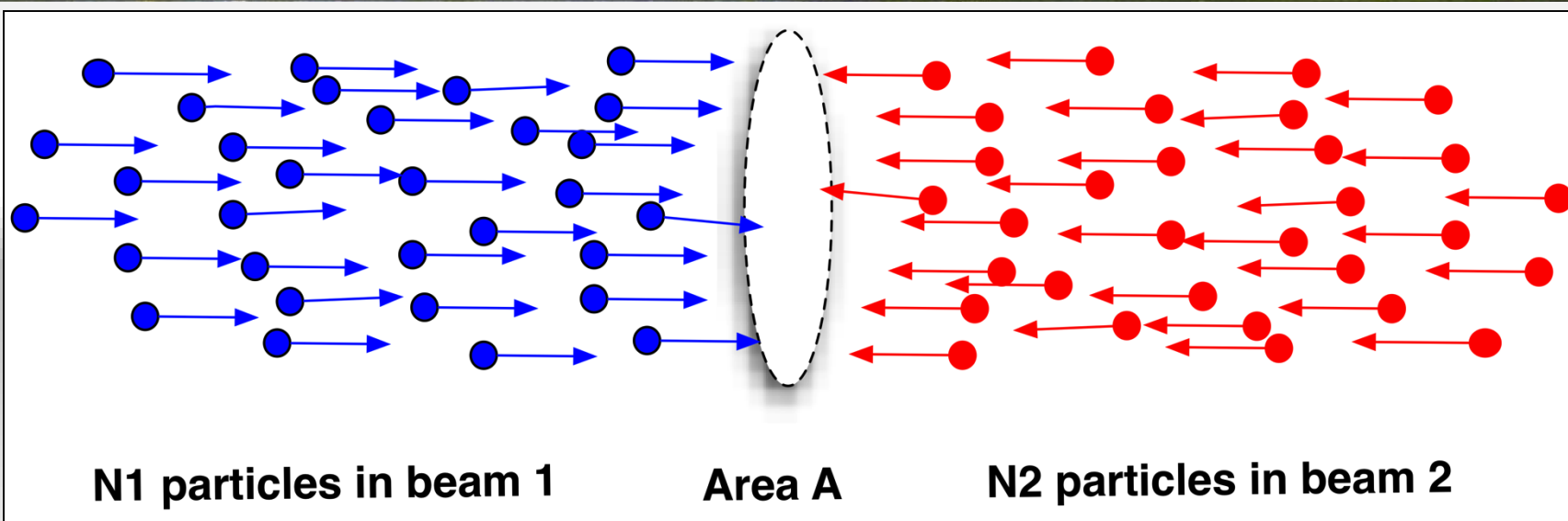


140,000,000,000 protons a bunch
~30 collide at each bunch crossing



Up to 50 collisions per crossing
11'000 crossings per second
2200 bunches per beam (2016)
1 Billion Collissions Per Second → GRID





Number of potential collisions per unit area = $\frac{N_1 N_2}{A}$

Energy in the Beam

- Electric Energy (RF cavity) → Kinetic energy

E-beam	6.5 TeV = 6.5e12 eV
1 eV	1.6e-19 Joules
Number of bunches	2300
Number of protons per bunch	1.3e11 protons
Energy	311 MJoules



What would be the speed of a car to have the same kinetic energy ?

Car Versus Beam

Electric Energy of the beam → Kinetic energy

E-beam	6.5 TeV = 6.5e12 eV
1 eV	1.6e-19 Joules
Number of bunches	2300 (for 2016)
Number of protons per bunch	1.3e11 protons
Energy	311 MJoules

Kinetic Energy of the car

Mass car	1800 kg
Kinetic energy	306 MJoules
v	583 m/s
v	2100 km/h



But at the size smaller than a hair



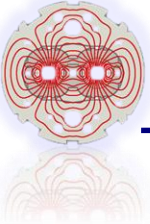
Don't break the machine!

Energy per beam up to 360 MJ



British aircraft carrier at 12 knots

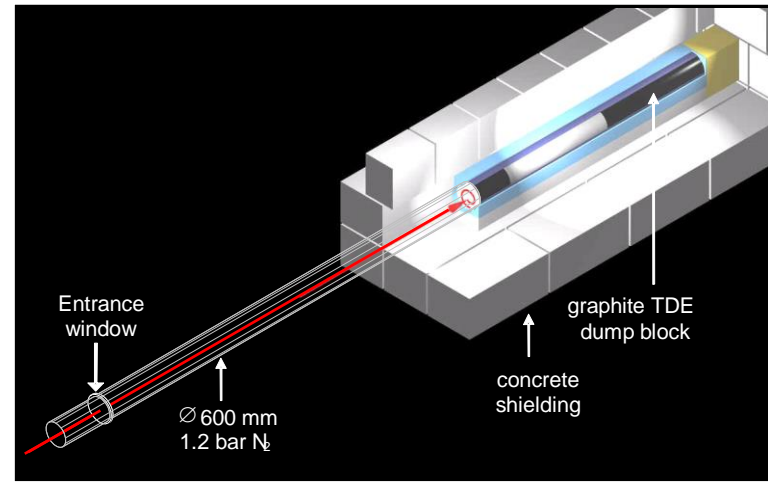
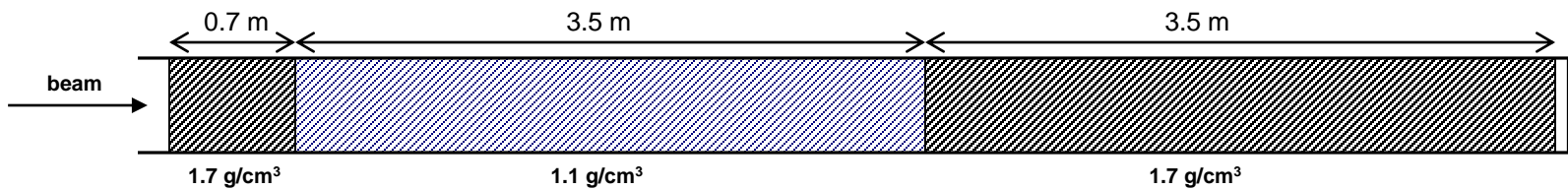
Thread through a very cold, very dark, very small hole...



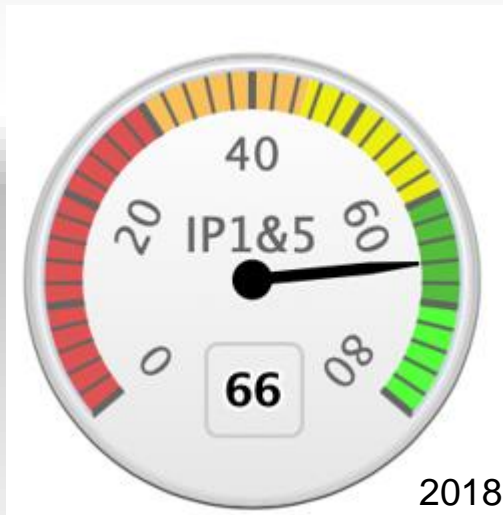
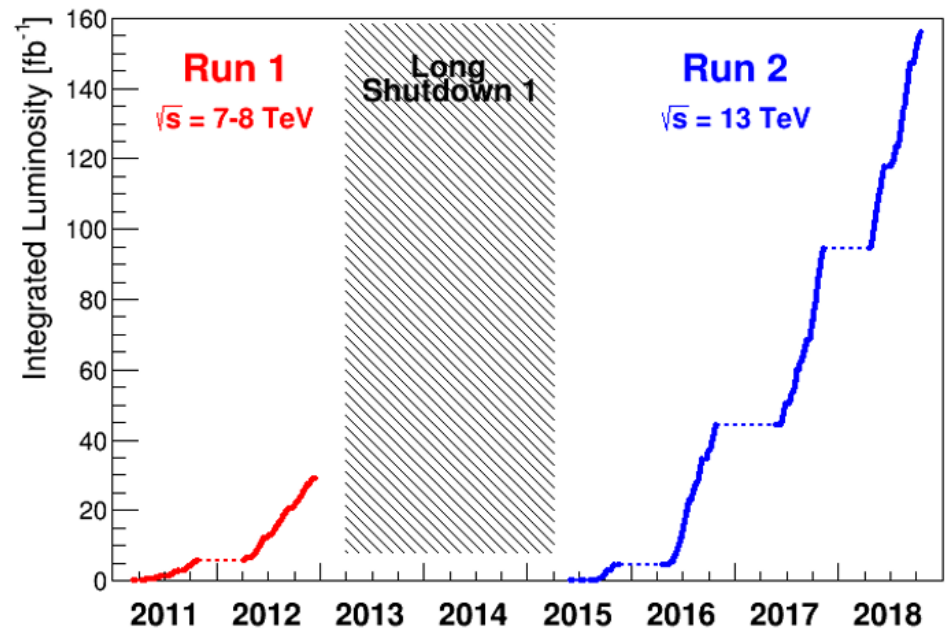
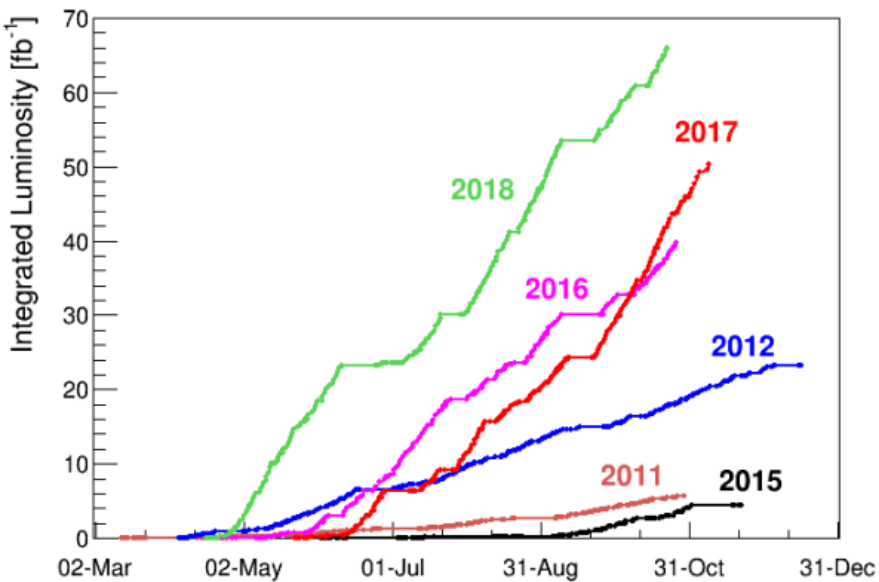
Beam dump block (TDE)



- 700 mm \varnothing graphite core, with graded density of 1.1 g/cm³ and 1.7 g/cm³
- 12 mm wall, stainless-steel welded pressure vessel, at 1.2 bar of N₂
- Surrounded by ~1000 tonnes of concrete/steel radiation shielding blocks



It is all about Luminosity



Period	Int. Luminosity [fb ⁻¹]
Run 1	29.2
Run 2: 2015	4.2
Run 2: 2016	39.7
Run 2: 2017	50.2
Run 2: 2018	66
Total Run 1+ 2	189.3

Luminosity

$$L = \frac{N^2 k_b f}{4 \rho S_x^* S_y^*} F = \frac{N^2 k_b f g}{4 \rho e_n b^*} F$$

N Number of particles per bunch

k_b Number of bunches

f Revolution frequency

σ* Beam size at interaction point

F Reduction factor due to crossing angle

ε Emittance

ε_n Normalized emittance

β* Beta function at IP

$$S^* = \sqrt{b^* e}$$

$$e_N = 2.5 \cdot 10^{-6} \text{ m.rad}$$

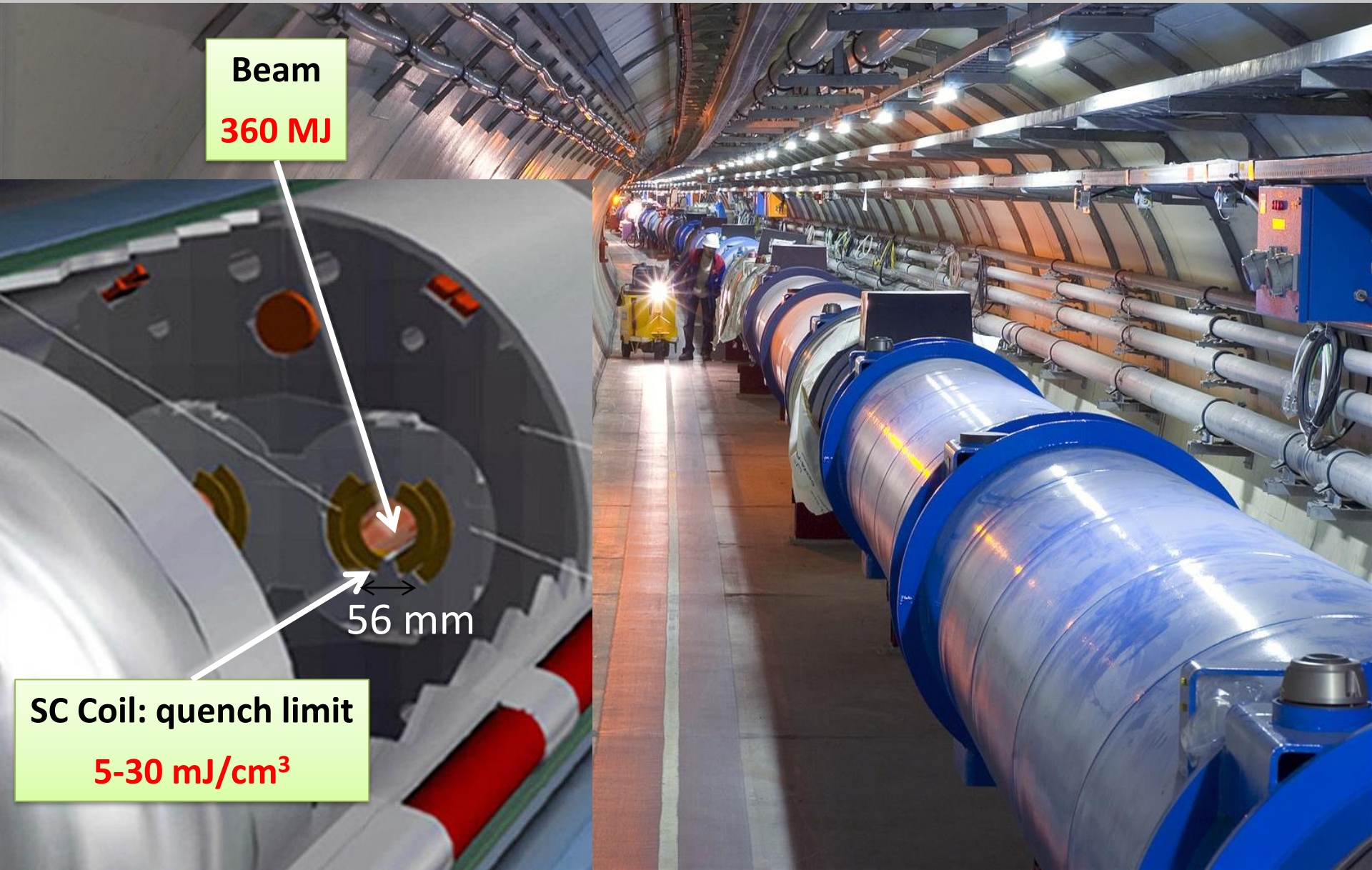
$$e = 3.35 \cdot 10^{-10} \text{ m.rad}$$

$$S^* = 11.6 \cdot 10^{-6} \text{ m}$$

$$(p = 7 \text{ TeV}, b^* = 0.4 \text{ m})$$

Quench Limit of LHC Super-Conducting Magnets

Nominal design at 7 TeV

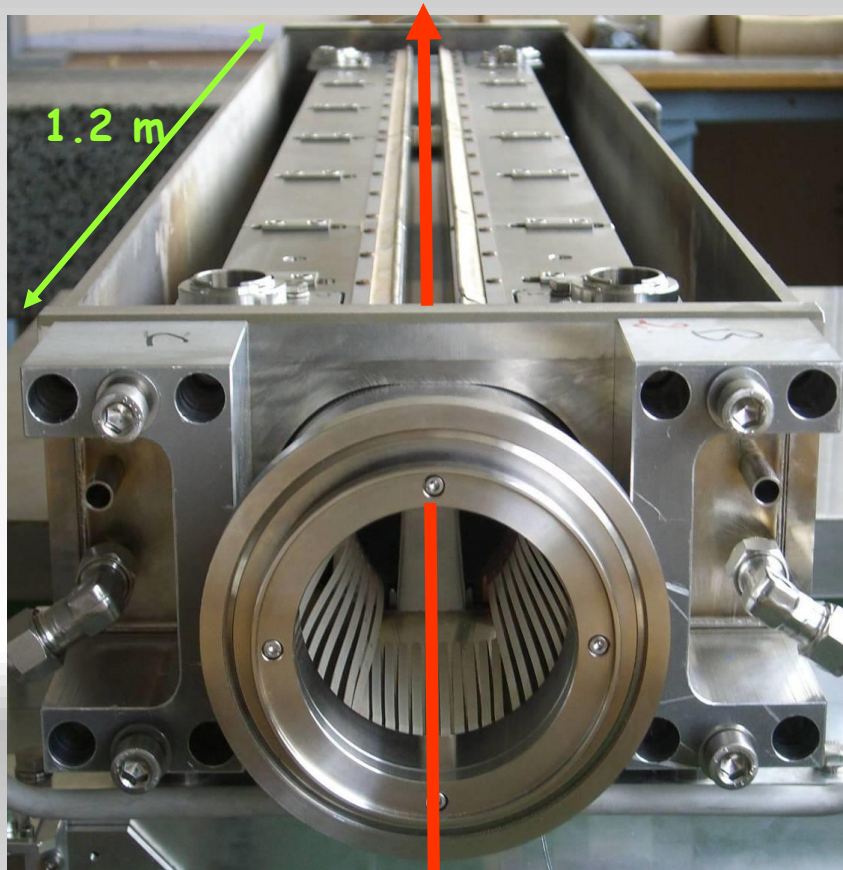


Beam
360 MJ

56 mm

SC Coil: quench limit
5-30 mJ/cm³

Collimation

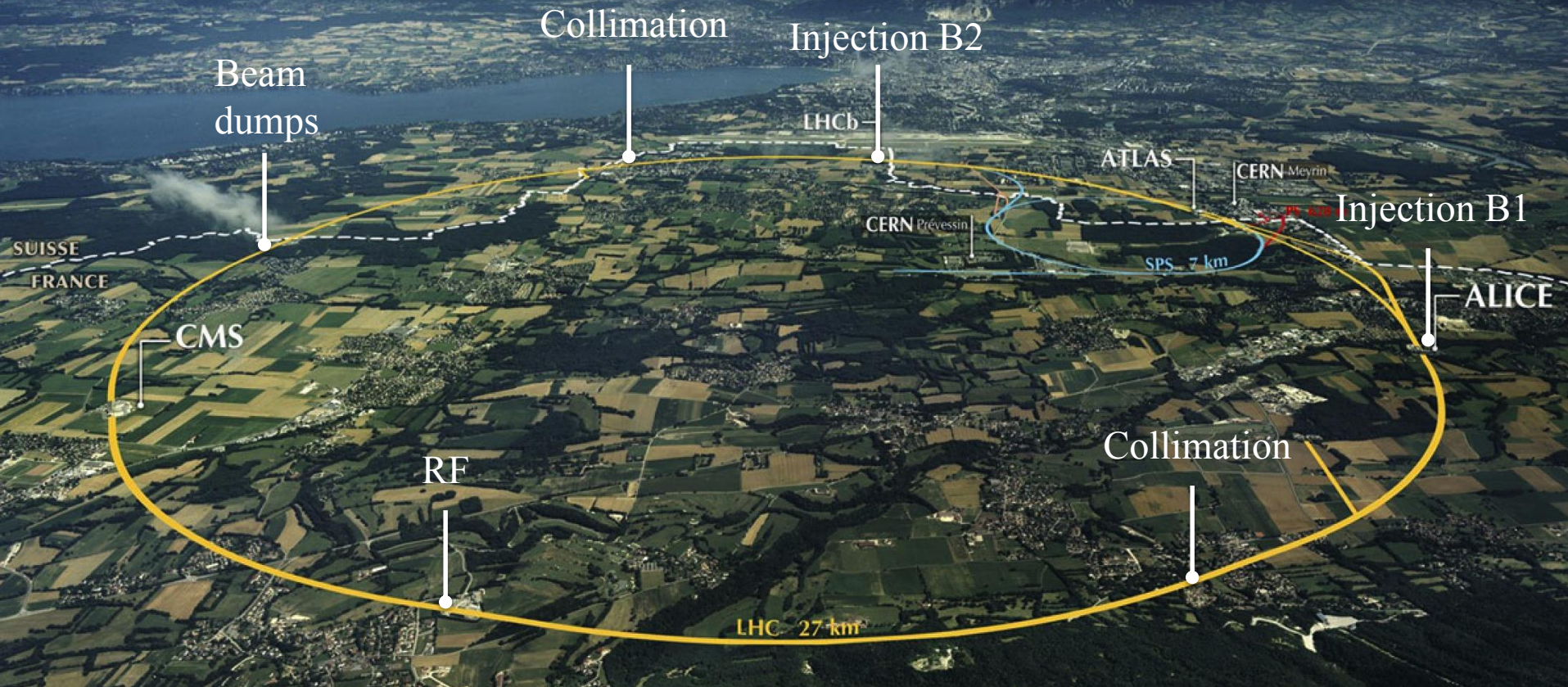


beam

Almost 100 collimators and absorbers.

Alignment tolerances < 0.1 mm to ensure that over 99.99% of the protons are intercepted. Primary and secondary collimators are made of reinforced graphite – robust.

LHC: big, cold, high energy



1720 Power converters
> 9000 magnetic elements
7568 Quench detection systems
1088 Beam position monitors
~4000 Beam loss monitors

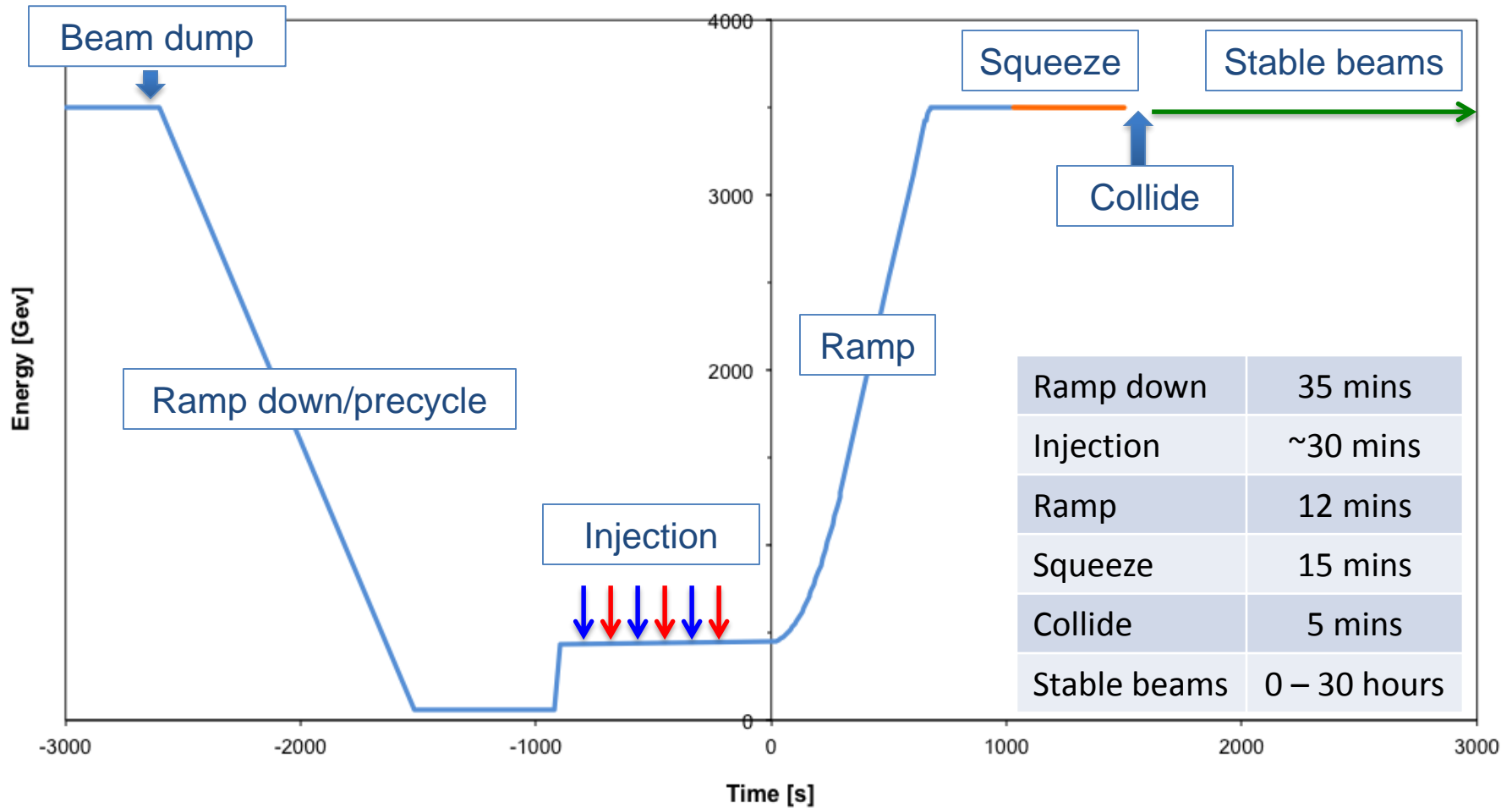
120 tonnes of Helium, down to 1.9 K
360 MJ stored beam energy per beam
11 GJ total stored energy in magnetic systems

Machine Elements

- Magnets: guidance and transverse ‘stability’
 - Dipoles, Quadrupoles, Sextupoles, Octupoles
- Radio Frequency – Longitudinal motion
 - Acceleration
 - Feedback
- Injection and Beam Dumping Systems
 - Fast Pulsed Magnets (‘Kicker Magnets’)
 - Septum Magnets
 - Beam dump block
- Machine Protection
 - Collimation System, other absorbers, Interlock Systems
- Beam Diagnostics & Protection
 - Beam Position, Beam Loss Monitors, Tune Measurement, Synchrotron Light Measurements, Beam Size Measurements
- Cryogenics & Vacuum



Operational cycle

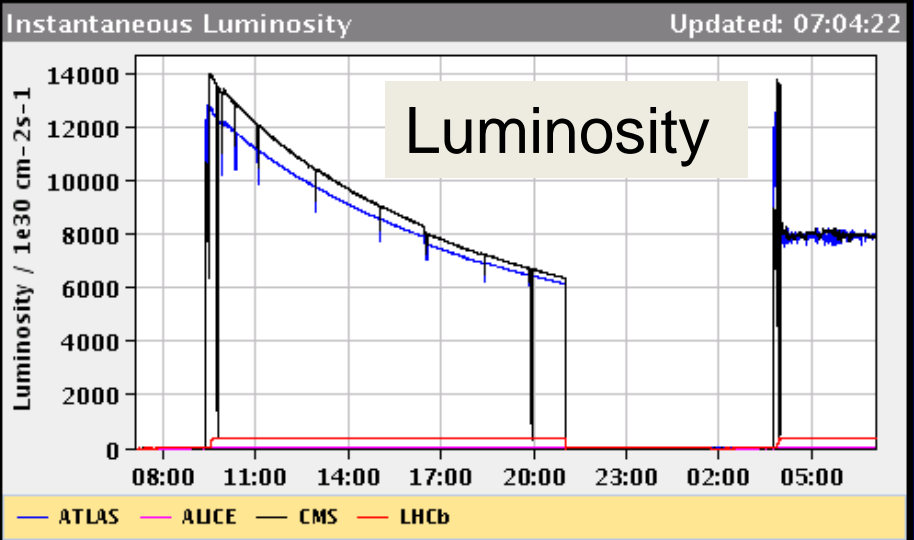
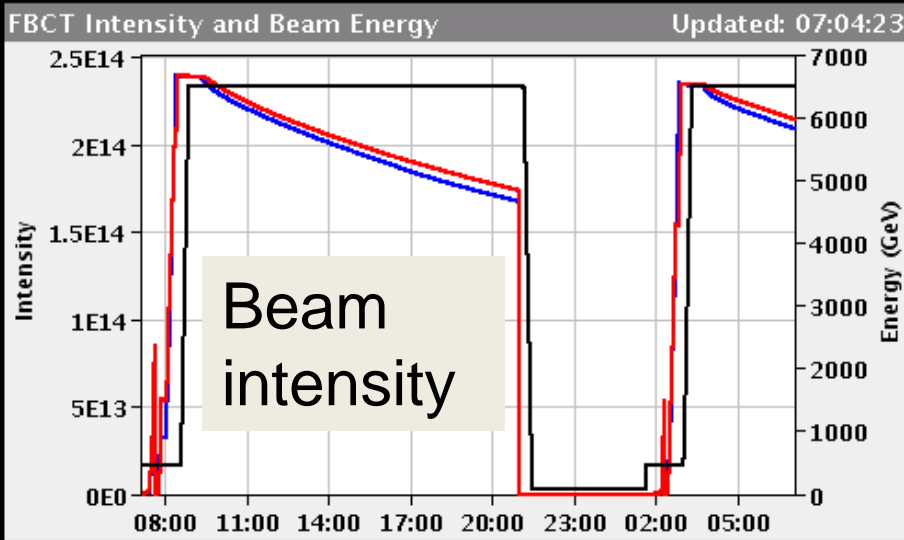


Turn around from stable beams to stable beams - 2 to 3 hours on a good day, followed by Stable Beams, average 6 hours.

PROTON PHYSICS: STABLE BEAMS

Energy: 6499 GeV I(B1): 2.10e+14 I(B2): 2.16e+14

Inst. Lumi [(ub.s)^-1] IP1: 7906.63 IP2: 1.69 IP5: 7897.24 IP8: 379.44



Comments (26-Oct-2016 02:29:17)

physics 2220 bunches/beam
with levelled luminosity at IP1 and IP5

BIS status and SMP flags

	B1	B2
Link Status of Beam Permits	true	true
Global Beam Permit	true	true
Setup Beam	false	false
Beam Presence	true	true
Moveable Devices Allowed In	true	true
Stable Beams	true	true

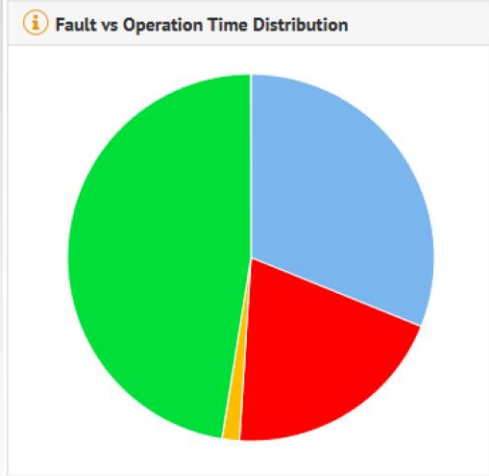
AFS: 25ns_2220b_2208_1940_2036_96bpi_24inj

PM Status B1 **ENABLED** PM Status B2 **ENABLED**

Machine Performance 2018

Availability 80.1%

Stable beams 47.5%



Fault labels

60A BPM Interaction

BLM Sanity Checks TIOC

Min Turnaround

0.5h

Avg Turnaround

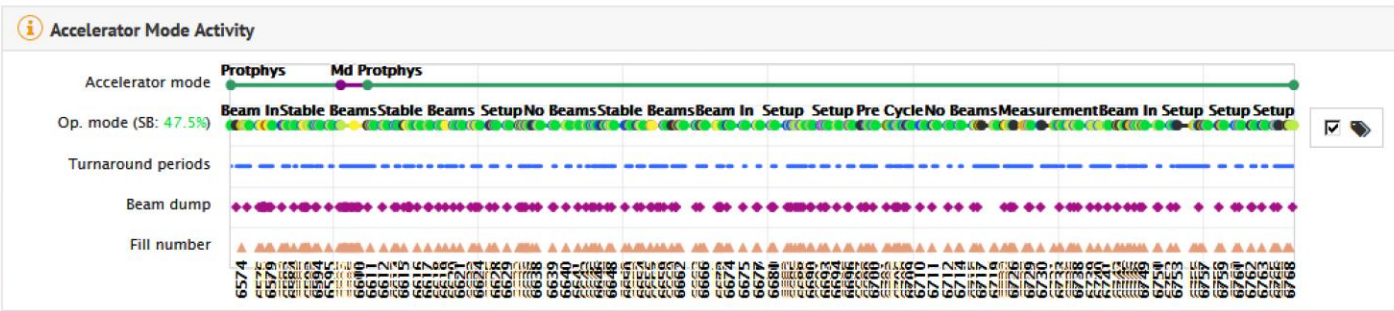
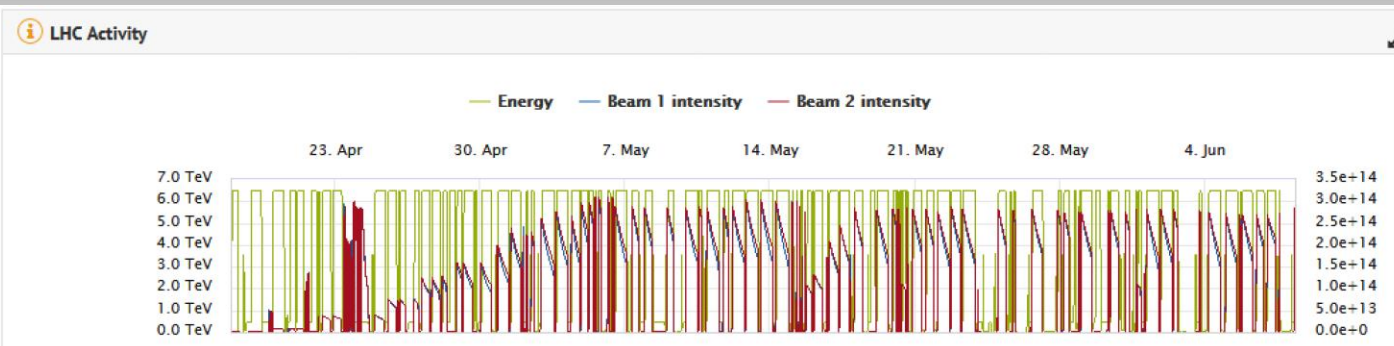
7.5h

Fault count

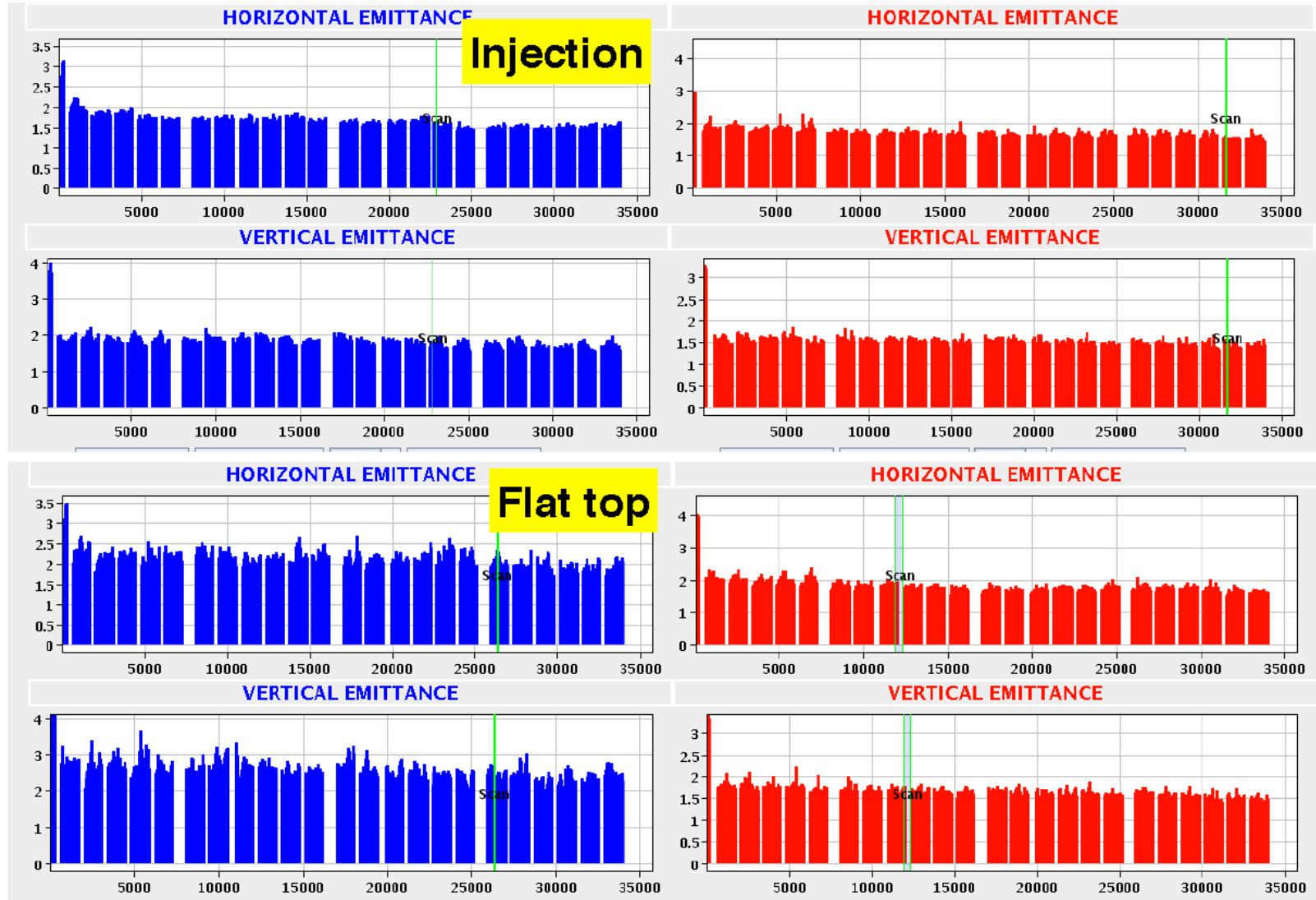
185

Max Turnaround

39.3h

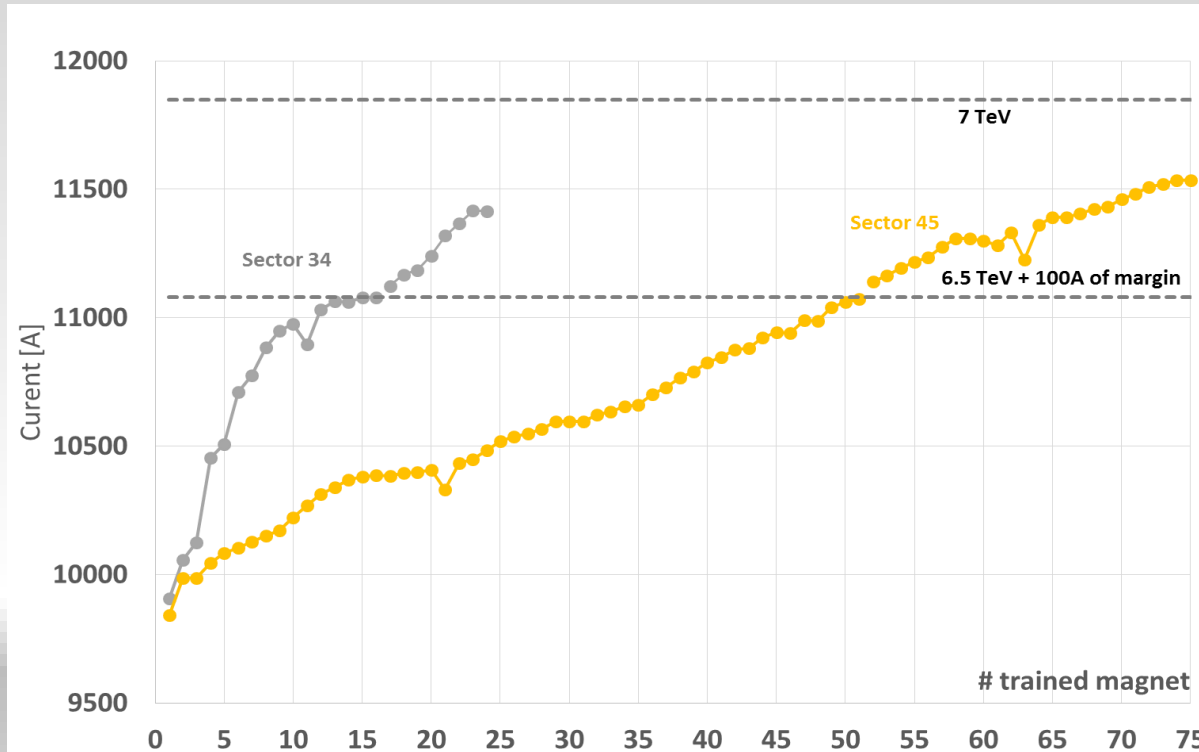


Emittances F5448



Magnet Training to reach 7 TeV

Beam Energy



'Nominal'

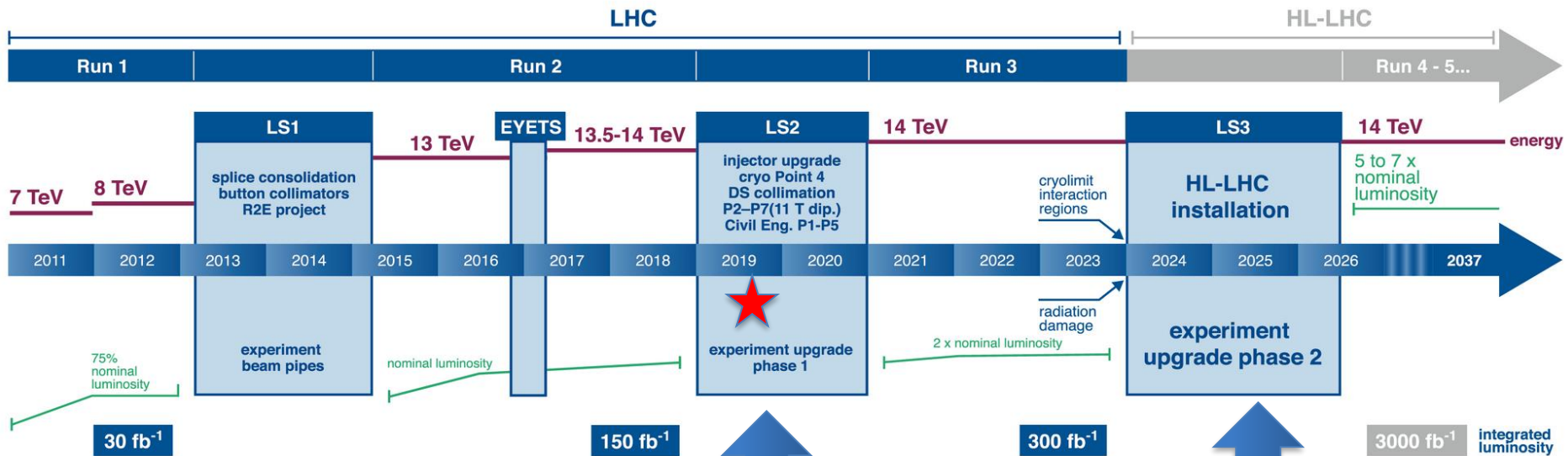
Present
Operation

In December 2016, additional training ramps were performed in 2 sectors

What's Next ?

High-Luminosity LHC

LHC / HL-LHC Plan



Injectors upgrade and LHC civil engineering

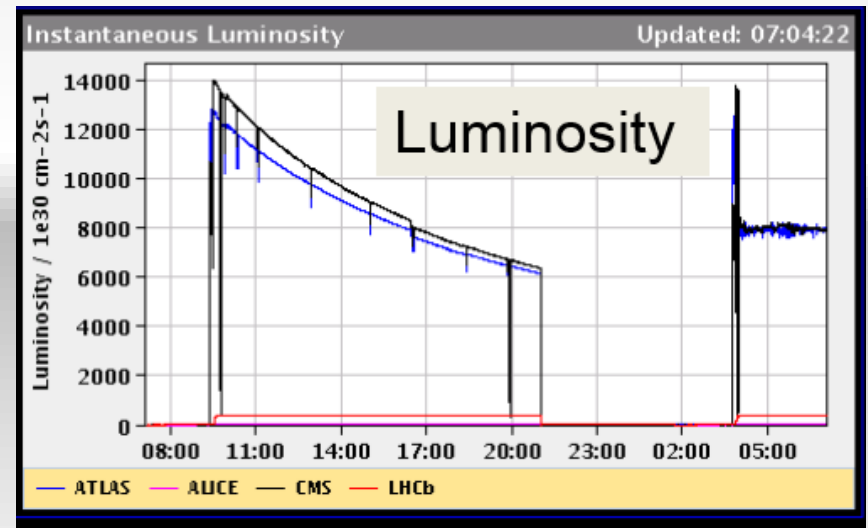
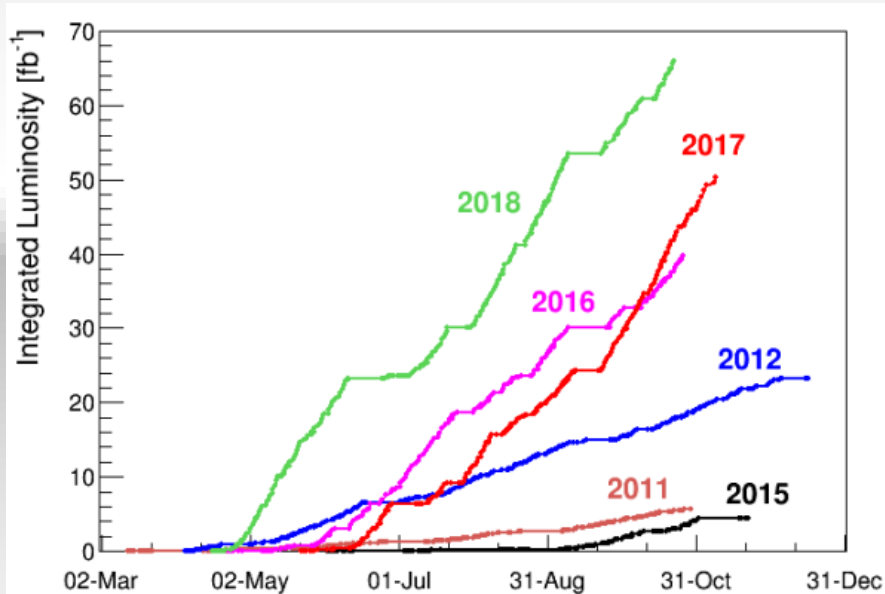
HL-LHC upgrade

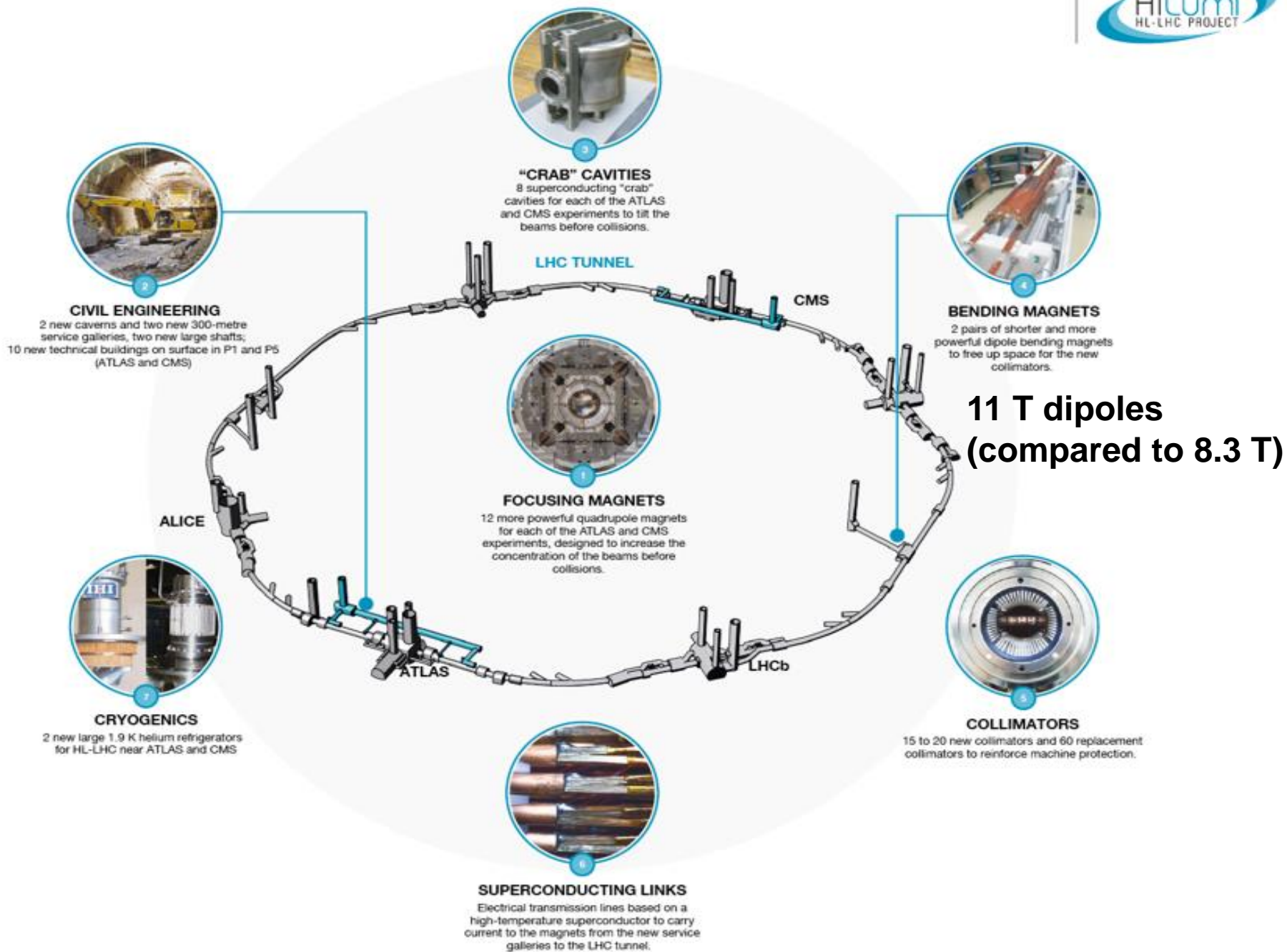
HL-LHC

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

An integrated luminosity of 250 fb^{-1} per year, enabling the goal of $L_{\text{int}} = 3000 \text{ fb}^{-1}$ twelve years after the upgrade.

Luminosity so far





The Future @ CERN after the HL-LHC

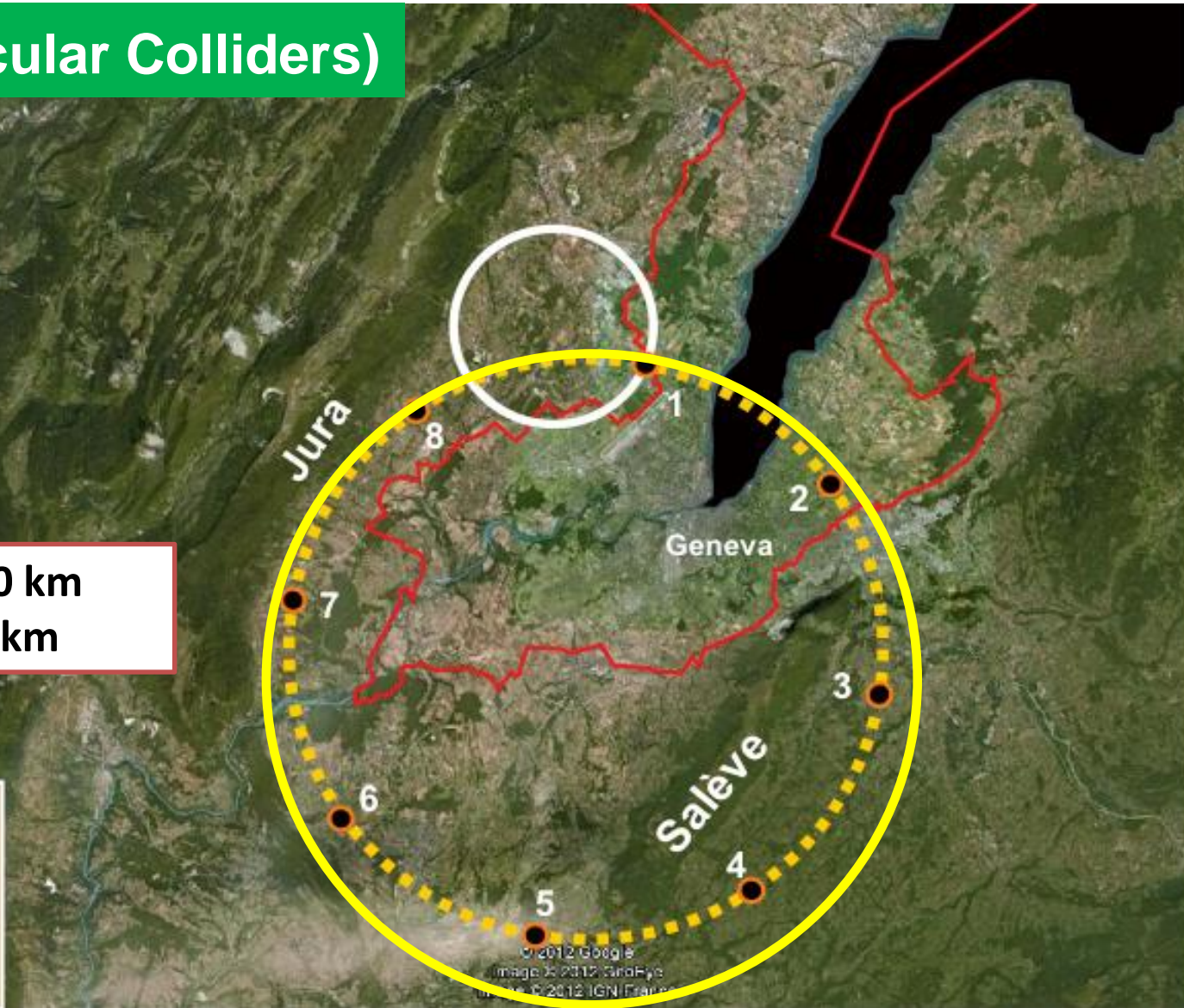
80-100 km tunnel infrastructure in Geneva area – design driven by pp-collider requirements with possibility of e⁺-e⁻ (TLEP) and p-e (VLHeC)

FCC (Future Circular Colliders)

15 T ⇒ 100 TeV in 100 km
20 T ⇒ 100 TeV in 80 km

LEGEND

- LHC tunnel
- HE_LHC 80km option
- potential shaft location



Future Circular Collider Conference

fcc.web.cern.ch

FCCWEEK 2018



UNIVERSITY OF TWENTE.



CLIC near CERN: e+e- Collider

Legend

— CERN existing LHC

Potential underground siting :

●●●● CLIC 500 GeV

●●●● CLIC 1.5 TeV

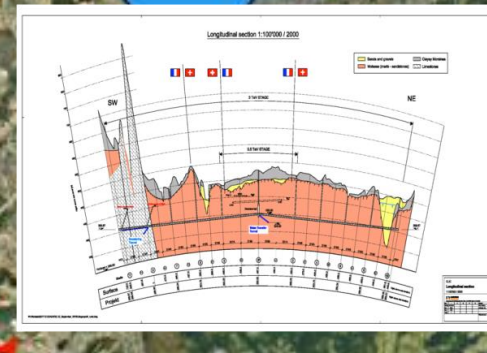
●●●● CLIC 3 TeV

Jura Mountains

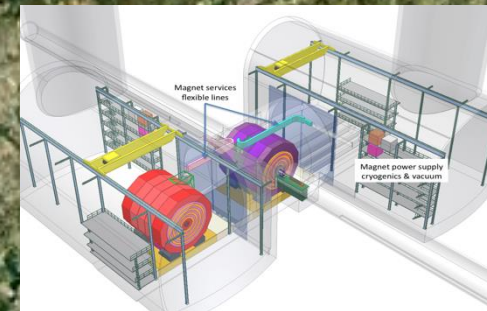
IP

Geneva

Lake Geneva



Tunnel implementations
(laser straight)



Central MDI & Interaction
Region



SUISSE
FRANCE

CMS

LHCb

CERN Préessin

ATLAS

CERN Meyrin

SPS 7 km

ALICE

LHC 27 km

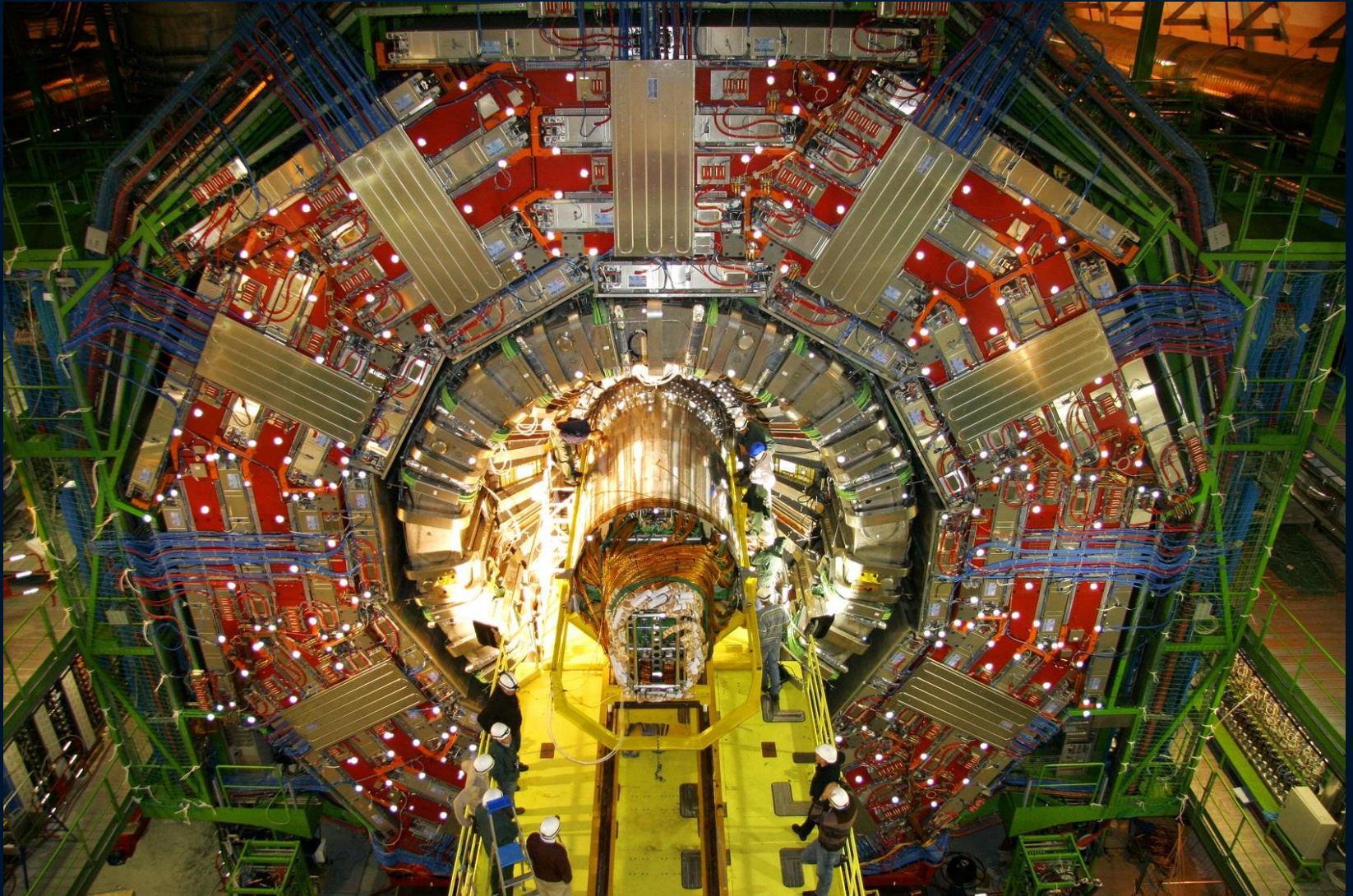
Bedankt voor jullie aandacht,
en een goede reis terug !



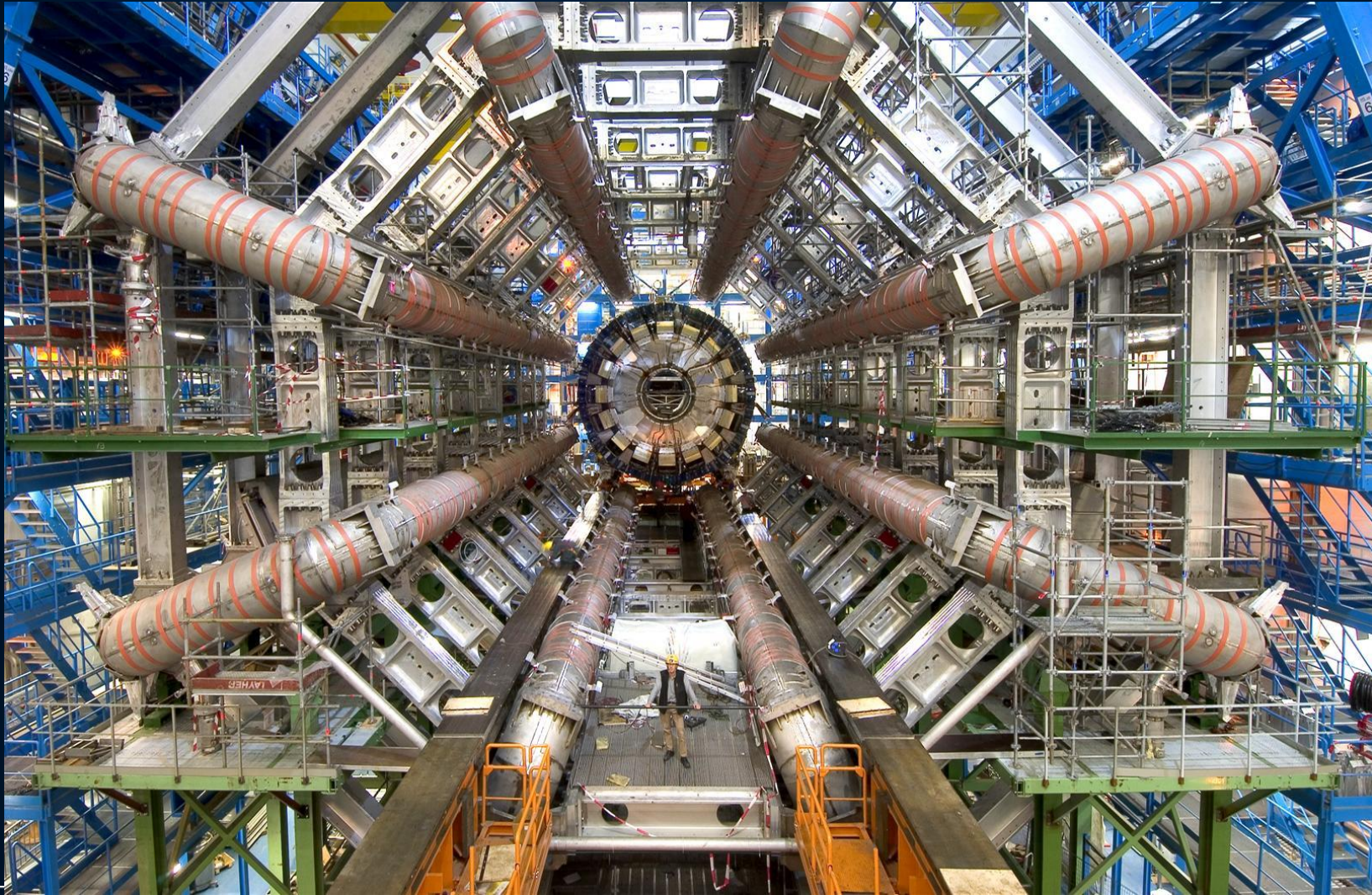
Accelerating Science and Innovation

SPARE SLIDES

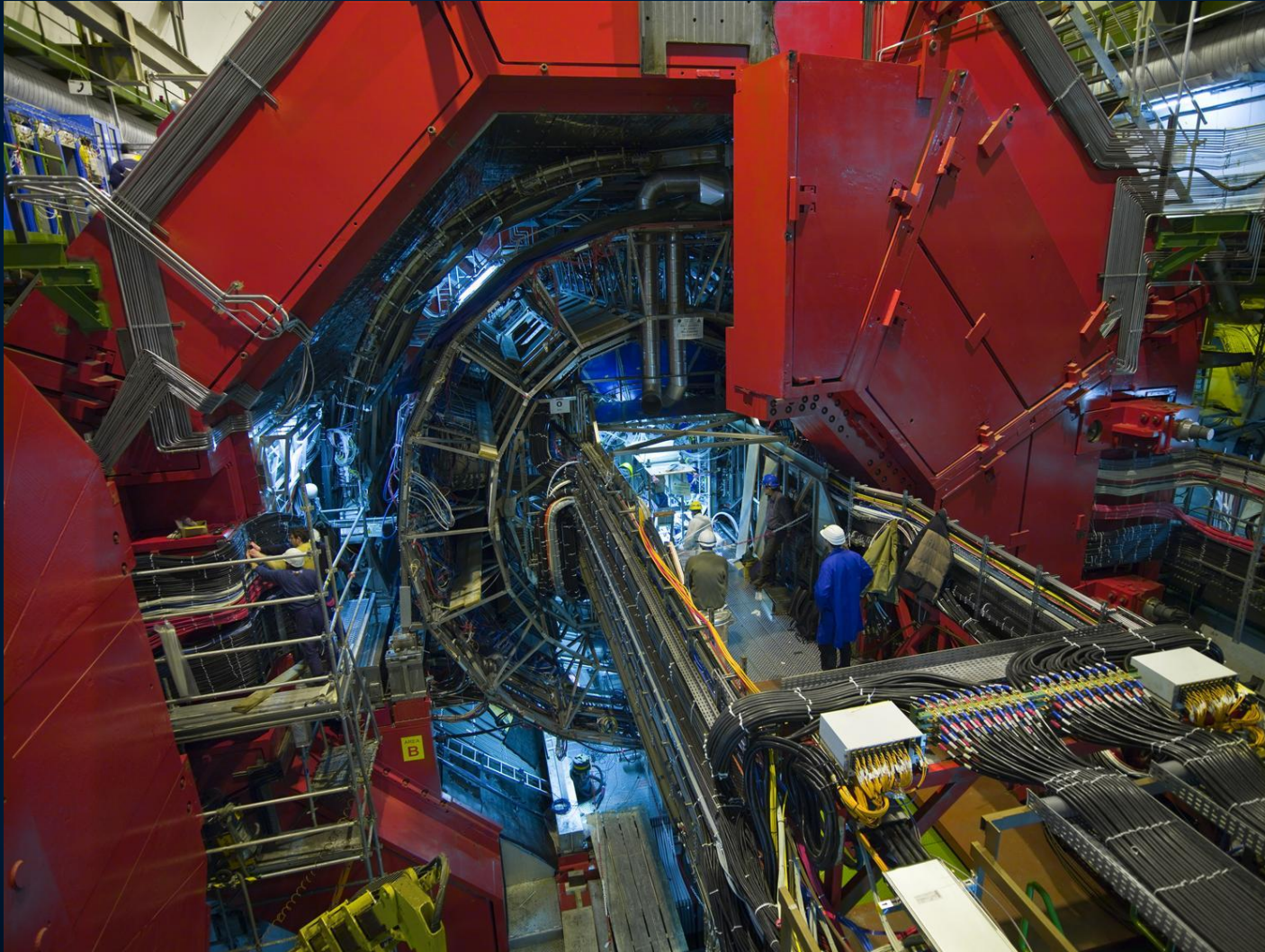
CMS: heavier than the Eifel tower



ATLAS: large as a building of 5 floors



ALICE: very sensitive, optimised for ion collisions

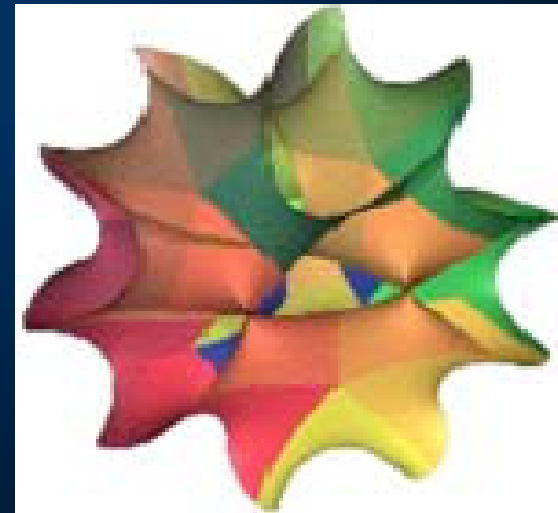
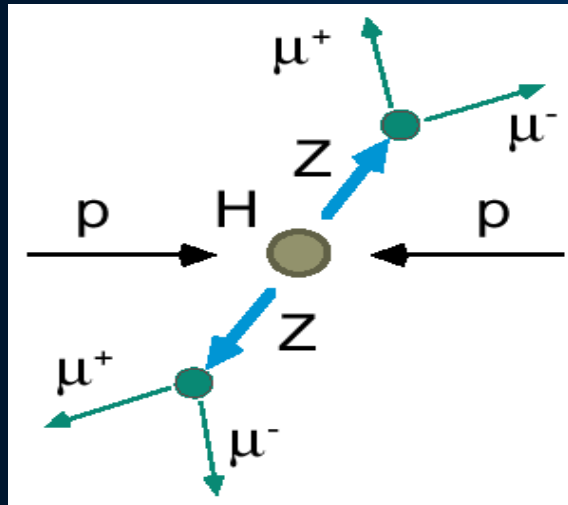


LHCb: asymmetric, B-physics



Aim of the game

We want to deliver maximum number of collisions at the maximum beam energy for maximum physics reach



$$E = m \cdot c^2$$

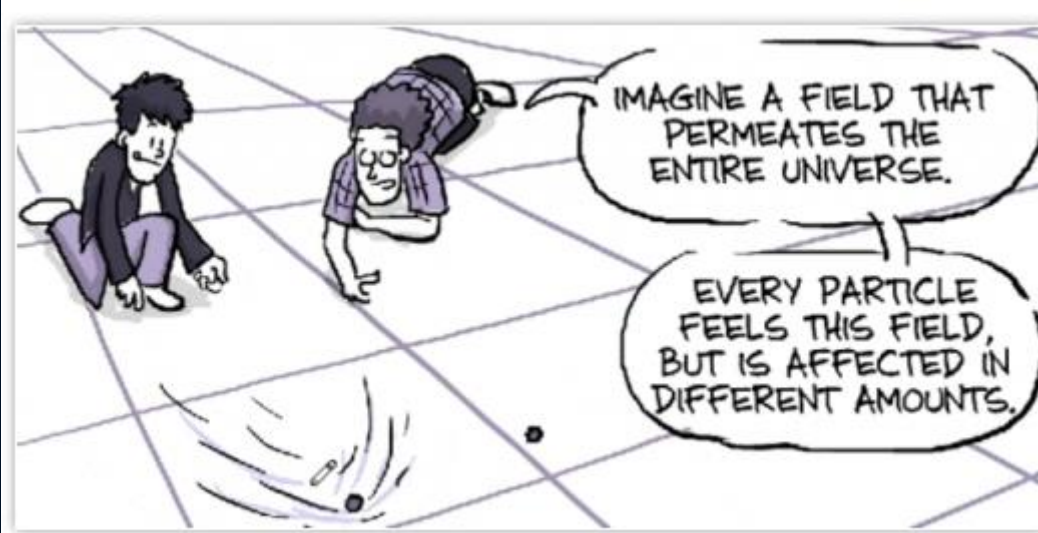
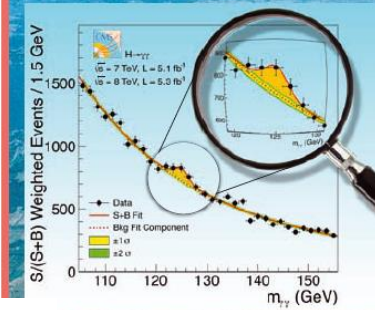
The Higgs field gives mass to other particles



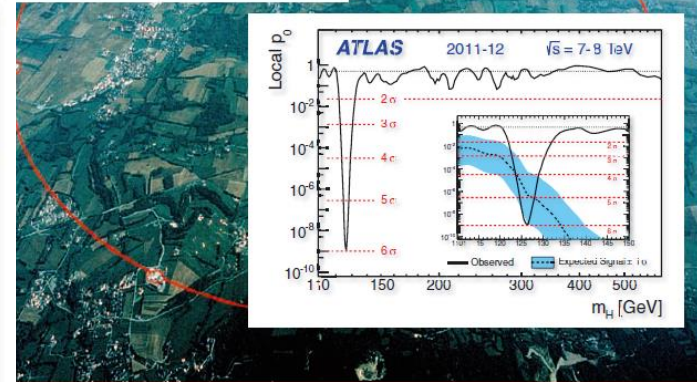
PHYSICS LETTERS B

Available online at www.sciencedirect.com

SciVerse ScienceDirect

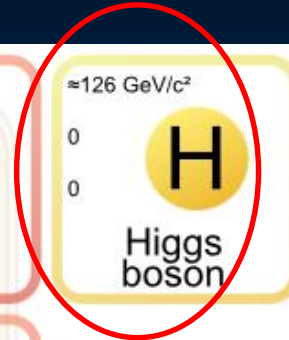


(Credit: PHD Comics)



Why is the Higgs so special?

	mass →	$\approx 2.3 \text{ MeV}/c^2$	$\approx 1.275 \text{ GeV}/c^2$	$\approx 173.07 \text{ GeV}/c^2$	0	$\approx 126 \text{ GeV}/c^2$
charge →	$2/3$	$2/3$	$2/3$	0	0	0
spin →	$1/2$	$1/2$	$1/2$	1	0	0
QUARKS		u up	c charm	t top	g gluon	H Higgs boson
		$\approx 4.8 \text{ MeV}/c^2$	$\approx 95 \text{ MeV}/c^2$	$\approx 4.18 \text{ GeV}/c^2$	0	
	$-1/3$	$-1/3$	$-1/3$	$-1/3$	0	
	$1/2$	$1/2$	$1/2$	$1/2$	1	
		d down	s strange	b bottom	γ photon	
		$0.511 \text{ MeV}/c^2$	$105.7 \text{ MeV}/c^2$	$1.777 \text{ GeV}/c^2$	$91.2 \text{ GeV}/c^2$	
	-1	-1	-1	-1	0	
	$1/2$	$1/2$	$1/2$	$1/2$	1	
		e electron	μ muon	τ tau	Z Z boson	
LEPTONS		$< 2.2 \text{ eV}/c^2$	$< 0.17 \text{ MeV}/c^2$	$< 15.5 \text{ MeV}/c^2$	$80.4 \text{ GeV}/c^2$	
	0	0	0	0	± 1	
	$1/2$	$1/2$	$1/2$	$1/2$	1	
		ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	W W boson	
						GAUGE BOSONS

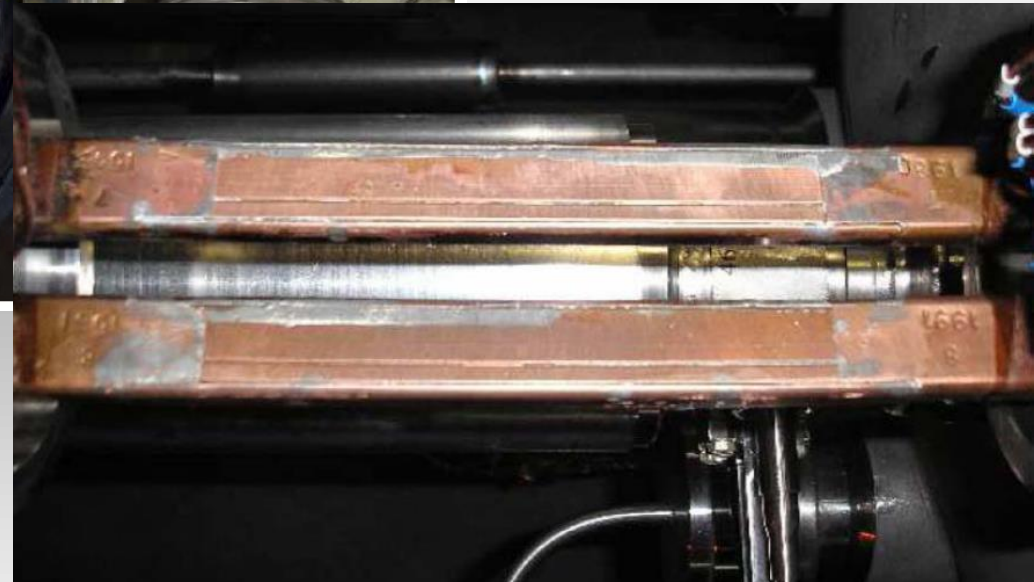
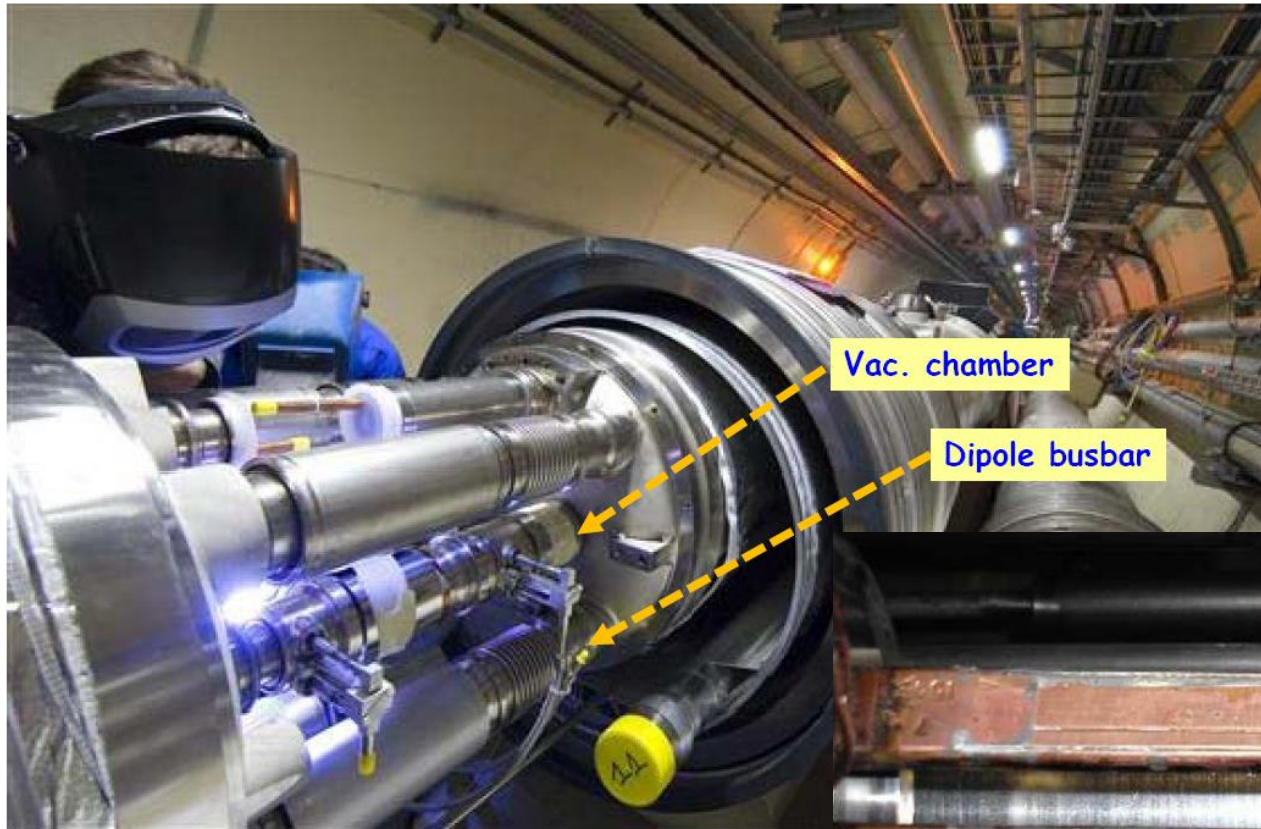


Reduced Energy – the history



10th September 2008: First circulating beams – all smiles

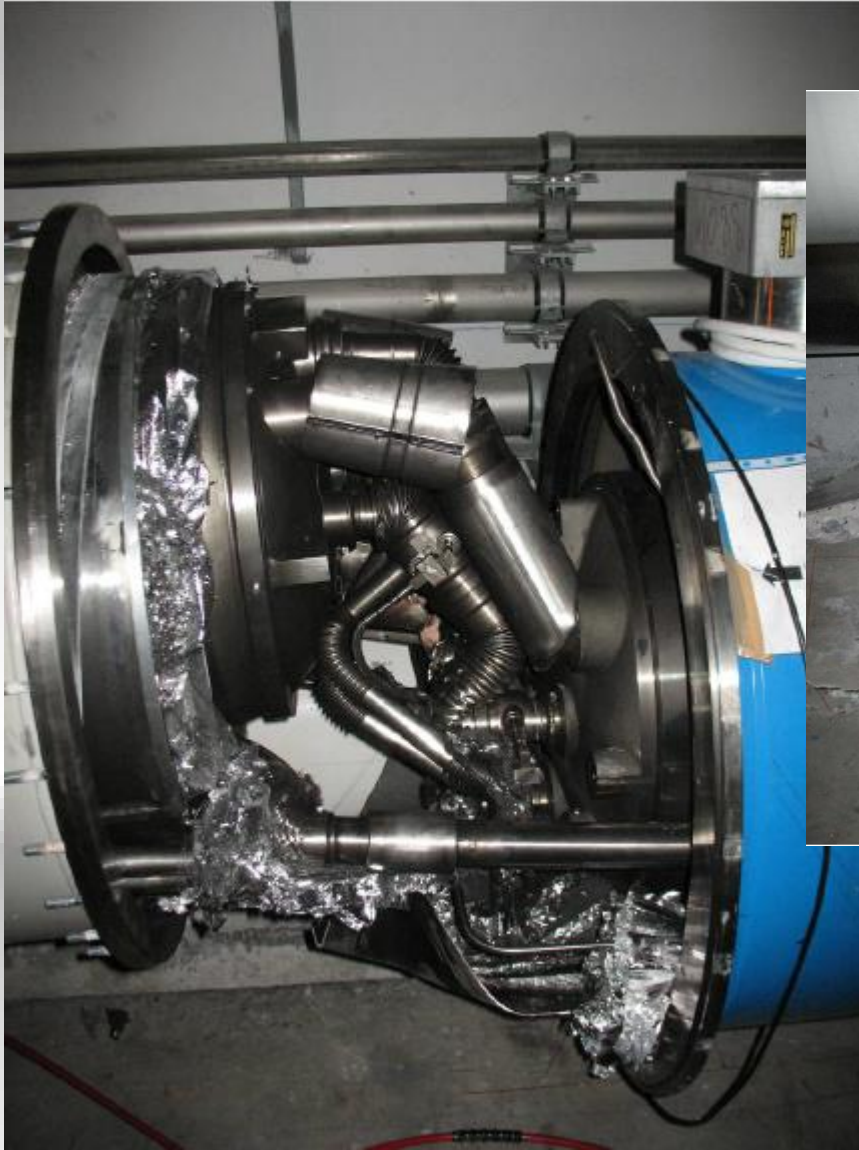
Reduced energy – the history



19th September 2008: electrical arc ruptured bus-bar interconnection during tests without beam – violent He blow-off

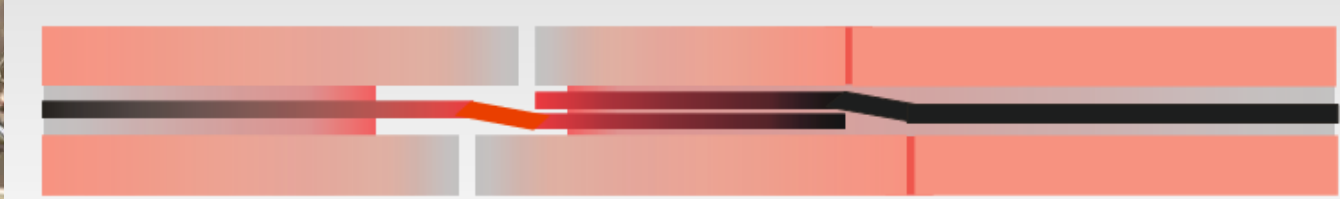
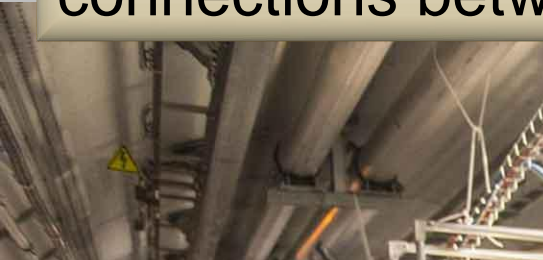


Reduced energy – the history



Major damage over a few hundred meters. Back in operation 1 year later.

2013 – 2014: Long Shutdown to repair defective connections between superconducting magnets



2015: Restart with beam energy of 6.5 TeV



Next 10 years

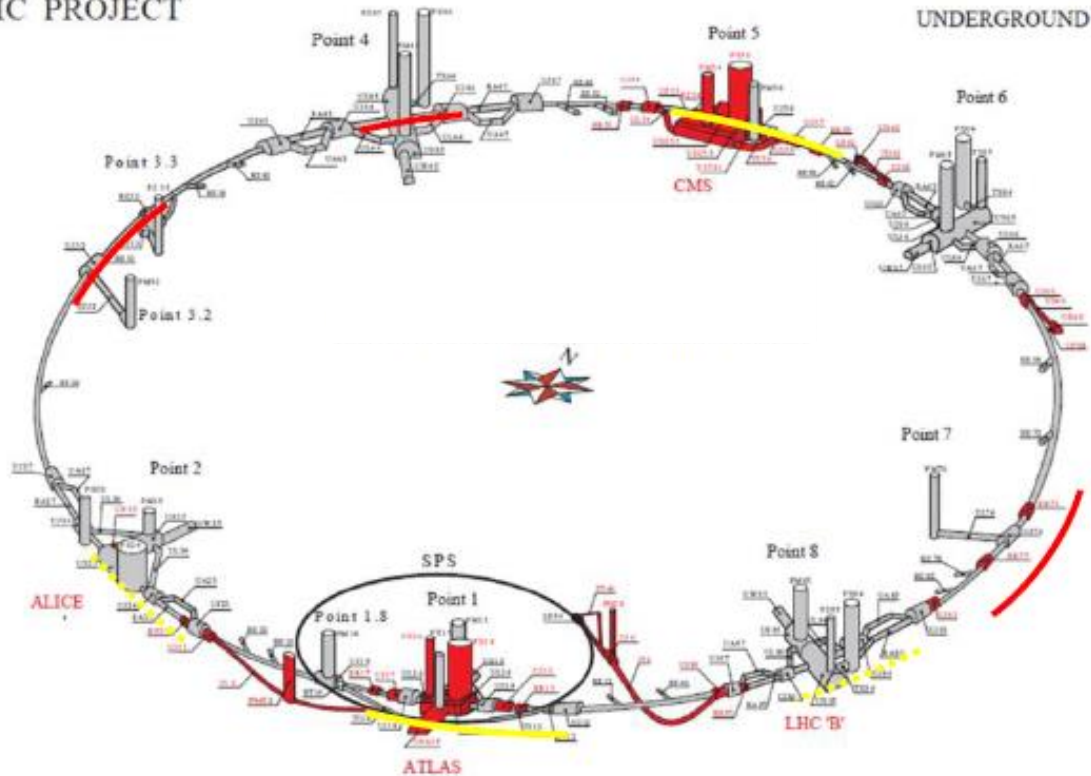
2012	Run I	4 TeV, peak luminosity $7.7e33$
2013	LS1	Splice consolidation, R2E, DN200... Experiments' consolidation and upgrades
2014		
2015	Run II	6.5 to 7 TeV, peak luminosity $1.7e34$
2016		
2017		
2018	LS2	LHC phase 1 and injector upgrades Experiments' consolidation and upgrades
2019	Run III	7 TeV, peak luminosity $2.0e34$
2020		
2021		
2022	LS3	HL-LHC upgrade (insertions, crab cavities...) Experiments' HL upgrades
2023		

Followed by many years of HL-LHC running

The LHC has a long future ahead

The HL-LHC Project

HC PROJECT



- New IR-quads Nb₃Sn (inner triplets)
- New 11 T Nb₃Sn (short) dipoles
- Collimation upgrade
- Cryogenics upgrade
- Crab Cavities
- Cold powering
- Machine protection
- ...

Major intervention on more than 1.2 km of the LHC

High Luminosity LHC Participants



Science & Technology
Facilities Council



UNIVERSITY OF
LIVERPOOL

LANCASTER
UNIVERSITY

MANCHESTER
1824



UNIVERSITY OF
Southampton



ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

CSIC
Consejo Superior de Investigaciones Científicas

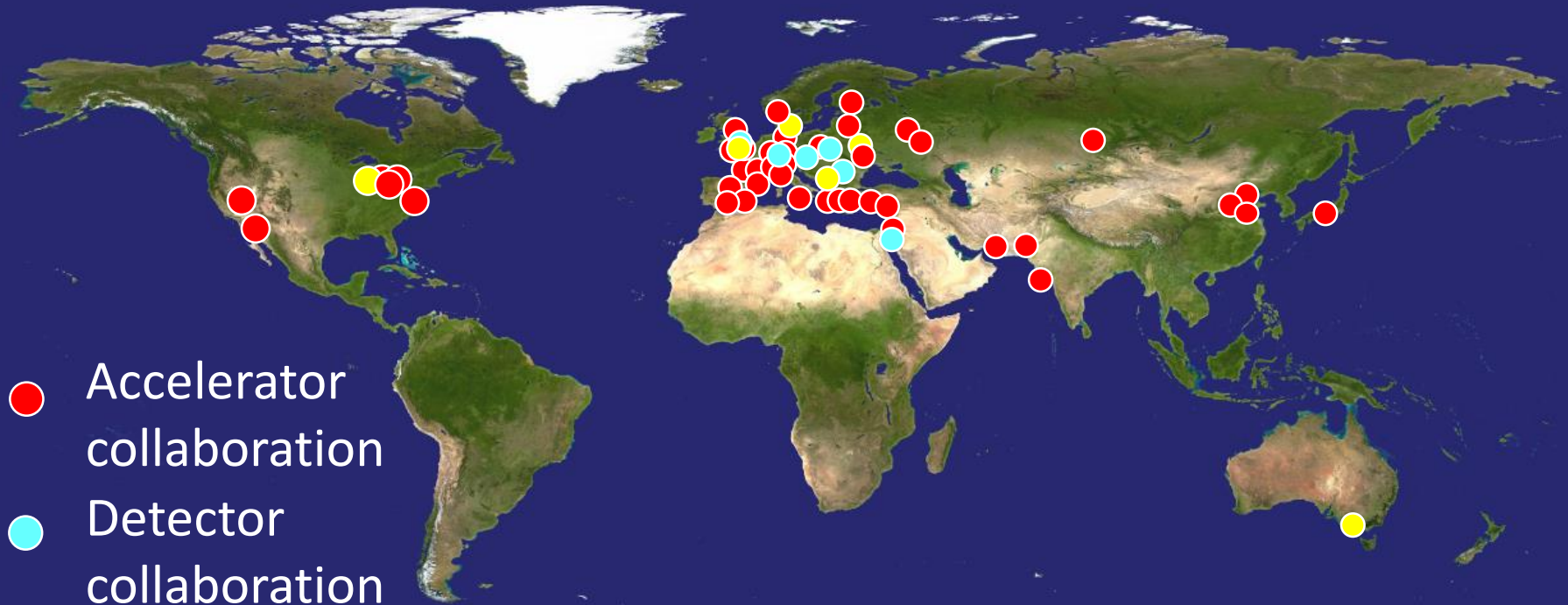
Ciemat
Centro de Investigaciones
Energéticas, Medioambientales
y Tecnológicas

INFN
Istituto Nazionale
di Fisica Nucleare



CLIC Collaboration

29 Countries – over 70 Institutes



- Accelerator collaboration
- Detector collaboration
- Accelerator + Detector collaboration





CERN: Particle Physics and Innovation

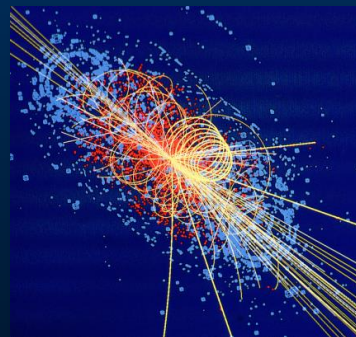
- **Interfacing** between fundamental science and key technological developments



- **CERN Technologies and Innovation**



Accelerating particle beams



Detecting particles



Large-scale computing (Grid)

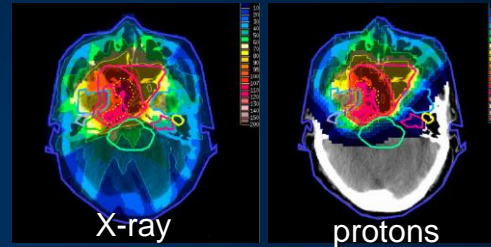
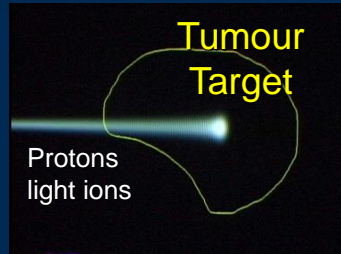
Medical Application as an Example of Particle Physics Spin-off

Combining Physics, ICT, Biology and Medicine to fight cancer



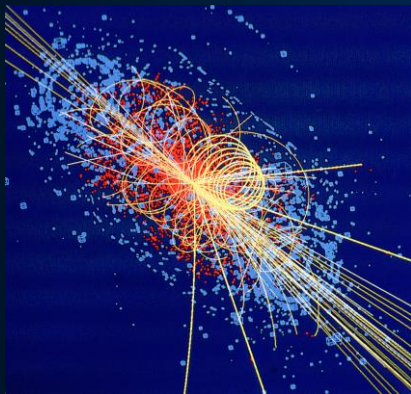
Hadron Therapy

Accelerating particle beams
~30'000 accelerators worldwide
~17'000 used for medicine



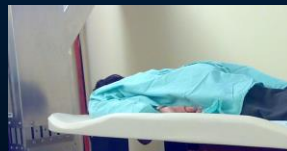
Leadership in Ion Beam Therapy now in Europe and Japan

>70'000 patients treated worldwide (30 facilities)
>21'000 patients treated in Europe (9 facilities)

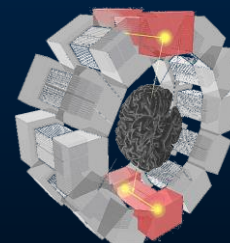


Imaging

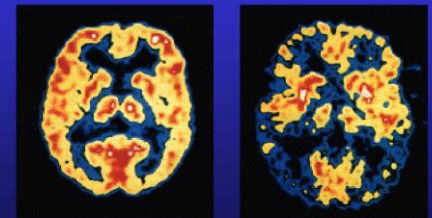
Clinical trial in Portugal for new breast imaging system (ClearPEM)



PET Scanner



Brain Metabolism in Alzheimer's Disease: PET Scan



Detecting particles

CERN Education Activities

Scientists at CERN

Academic Training Programme



Latin American School
Natal, Brazil, 2011
Arequipa, Peru, 2013



Young Researchers

CERN School of High Energy Physics
CERN School of Computing
CERN Accelerator School



Physics Students

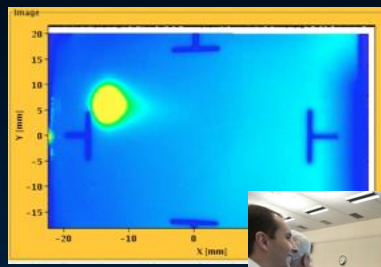
Summer Students
Programme



CERN Teacher Schools

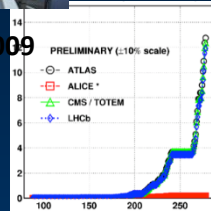
International and National
Programmes

August 2008
First injection test

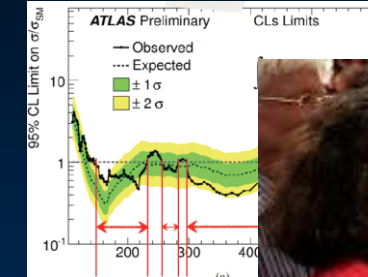


September 10, 2008
First beams around

November 29, 2009
Beam back



October 14
2010
1e32
248 bunches



June 28 2011
1380 bunches

1380



August
2.3e33,
1380 b

4 July, 2012

6 June, 2012
6.8e33

2008

2009

2010

2011

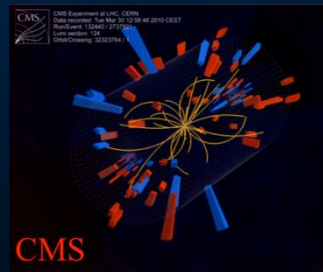
2012

September 19,
2008
Disaster

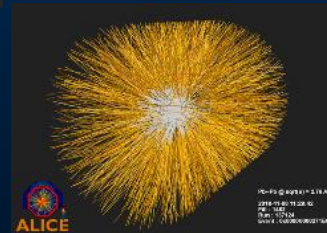
Accidental release
of 600 MJ stored
in one sector of
LHC dipole
magnets



March 30, 2010
First collisions at
3.5 TeV



November 2010
Ions



18 June, 2012
6.6 fb⁻¹
to ATLAS & CMS

LHC Timeline

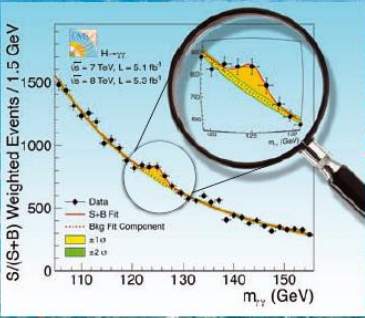
The highlight of a remarkable year 2012

Volume 712, Issue 3, 6 June 2012 ISSN 0370-2693

ELSEVIER

PHYSICS LETTERS B

Available online at www.sciencedirect.com
SciVerse ScienceDirect

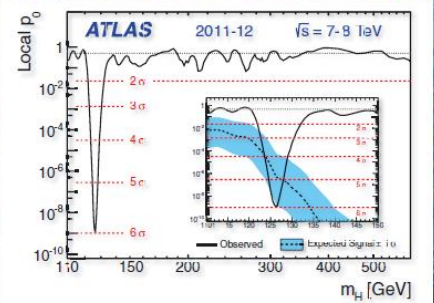


$S/(S+B)$ Weighted Events / 1.5 GeV

m_H (GeV)

Legend:
• Data
— S+B Fit
--- Big Fit Component
■ 1σ
■ 2σ

Parameters:
 $\sqrt{s} = 7 \text{ TeV}, L = 5.1 \text{ fb}^{-1}$
 $\sqrt{s} = 8 \text{ TeV}, L = 5.3 \text{ fb}^{-1}$



ATLAS 2011-12 $\sqrt{s} = 7-8 \text{ TeV}$

Local p_0

m_H [GeV]

Legend:
— Observed
— Expected Signal: 1σ

Significance levels: $2\sigma, 3\sigma, 4\sigma, 5\sigma, 6\sigma$

<http://www.elsevier.com/locate/physletb>

The Economist

JULY 7TH - 13TH 2012 Economist.com

In praise of charter schools
Britain's banking scandal spreads
Volkswagen overtakes the rest
A power struggle at the Vatican
When Lonesome George met Nora

A giant leap for science



Finding the Higgs boson

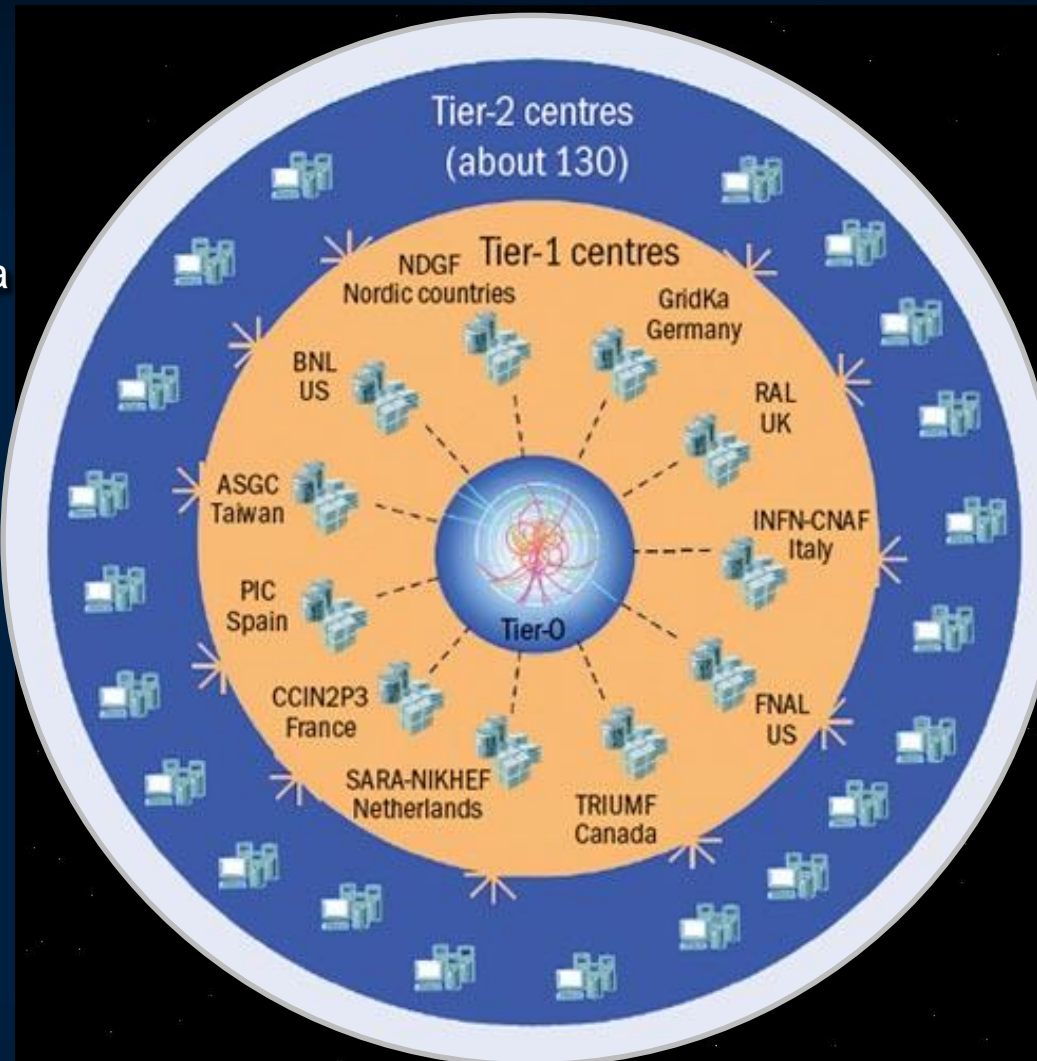


Nobel Prize in Physics 2013



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"*.

The Worldwide LHC Computing Grid



Tier-0 (CERN): data recording, reconstruction and distribution

Tier-1: permanent storage, re-processing, analysis

Tier-2: Simulation, end-user analysis

nearly 160 sites,
35 countries

~250'000 cores

173 PB of storage

> 2 million jobs/day

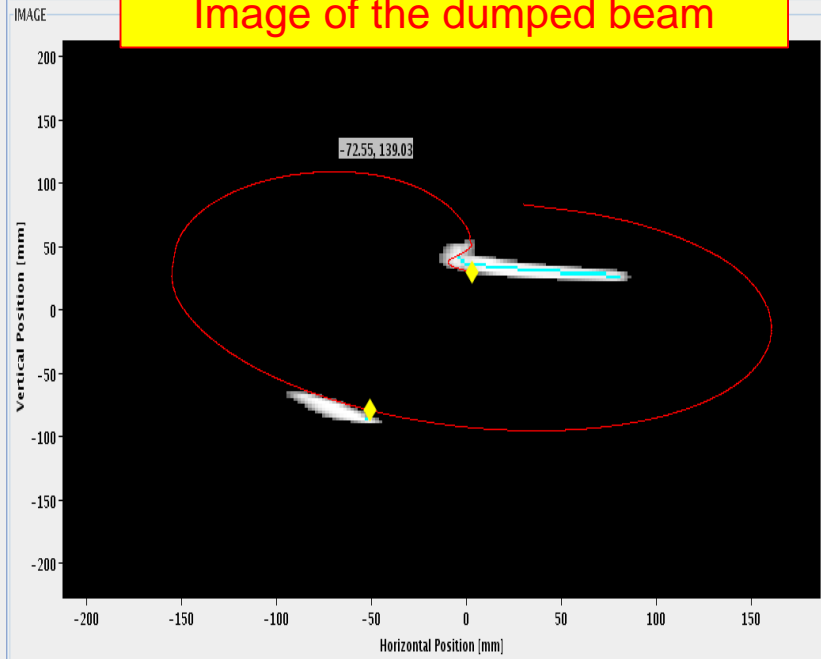
10 Gb links

An International collaboration to distribute and analyse LHC data

Integrates computer centres worldwide that provide computing and storage resource into a single infrastructure accessible by all LHC physicists

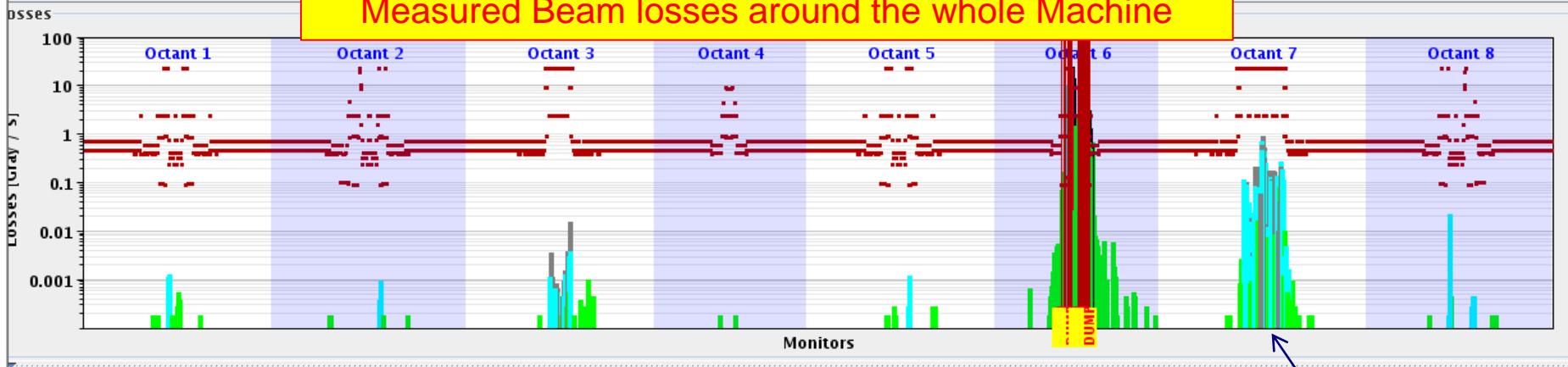
Verification of Dump Protection

Image of the dumped beam



- Switch off the RF
 - Debunching fills the abort gap
- Dump Beam
 - Loss in point 6 on absorber elements
 - Some losses collimation
 - Clean at experiments: factor 1 : 10 000

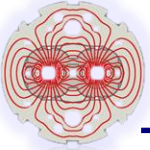
Measured Beam losses around the whole Machine



Rest of the machine is clean

Dump

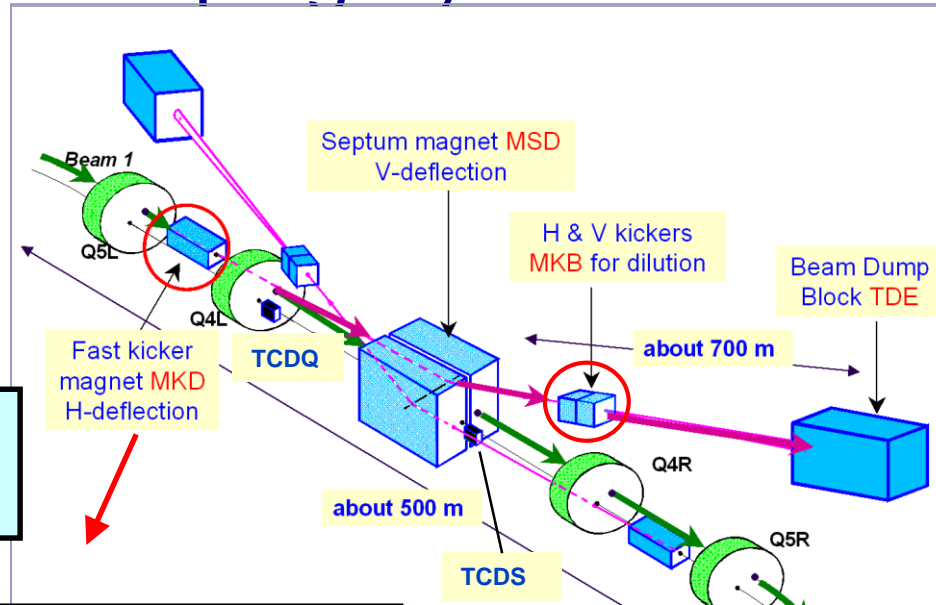
Collimation



Only one way to safely get rid of the beam



LHC Beam Dumping System

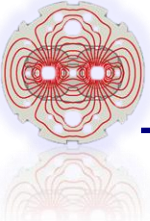


Extraction Kickers

2 x 15 Systems

10 Dilution kickers MKB

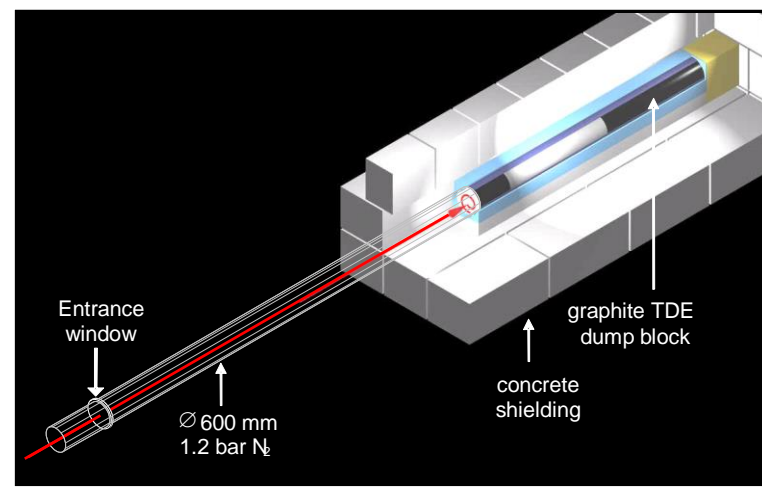
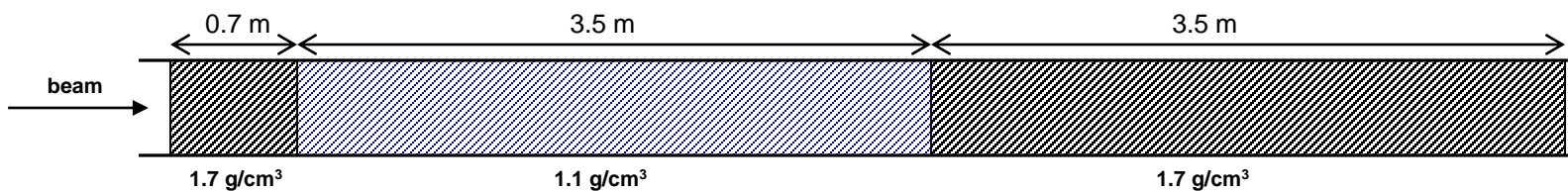


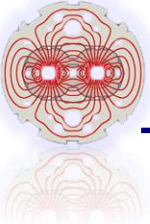


Beam dump block (TDE)



- 700 mm \varnothing graphite core, with graded density of 1.1 g/cm³ and 1.7 g/cm³
- 12 mm wall, stainless-steel welded pressure vessel, at 1.2 bar of N₂
- Surrounded by ~1000 tonnes of concrete/steel radiation shielding blocks





Extraction kicker – Abort Gap

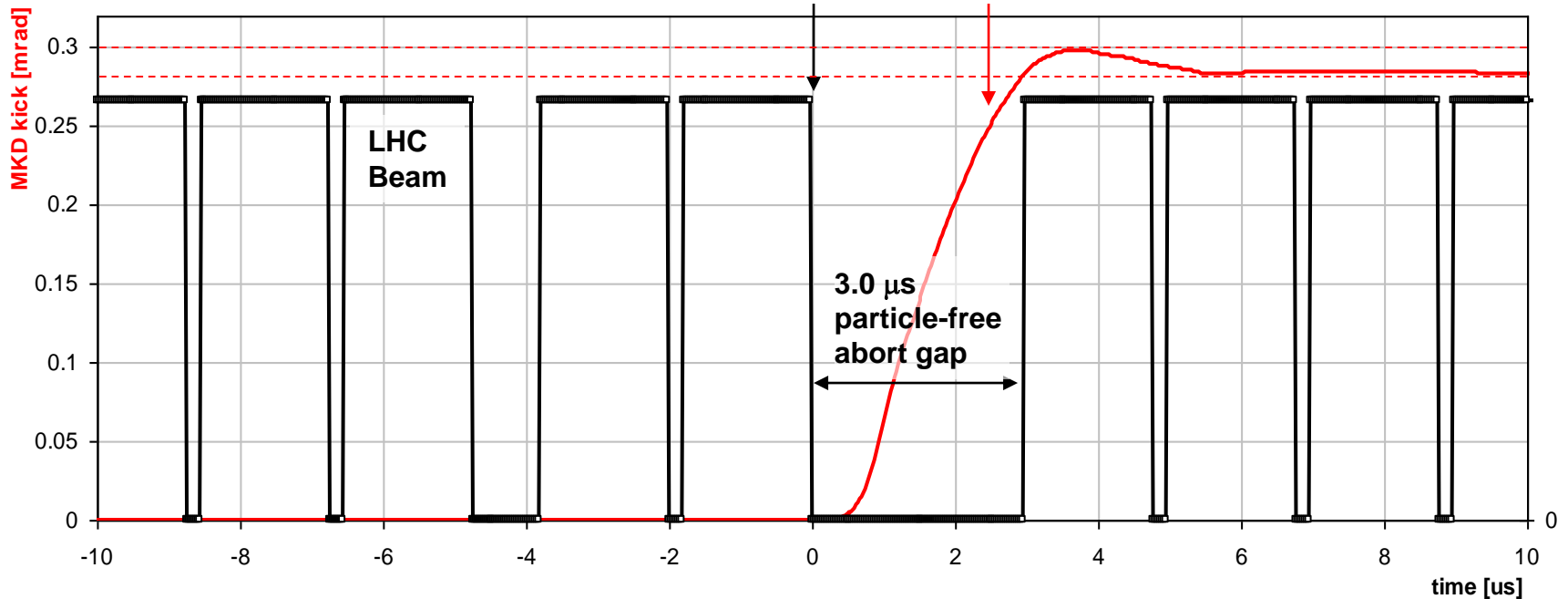


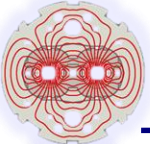
Within 3 turns of dump request



Synchronised
dump trigger

Extraction kicker MKD deflection





At every dump: Check the Extraction Kickers



XPOC : XPOC_B2 : 27.09.2010 10:33:08 (1285576388150738525)

Final analysis is confirmed

XPOC Modules graph Results

Session: BEAM 2 3500.16 GeV 27.09.2010 - 10:33:08:150.183250

CONTEXT

Module: MKD

State: FINISHED

Analysis: OK

Check: OK

MKD

Results Journal

MKB

BLM

VAC

BT VDD

BPMD

BCT

BSRA

TSU

- Source
- MKD.UA67.XPOC1.MB2
- MKD.UA67.XPOC2.CB2
- MKD.UA67.XPOC2.GB2
- MKD.UA67.XPOC2.BB2
- MKD.UA67.XPOC1.LB2
- MKD.UA67.XPOC2.HB2
- MKD.UA67.XPOC1.HB2
- MKD.UA67.XPOC2.NB2
- MKD.UA67.XPOC2.DB2
- MKD.UA67.XPOC1.BB2
- MKD.UA67.XPOC1.OB2
- MKD.UA67.XPOC2.EB2
- MKD.UA67.XPOC1.AB2
- MKD.UA67.XPOC1.CB2
- MKD.UA67.XPOC2.JB2
- MKD.UA67.XPOC1.NB2
- MKD.UA67.XPOC1.DB2
- MKD.UA67.XPOC2.JB2
- MKD.UA67.XPOC1.JB2
- MKD.UA67.XPOC1.GB2
- MKD.UA67.XPOC2.MB2
- MKD.UA67.XPOC2.LB2
- MKD.UA67.XPOC1.FB2
- MKD.UA67.XPOC2.AB2
- MKD.UA67.XPOC2.OB2
- MKD.UA67.XPOC1.KB2
- MKD.UA67.XPOC1.JB2
- MKD.UA67.XPOC1.EB2
- MKD.UA67.XPOC2.KB2
- MKD.UA67.XPOC2.FB2

Source: MKD.UA67.XPOC2.IB2

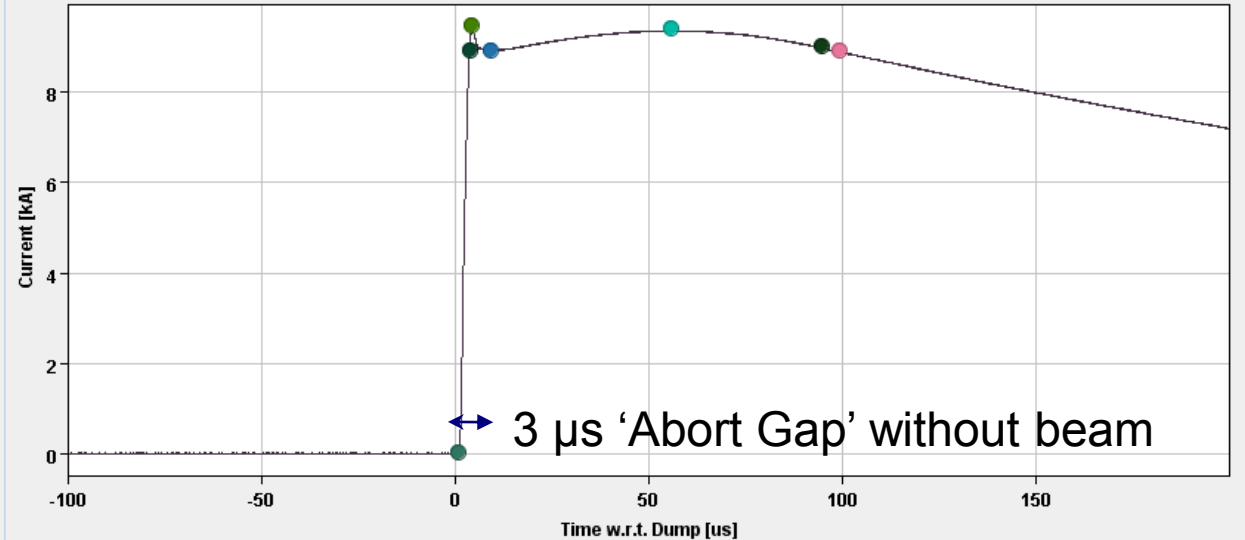
Analysis: OK

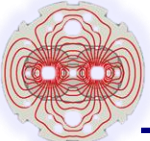
Check: OK

CHECKS

Property	Value	Min.Value	Ref.Value	Max.Value	Units	Check
endRatio	9.132E-1	4.921E-1	9.921E-1	1.492E0	%	OK
ref100pctCurrent	8.942E3	8.865E3	8.955E3	9.045E3	kA	OK
overShoot1Ratio	6.066E0	5.361E0	6.061E0	6.761E0	%	OK
delay	3.817E0	3.762E0	3.812E0	3.862E0	us	OK
riseTime	2.756E0	2.699E0	2.749E0	2.799E0	us	OK
overShoot2Ratio	5.176E0	4.717E0	5.217E0	5.717E0	%	OK

Waveform & Points





At every dump: Check the Dump Pattern



XPOC : XPOC_B2 : 27.09.2010 10:33:08 (1285576388150738525)

Final analysis is confirmed

XPOC Modules graph Results

Session: BEAM 2 3500.16 GeV 27.09.2010 - 10:33:08:150.183250

CONTEXT

Module: BTVDD State: FINISHED

Analysis: OK

Check: OK

MKD

Results Journal

MKB

Checks Measures References

CHECKS

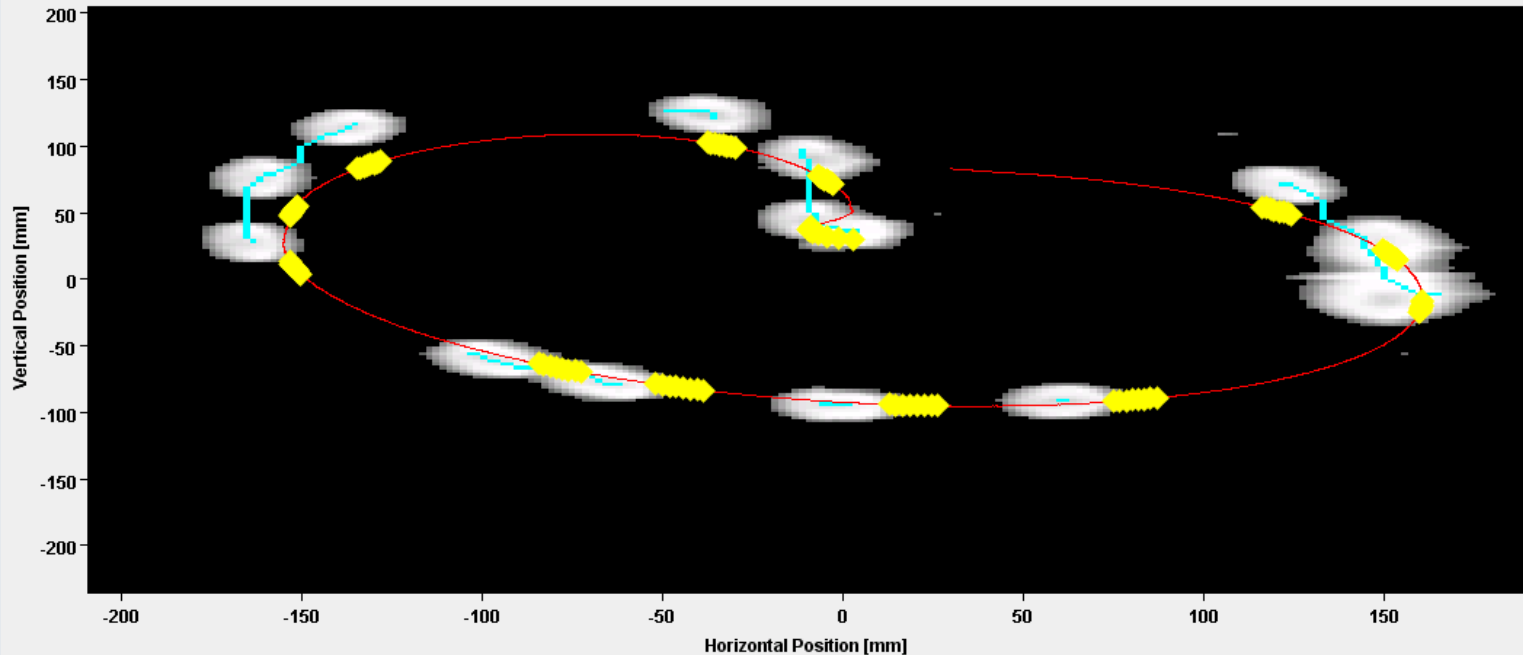
Property	Value	Min.Value	Ref.Value	Max.Value	Units	Check
height	2.014E2	1.580E2	1.980E2	2.380E2	mm	OK
centerV	1.373E1	-3.608E1	3.923E0	4.392E1	mm	OK
centerH	0.000E0	-3.621E1	3.785E0	4.379E1	mm	OK
width	3.320E2	2.640E2	3.140E2	3.640E2	mm	OK

BLM

IMAGE

VAC

BTVDD

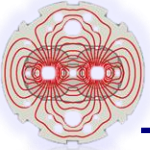


BPMD

BCT

BSRA

TSU



At every dump: Check the Beam Losses



XPOC : XPOC_B1 : 27.09.2010 10:33:08 (1285576388150488525) Final analysis is confirmed

XPOC **Modules graph** Results

Session: BEAM 1 3500.16 GeV 27.09.2010 - 10:33:08:150.237300

Module: BLM State: FINISHED **Analysis: OK** **Check: OK**

CONTEXT MKD MKB BLM VAC BTVDD BPMD BCT BSRA TSU

Results Journal

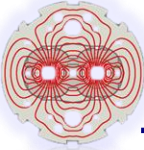
BLM Details for Group 'ALL BLMs'

Group	Analysis	Check	Loss Max	Nb BLM	Nb Faulty	Nb Invalid	Nb Masked	Nb Missing	Nb Unconnected
ALL BLMs	OK	OK	3.355E4	91	0	0	0	0	0

BLM Name	Loss [Gy/s]	Limit [Gy/s]	Limit Min [...]	Limit Max [...]	Low Limit	RC Factor [-]	Check	Valid	Masked	Missing	Connected
BLMDL683243.D1E1_MKBH	2.353E-3	5.000E0	1.000E0	1.000E5	NO	1.000E0	OK	YES	NO	NO	YES
BLMDL683290.D1E1_MKBV	0.000E0	5.000E0	1.000E0	1.000E5	NO	1.000E0	OK	YES	NO	NO	YES
BLMDL683325.D1E2_MKBV	0.000E0	5.000E0	1.000E0	1.000E5	NO	1.000E0	OK	YES	NO	NO	YES
BLMDL683780.D1T1_MQY.4R6	3.373E-1	5.000E0	1.000E0	1.000E5	NO	1.000E0	OK	YES	NO	NO	YES
BLMDL683840.D1L1_175_R9	3.620E-4	5.000E0	1.000E0	1.000E5	NO	1.000E0	OK	YES	NO	NO	YES
BLMDL683841.D1R1_175_R9	8.145E-4	5.000E0	1.000E0	1.000E5	NO	1.000E0	OK	YES	NO	NO	YES

BLM Losses & Limits for Group 'ALL BLMs'

Losses for BLM 'BLMDL683243.D1E1_MKBH'



Protection against 'Kicker Sweep'



- Beam in the Abort Gap
- Asynchronous beam dump → quench or damage
 - Several failures possible (synchronisation, MKD erratic)
- Precautionary measures include:
 - TCDS (fixed) – 6 m long diluter protects extraction septum
 - TCDQ/TCS (**mobile**) – 7 m long diluter kept at about **7-8 σ from the beam at all times**

