The LHC Project and Future of CERN

Robert Aymar

Symposium on Physics of Elementary Interactions
in the LHC Era

Warsaw, 21–22 April 2008

Contents

- about CERN: a facility for the benefit of the European Particle Physics Community
- the LHC project: completion of installation, start of commissioning for accelerator, experiments and computing,
- the CNGS: start of operations and the CLIC scheme for multi Tev e^+e^- Linear Collider
- plans for CERN in the next decade


CERN...
• Seeking answers to questions about the Universe
• Advancing the frontiers of technology
• Training the scientists of tomorrow
• Bringing nations together through science

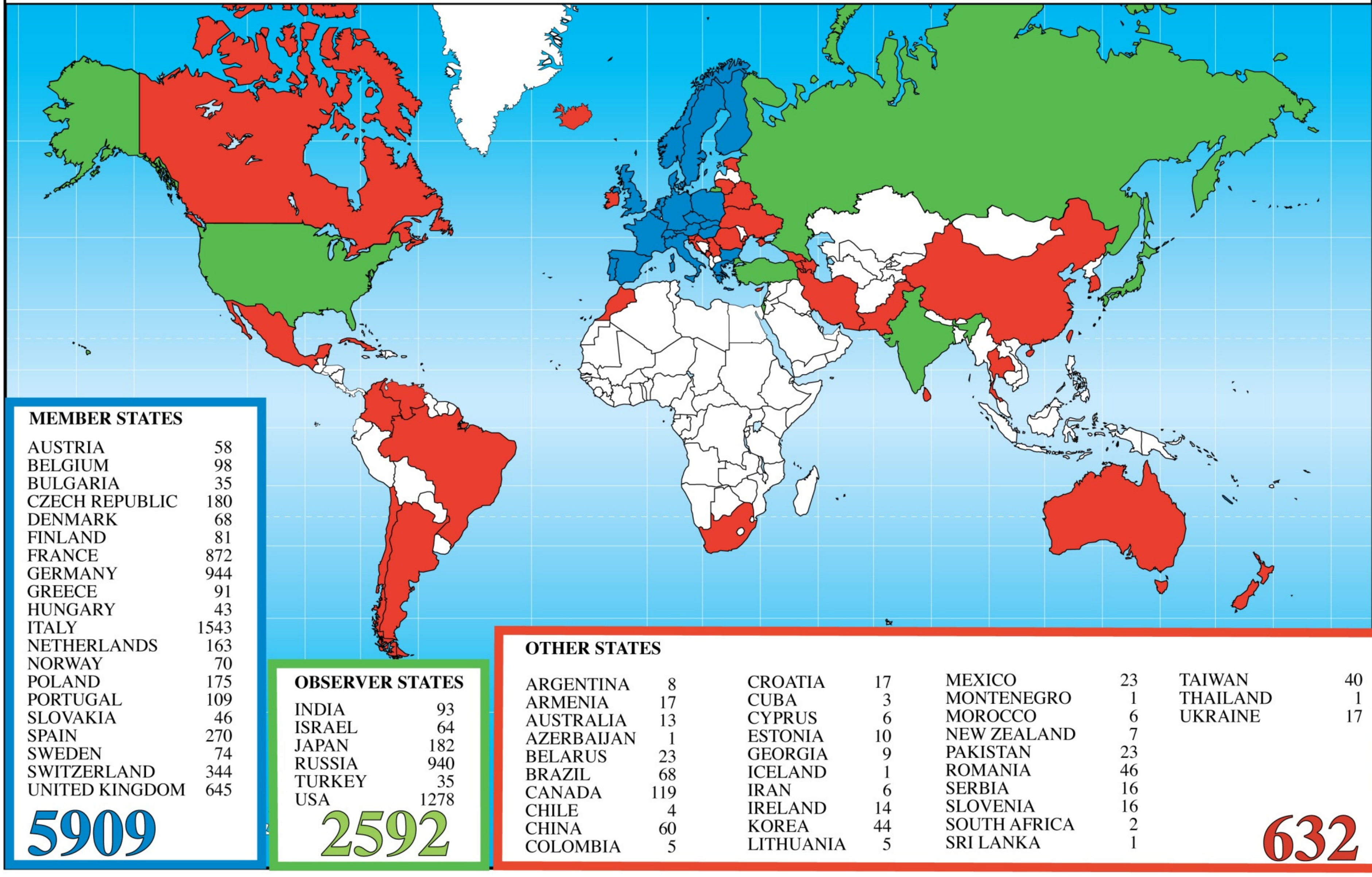
CERN in Numbers

- 2415 staff*
- 730 Fellows and Associates*
- 9133 users*
- Budget (2007) 982 MCHF (610M Euro)

*5 February 2008

- Member States: Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.
- Observers to Council: India, Israel, Japan, the Russian Federation, the United States of America, Turkey, the European Commission and Unesco

Distribution of All CERN Users by Nation of Institute on 5 February 2008



MEMBER STATES

AUSTRIA	58
BELGIUM	98
BULGARIA	35
CZECH REPUBLIC	180
DENMARK	68
FINLAND	81
FRANCE	872
GERMANY	944
GREECE	91
HUNGARY	43
ITALY	1543
NETHERLANDS	163
NORWAY	70
POLAND	175
PORTUGAL	109
SLOVAKIA	46
SPAIN	270
SWEDEN	74
SWITZERLAND	344
UNITED KINGDOM	645

5909

OBSERVER STATES

INDIA	93
ISRAEL	64
JAPAN	182
RUSSIA	940
TURKEY	35
USA	1278

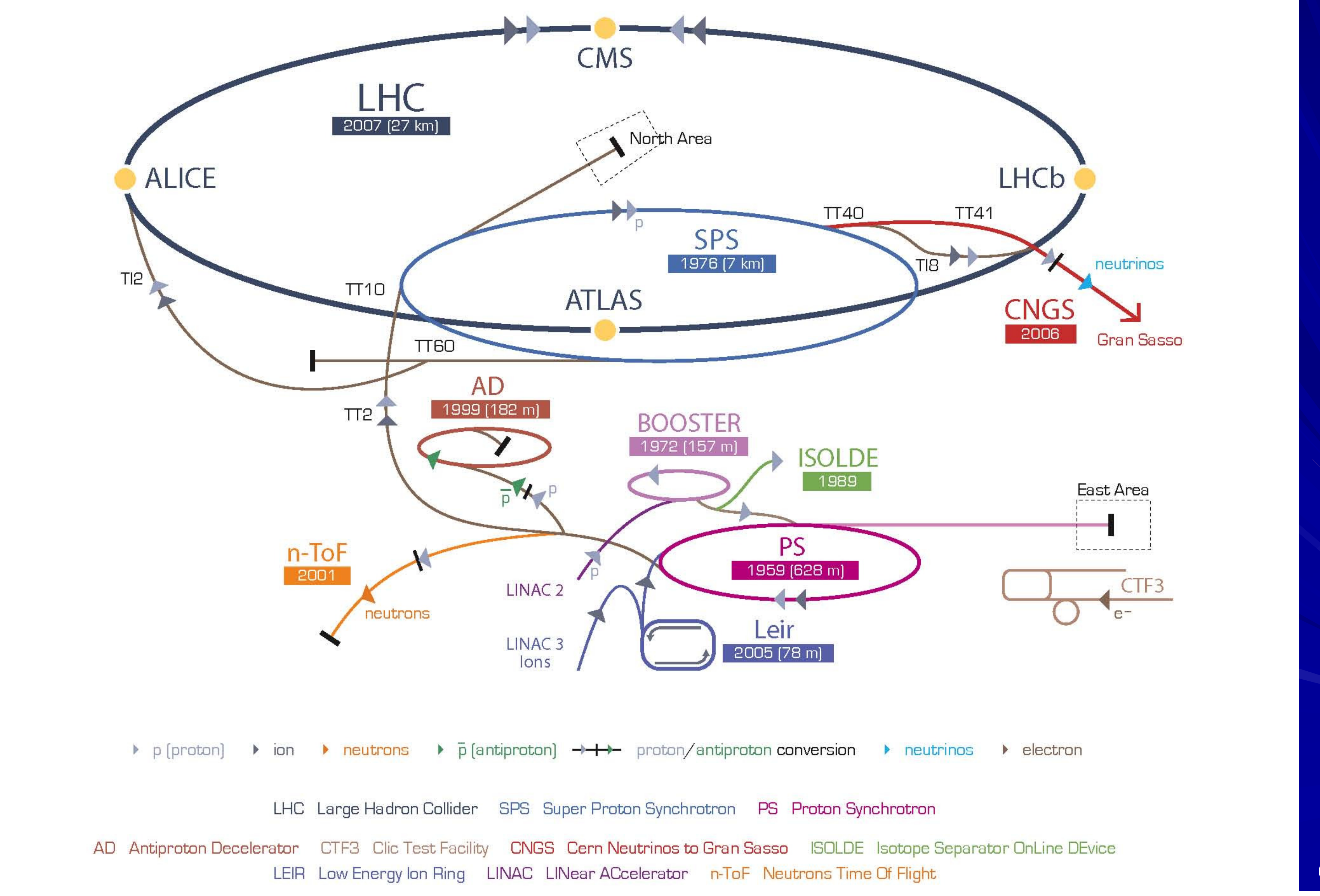
2592

OTHER STATES

ARGENTINA	8
ARMENIA	17
AUSTRALIA	13
AZERBAIJAN	1
BELARUS	23
BRAZIL	68
CANADA	119
CHILE	4
CHINA	60
COLOMBIA	5
CROATIA	17
CUBA	3
CYPRUS	6
ESTONIA	10
GEORGIA	9
ICELAND	1
IRAN	6
IRELAND	14
KOREA	44
LITHUANIA	5
MEXICO	23
MONTENEGRO	1
MOROCCO	6
NEW ZEALAND	7
PAKISTAN	23
ROMANIA	46
SERBIA	16
SLOVENIA	16
SOUTH AFRICA	2
SRI LANKA	1
TAIWAN	40
THAILAND	1
UKRAINE	17

632

CERN: the World's Most Complete Accelerator Complex (not to scale)



The Long-Term Scientific Programme

Legend: Approved ▬ Under Consideration ▥

	2007	2008	2009	2010	2011
LHC Experiments					
ALICE		Approved	Approved	Approved	Approved
ATLAS		Approved	Approved	Approved	Approved
CMS		Approved	Approved	Approved	Approved
LHCb		Approved	Approved	Approved	Approved
TOTEM		Approved	Approved	Approved	Approved
LHCf		Approved			
Other LHC Experiments (e.g. MOEDAL)		Under Consideration	Under Consideration	Under Consideration	Under Consideration
Non-LHC Experimental Programme					
SPS					
NA58 (COMPASS)	Approved	Under Consideration	Under Consideration	Under Consideration	
P326 (NA48/3)/NA62	Approved	Under Consideration	Under Consideration	Under Consideration	Under Consideration
P327 (EM processes in strong crystalline fields)	Approved				
NA49-future/NA61	Approved	Under Consideration	Under Consideration	Under Consideration	Under Consideration
Neutrino / CNGS	Approved	Approved	Approved	Approved	Under Consideration
New initiatives		Under Consideration	Under Consideration	Under Consideration	Under Consideration
PS					
PS212 (DIRAC)	Approved	Approved			
PS215 (CLOUD)	Approved	Approved	Approved	Approved	Approved
OTHER FACILITIES					
AD	Approved	Approved	Approved	Approved	Under Consideration
ISOLDE	Approved	Approved	Approved	Approved	Approved
n-TOF Neutron	Under Consideration	Under Consideration	Under Consideration	Under Consideration	Under Consideration
CAST	Approved	Under Consideration	Under Consideration	Under Consideration	
P331 (optical axion search and QED test)	Under Consideration	Under Consideration	Under Consideration	Under Consideration	Under Consideration
Test Beams					
North Areas	Approved	Approved	Approved	Approved	Approved
West Areas					
East Hall	Under Consideration	Under Consideration	Under Consideration	Under Consideration	Under Consideration
R&D (Detector & Accelerator)	Approved	Approved	Approved	Approved	Approved

Poland and the Four Strategic Missions of CERN
FUNADAMENTAL RESEARCH

- Polish physicists collaborate with CERN since 1959.
- Poland (including Polish industry) has actively participated in the construction of all four LHC experiments, has provided a notable contribution to the engineering of the LHC accelerator, and is marking its presence in LHC with strong theory and experiment teams. Poland has a well prepared LHC Computing Grid structure.

- Contribution of Poland to LHC Experiments (kCHF): Construction and CtC (C) and M&O-A (M):

	C: Agreed end 2008	C: Already Paid	M: Paid
ATLAS	1093	1093	333
CMS	3000	2696	195.9
ALICE	1035.5	830	345.7
LHCb	500	500	238.6
Total	5628.5	5119	1113.2

- 38 Poles are CERN staff members, 175 “Users” (February 2008).
- All conditions are fulfilled for the LHC physics!

Poland and the Four Strategic Missions of CERN: Education – Training

- **A. Polish participation in the CERN National Teacher Programme for High School Teachers of physics**
  - Poland is the leading participant in the CERN National Teacher Programme.
  - During last year: 5 courses (one-week sessions) with a 6th planned for June this year.
  - 200 Polish teachers have already attended with another 40 expected in June 2008.
  - Many follow-up activities and outcomes in Poland – beyond initial expectations!
  - Imperative to this success has been an extensive collaboration between Polish physics community (both in Poland and at CERN), Polish Ministry of National Education, CODN (Centralny Ośrodek Doskonalenia Nauczycieli), CERN Education unit.
  - CERN will continue to support these pioneering efforts in making such effective use of our unique laboratory to promote science and physics in schools.
  - **CERN counts on further support of Polish authorities and Polish physics community for this excellent programme.**

- **B. Training of Students**
  - Thanks to a good educational level, Poland has constantly a relatively high number of Technical Students, Summer Students and Doctoral Students selected to CERN within the available financial limits.
  - **Enlargement of this number is possible through additional programmes financed by national funding agencies – CERN highly encourages such programmes, already used by several Member States, and would welcome also a Polish programme of this type.**

Poland and the Four Strategic Missions of CERN: Technology Transfer

- **A. Successful transfer** to the Polish industry of the **GEM and Micro-Chemical-Vias** technology developed at CERN, now fully acquired by a Polish industrial partner. This was honoured during the 35th “Salon des Inventions”, held in Geneva in 2007, by a Silver Award for the Polish “TTA Techtra” company.

- Future: This gives a good basis for Polish industry and HEP institutes for the construction of GEM detectors, both for CERN and other HEP centres.

- **B. Possible participation** of Polish Institutes and industry in the **construction of Linac4** accelerating structures, now under discussion and technical analysis, could constitute another step in the **transfer of CERN’s know-how** in this field (highly useful e.g. for medical accelerators) and at the same time **a new collaboration domain.**

Poland and the Four Strategic Missions of CERN: Collaboration

- **Bilateral (CERN-Polish Institutes)**
- CERN highly appreciates the contribution of **Polish Teams in the commissioning** of the LHC accelerator; five teams detached by Krakow Institutes, working during several years, totalling around 150 man-years of the work of highly qualified specialists, **well supported and organized by their mother institutes**.
- CERN would welcome if such forms of collaboration, adapted to the new phase of functioning and upgrade of LHC , could continue.
- **Multilateral (CERN-Polish Institutes-other countries)**
- **Poland has a very well developed GRID** structure prepared for LHC and excellent specialists in this field, who have also participated in a very effective way in several EU programmes on further extension of the network beyond the Central Europe (Baltic Grid, Porta Optica).
- **CERN would welcome** if Poland could take more duties (coordination, expertise, advice) in the development of the GRID structure in East European countries (including Caucasian Region), extending its role (ROC) played in EGEE for Central Europe.

Contents

- about CERN: a facility for the benefit of the European Particle Physics Community
- the LHC project: completion of installation, start of commissioning for accelerator, experiments and computing,
- the CNGS: start of operations and the CLIC scheme for multi Tev e^+e^- Linear Collider
- plans for CERN in the next decade

The LHC

- **The LHC is one of the most ambitious and best motivated projects in science ever …**

- **Construction is ~ finished and emphasis is now on installation and commissioning of a machine and detectors of unprecedented complexity, technology and performance requirements**

- **All efforts are being made to deliver first collisions in Summer 2008**
- **Experiments are on track toward this target**

Key Questions of Particle Physics

1. Mass: What is the origin of mass?

- How is the electroweak symmetry broken ?
- Does the Higgs boson exist ?

2. Unification: What is the underlying fundamental theory ?

Motivation: Gravity not yet included;
Standard Model as a low energy approximation

- Is our world supersymmetric ?
- Are there extra space time dimensions ?
- Other extensions ?

3. Flavour: or the generation problem

- Why are there three families of matter?
- Neutrino masses and mixing?
- What is the origin of CP violation?

The LHC = Proton - Proton Collider

7 TeV + 7 TeV

Luminosity = $10^{34} cm^{-2} sec^{-1}$

Primary targets:
- Origin of mass
- Nature of Dark Matter
- Primordial Plasma
- Matter vs Antimatter

The LHC results will determine the future course of High Energy Physics

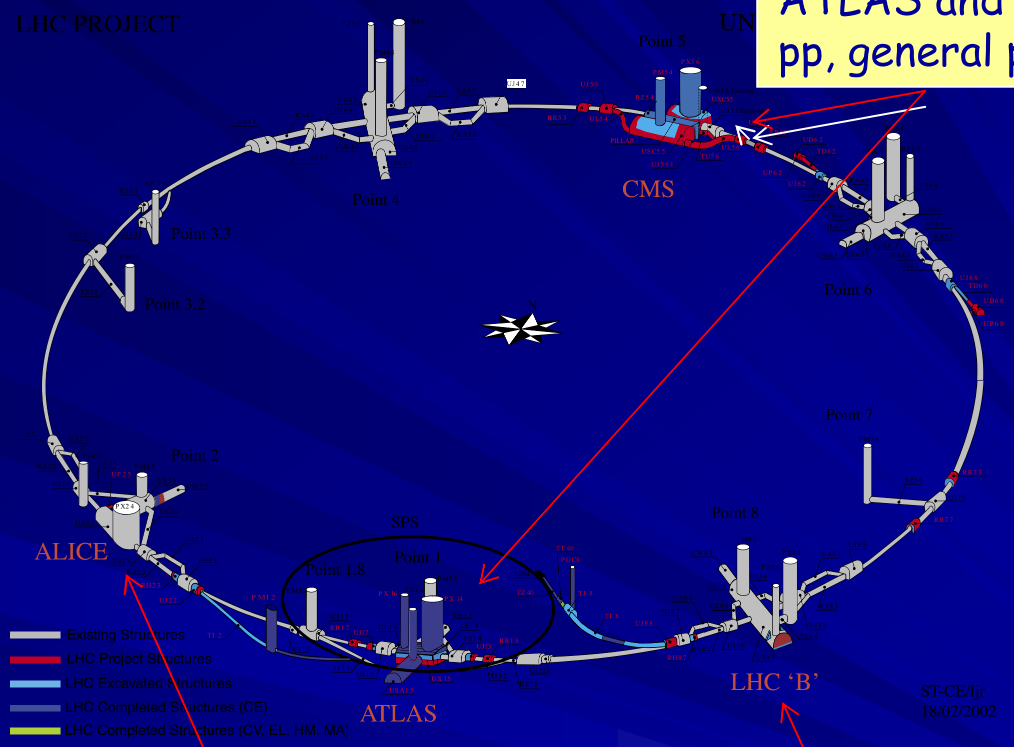
Large Hadron Collider (LHC)

Injection Energy	0.45 TeV
Collision Energy	7 TeV
Dipole field at 7 TeV	8.33 T
Design Luminosity	10^{34} cm^{-2} s^{-1}
Luminosity Lifetime	10 h
Protons per bunch	10^{11}
Bunches per beam	2808
Bunch spacing	25 ns
DC Beam Current	0.56 A

- ≈ 1 GHz interaction rate
- ≈ 23 minimum bias interactions per bunch crossing (pile-up)

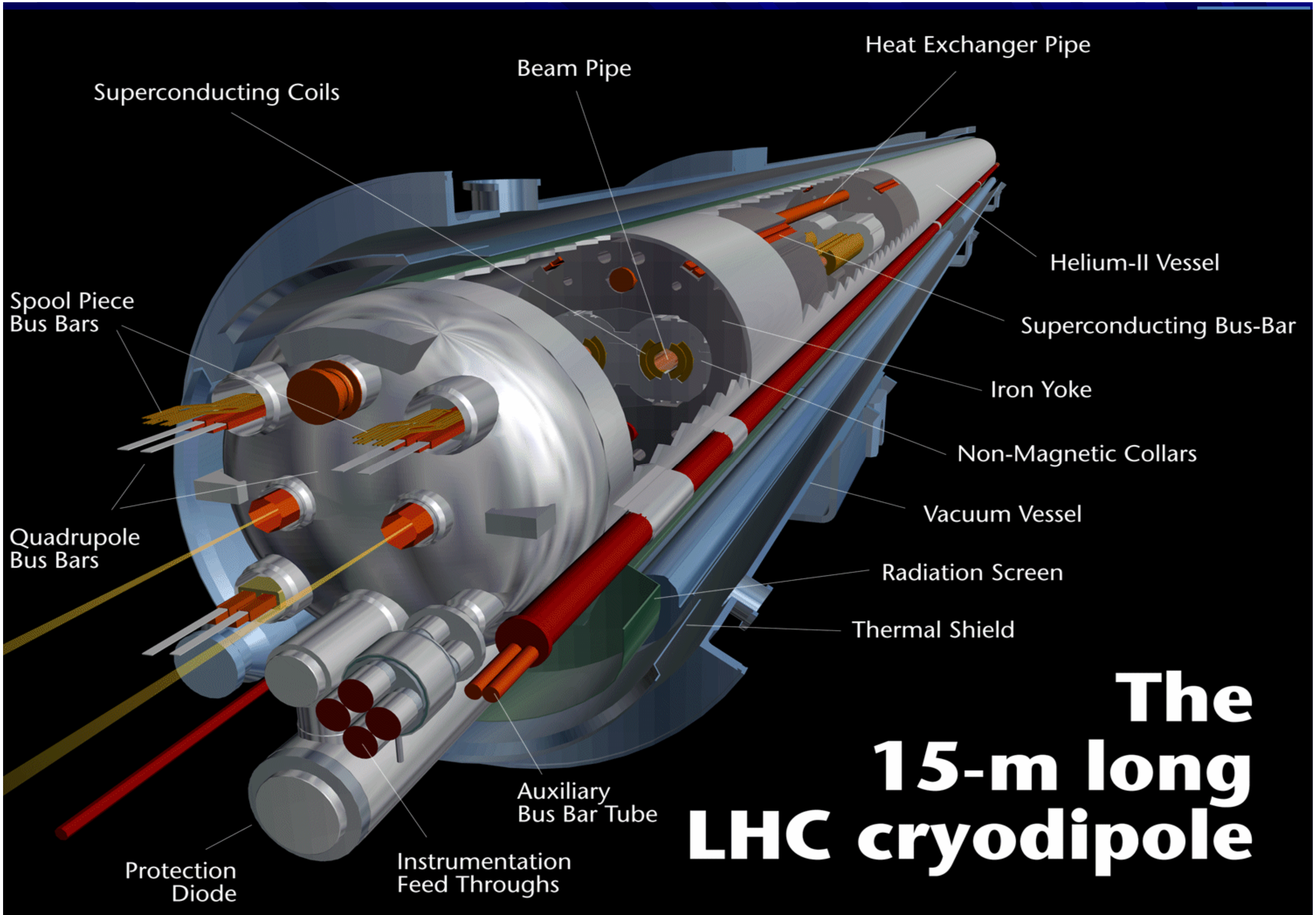
Extreme demands on detectors:
- high granularity
- high data-taking rate
- high radiation environment

ATLAS and CMS : pp, general purpose



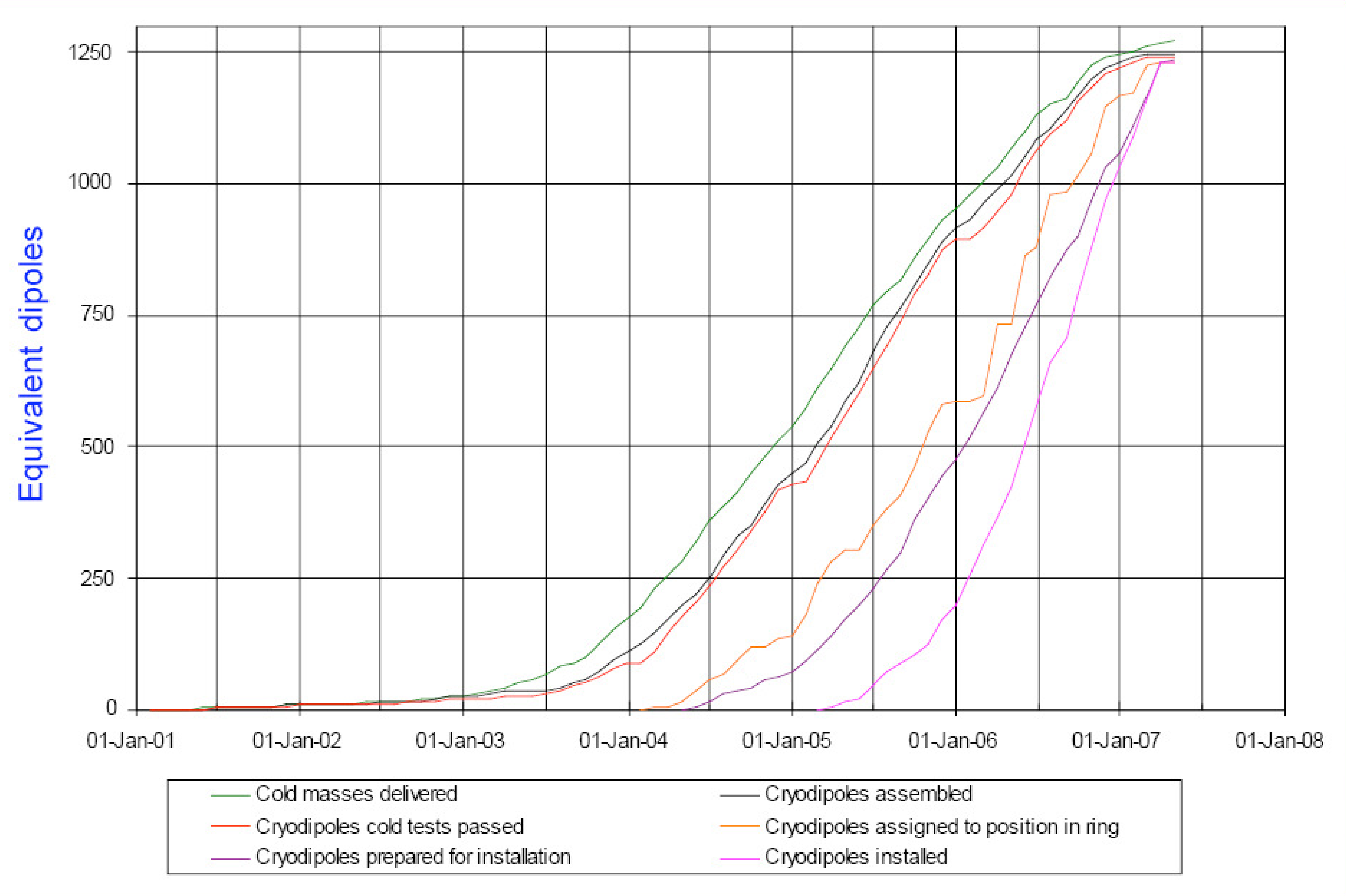
ALICE : ion-ion, p-ion

LHCb : pp, B-physics, CP-violation

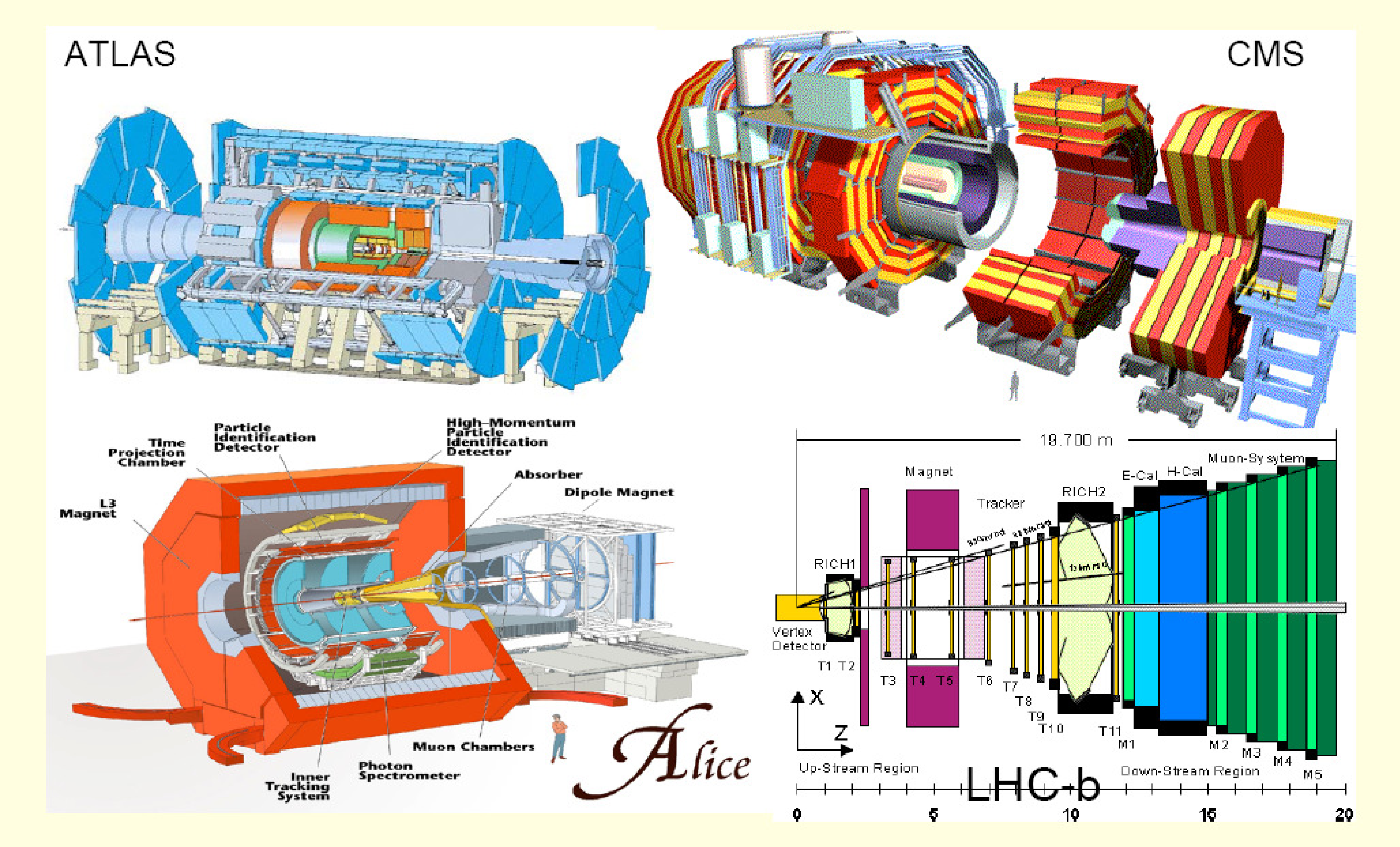


The 15-m long LHC cryodipole

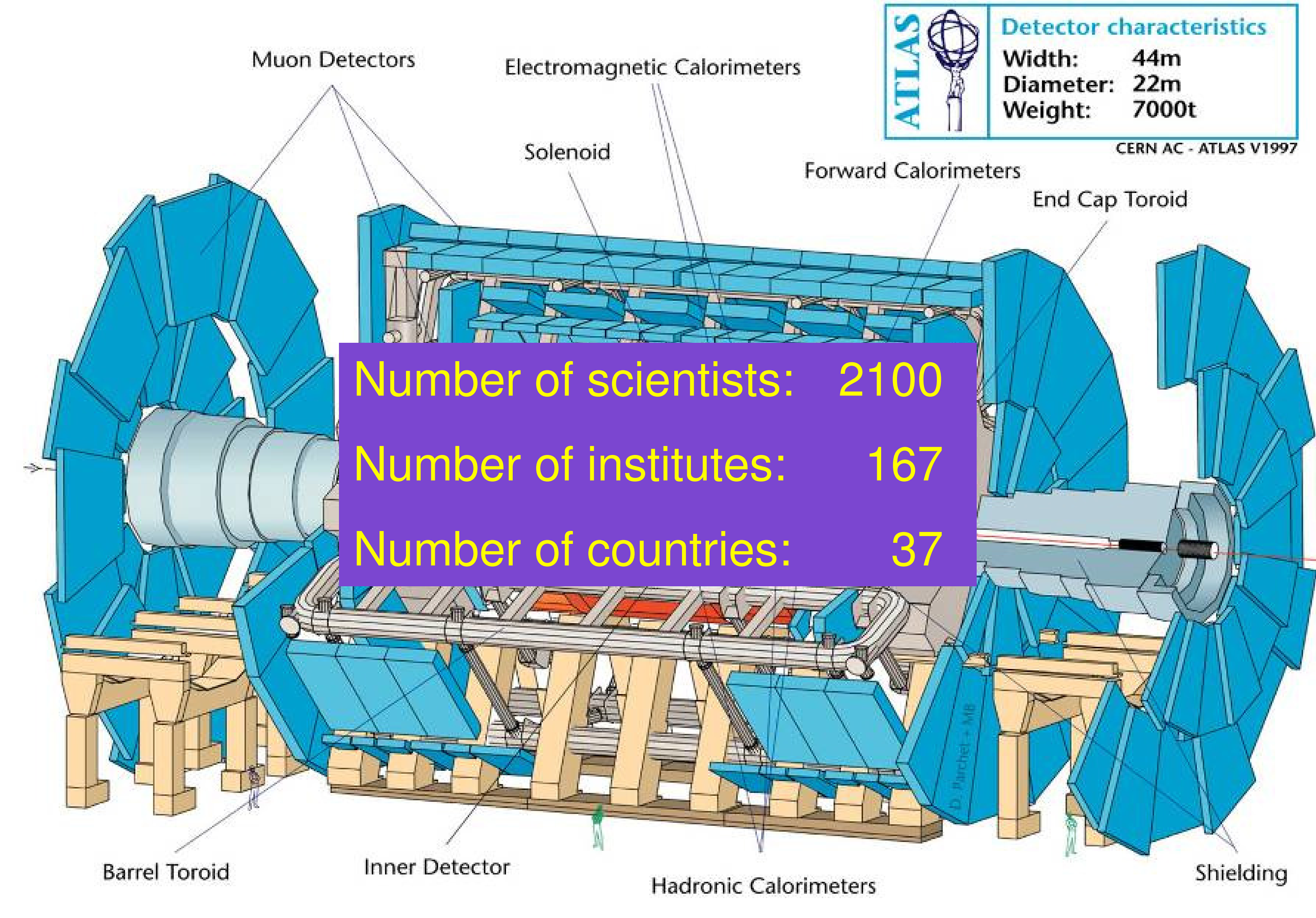
LHC Cryodipole Overview



Four LHC Experiments



ATLAS (spokesperson Peter Jenni)



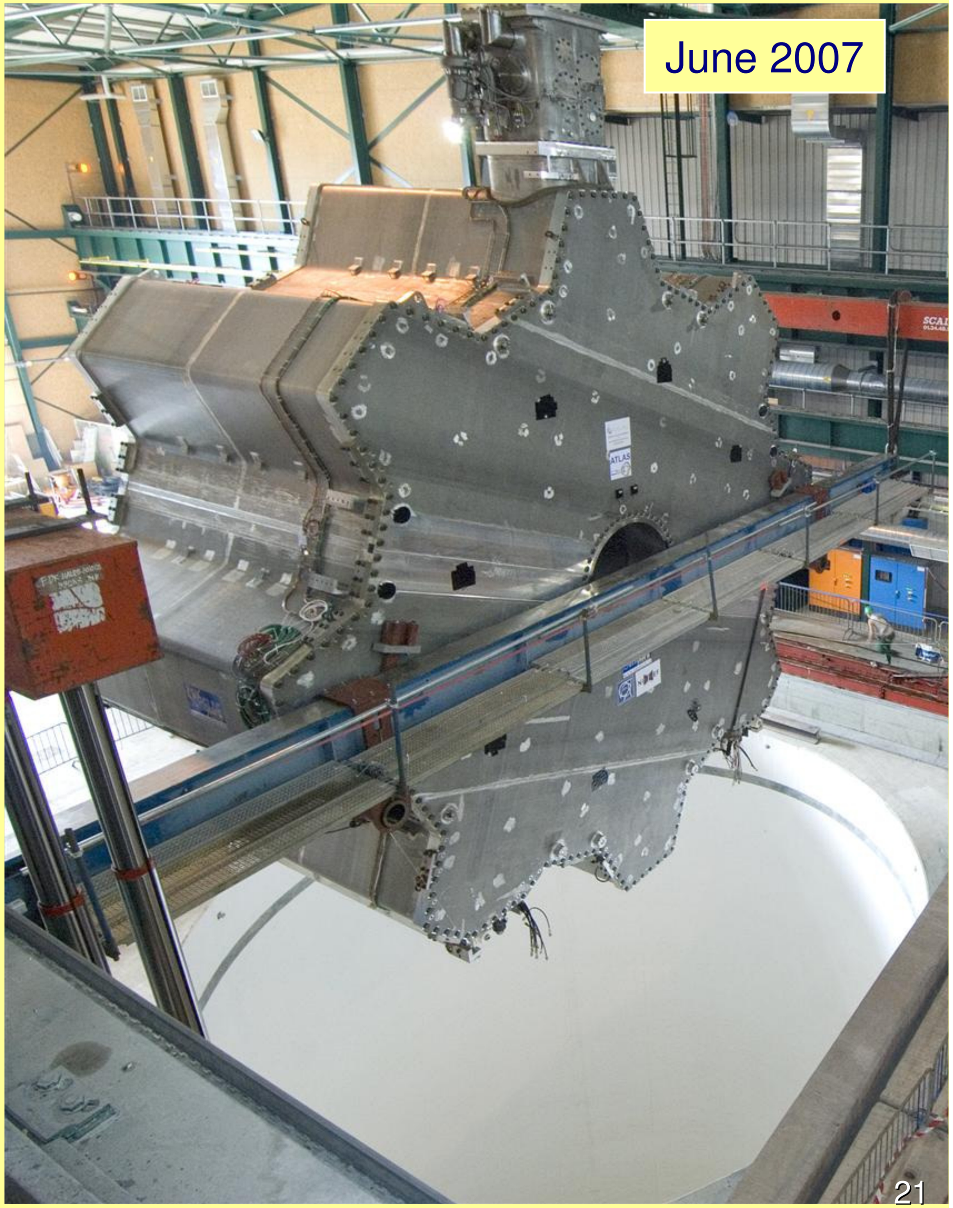
Number of scientists: 2100

Number of institutes: 167

Number of countries: 37

ATLAS - Spectacular Operations

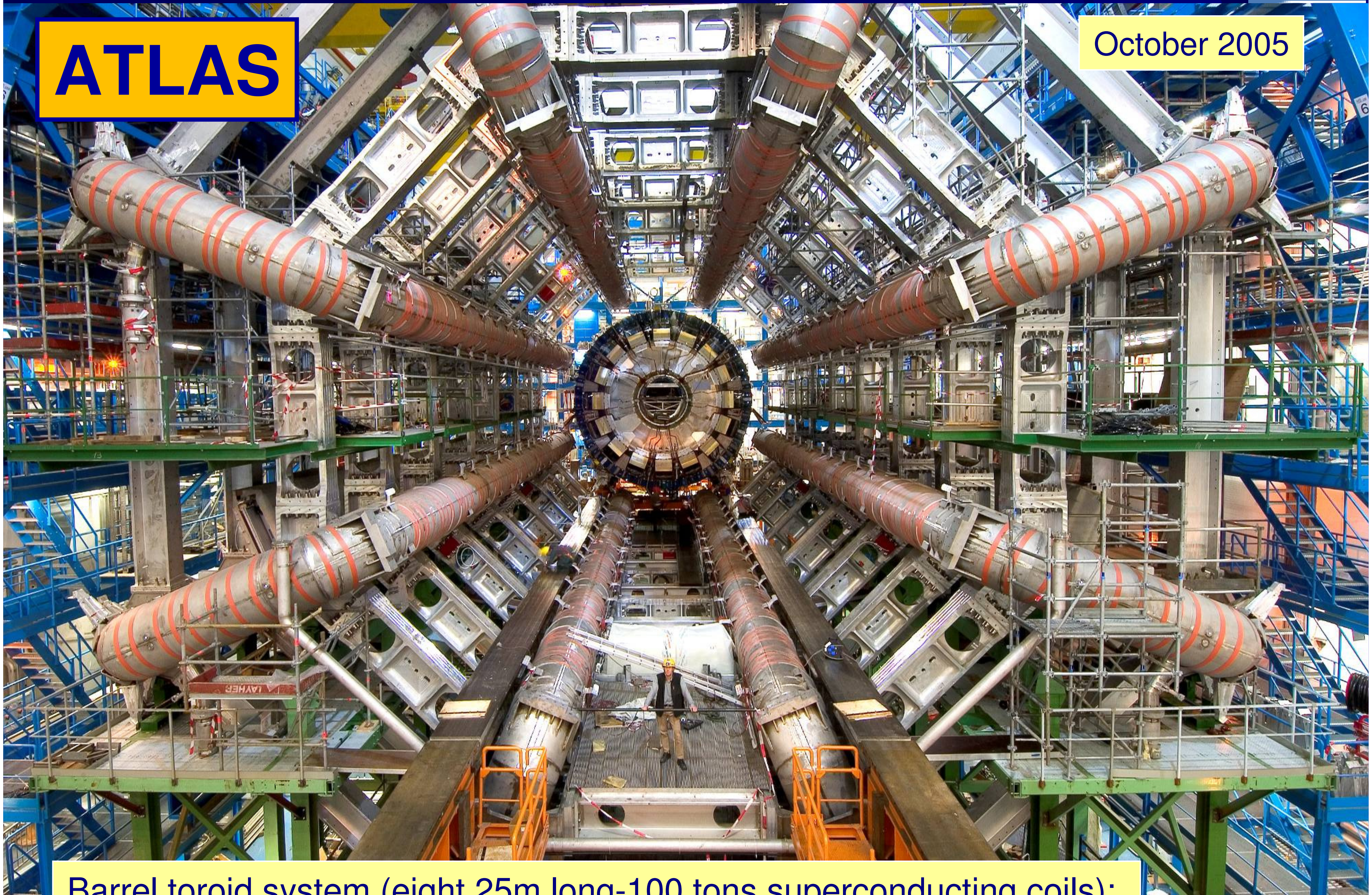
October 2004



June 2007

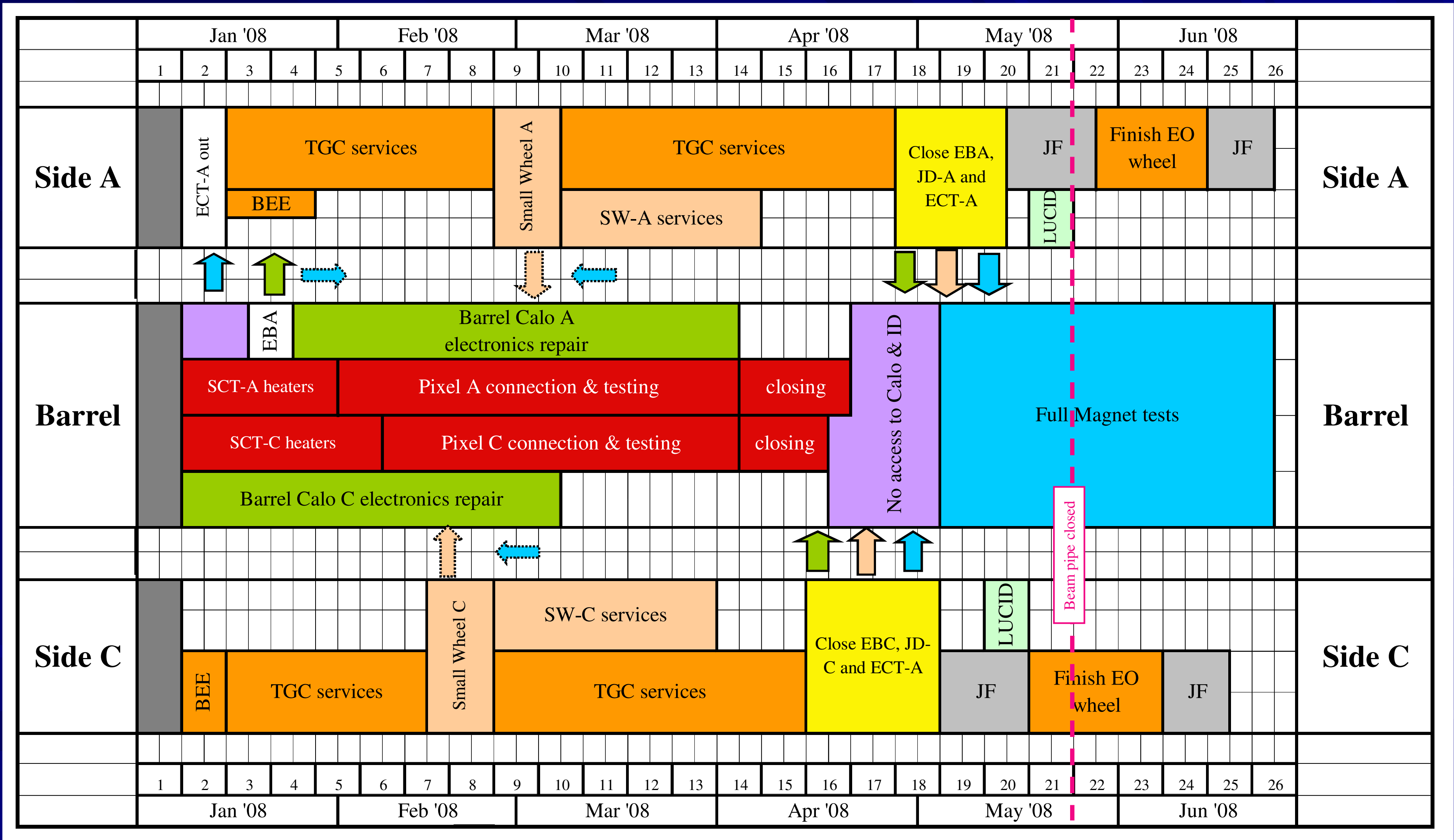
ATLAS

October 2005

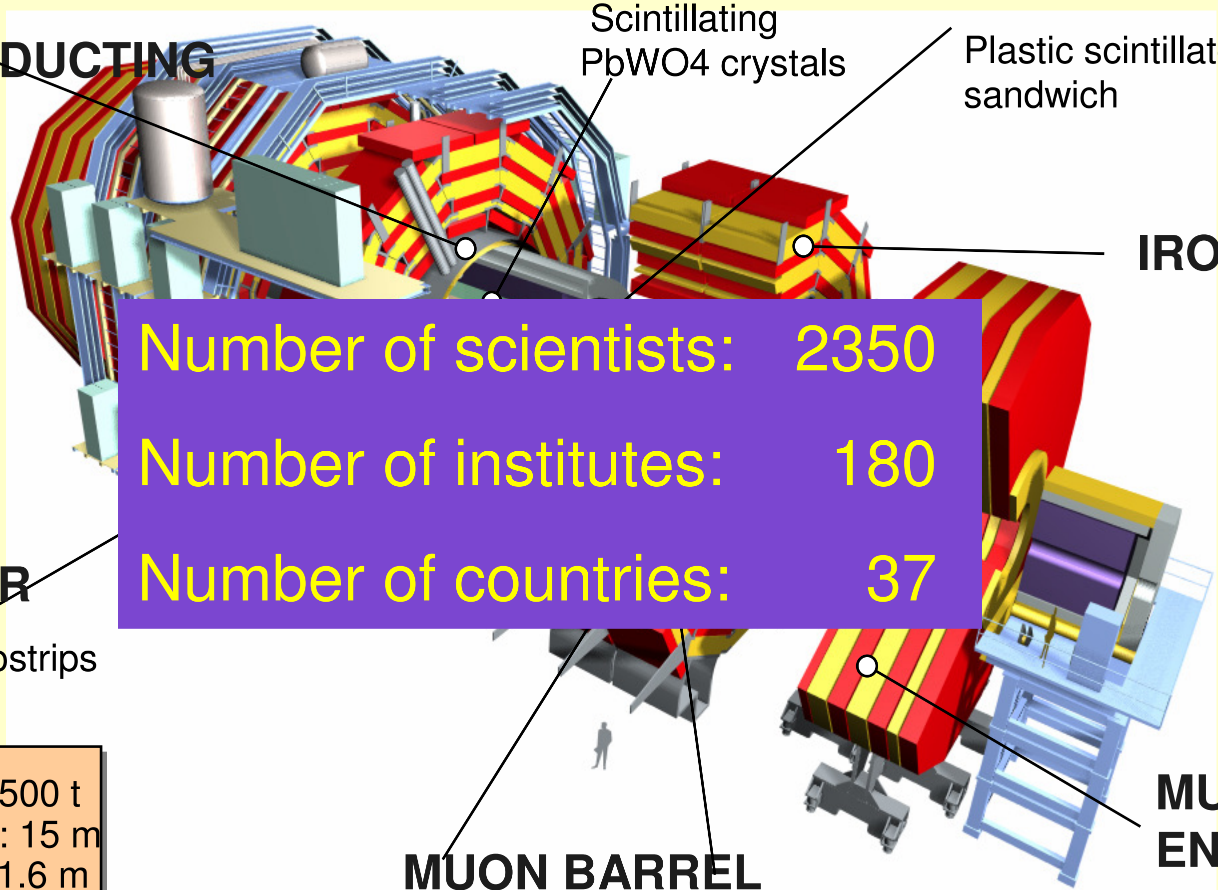


Barrel toroid system (eight 25m long-100 tons superconducting coils): tested at full field (20 kA current) in November 2006.

Installation Schedule Version 9.3 for Completing the Detector



The CMS Detector - Spokesperson: Jim Virdee

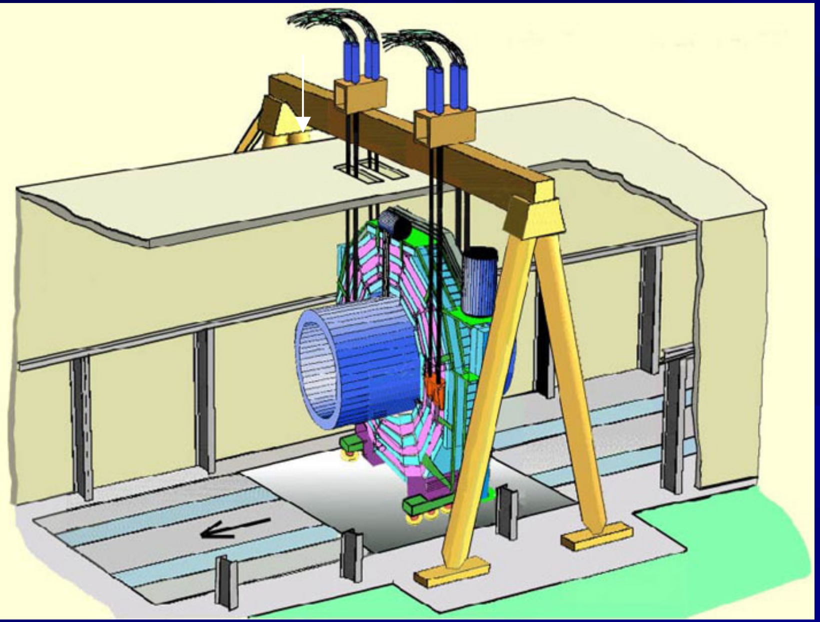


Number of scientists:	2350
Number of institutes:	180
Number of countries:	37

Total weight : 12,500 t
Overall diameter : 15 m
Overall length : 21.6 m
Magnetic field : 4 Tesla

CMS

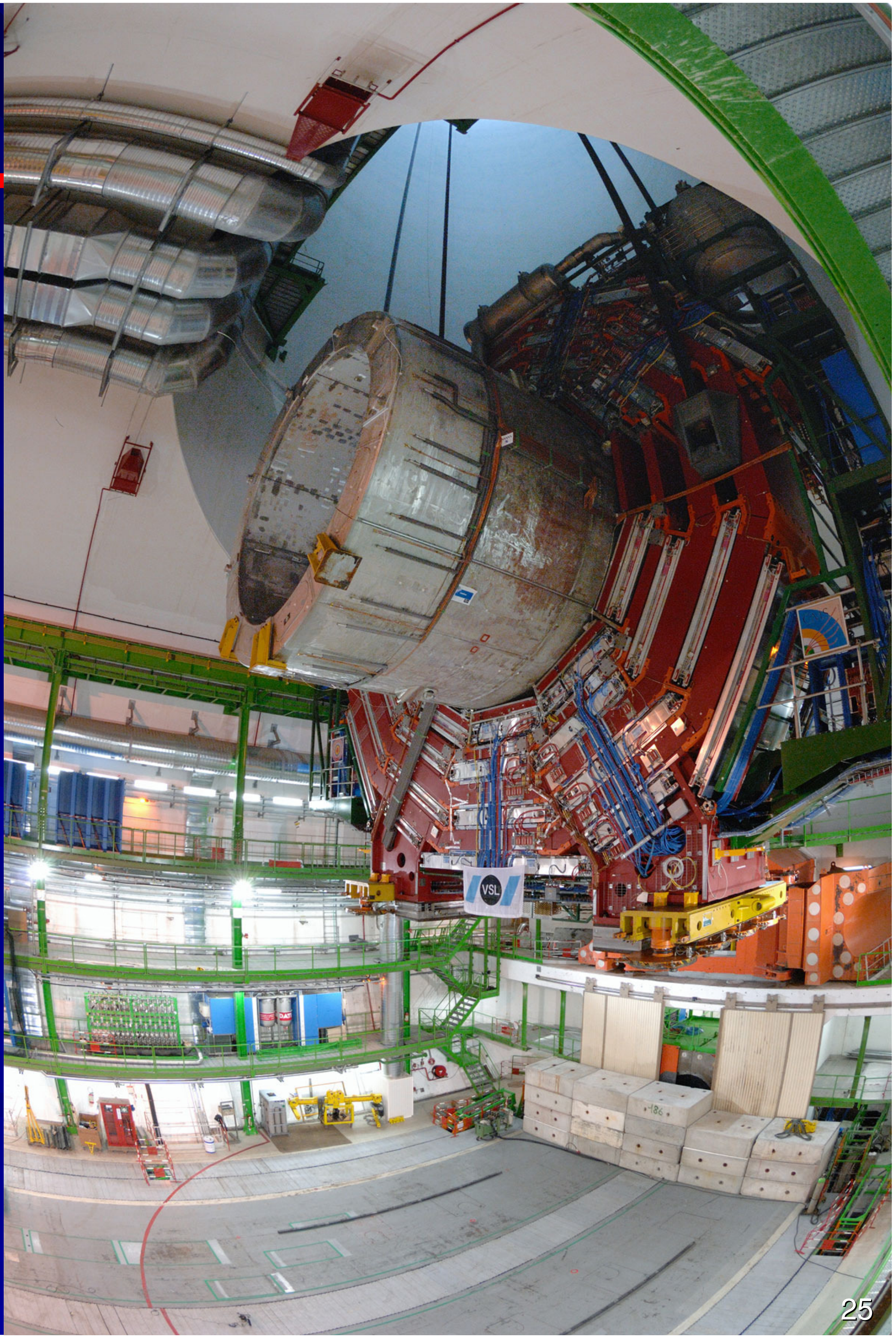
The central heaviest slice (2000 tons !) including the solenoid magnet lowered in the underground cavern in Feb. 2007



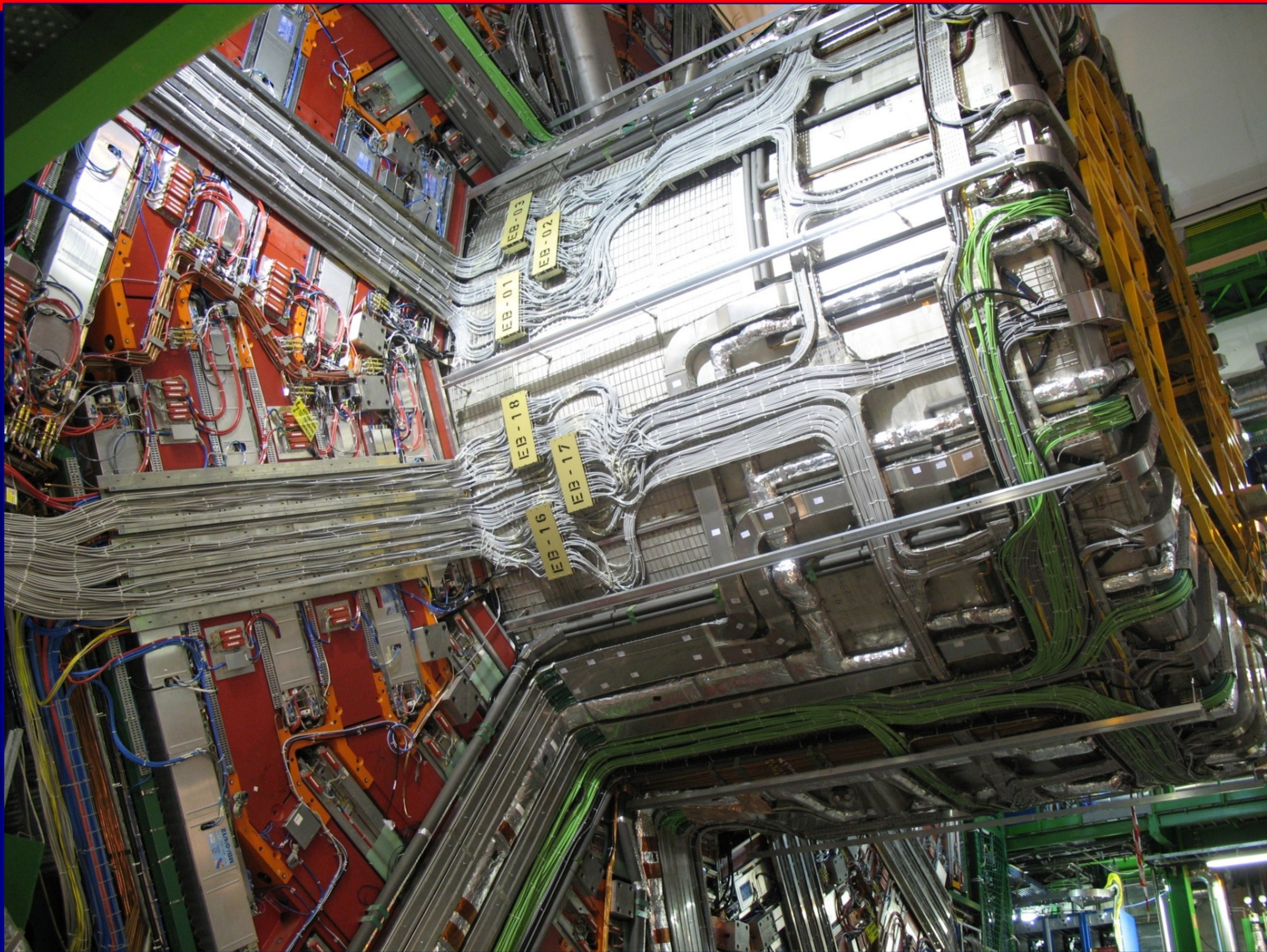
CMS solenoid:

Magnetic length	12.5 m
Diameter	6 m
Magnetic field	4 T
Nominal current	20 kA
Stored energy	2.7 GJ

Tested at full current in Summer 2006



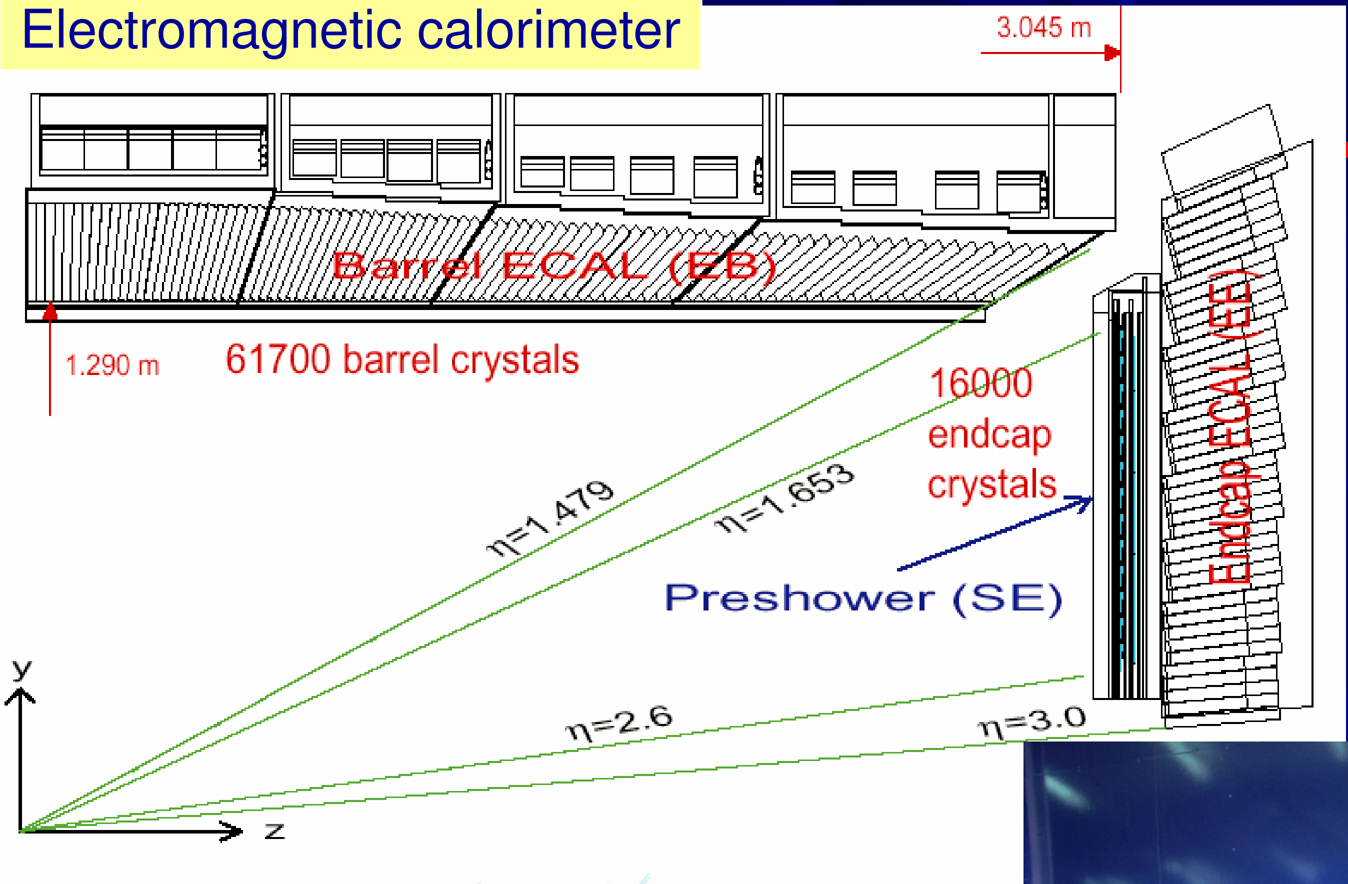
Cabling Challenge

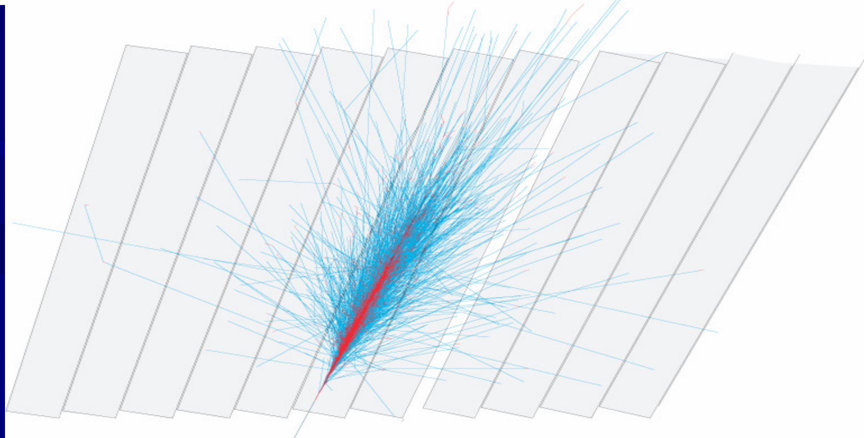


Electromagnetic calorimeter

CMS

~ 80000 $PbW0_4$ crystals

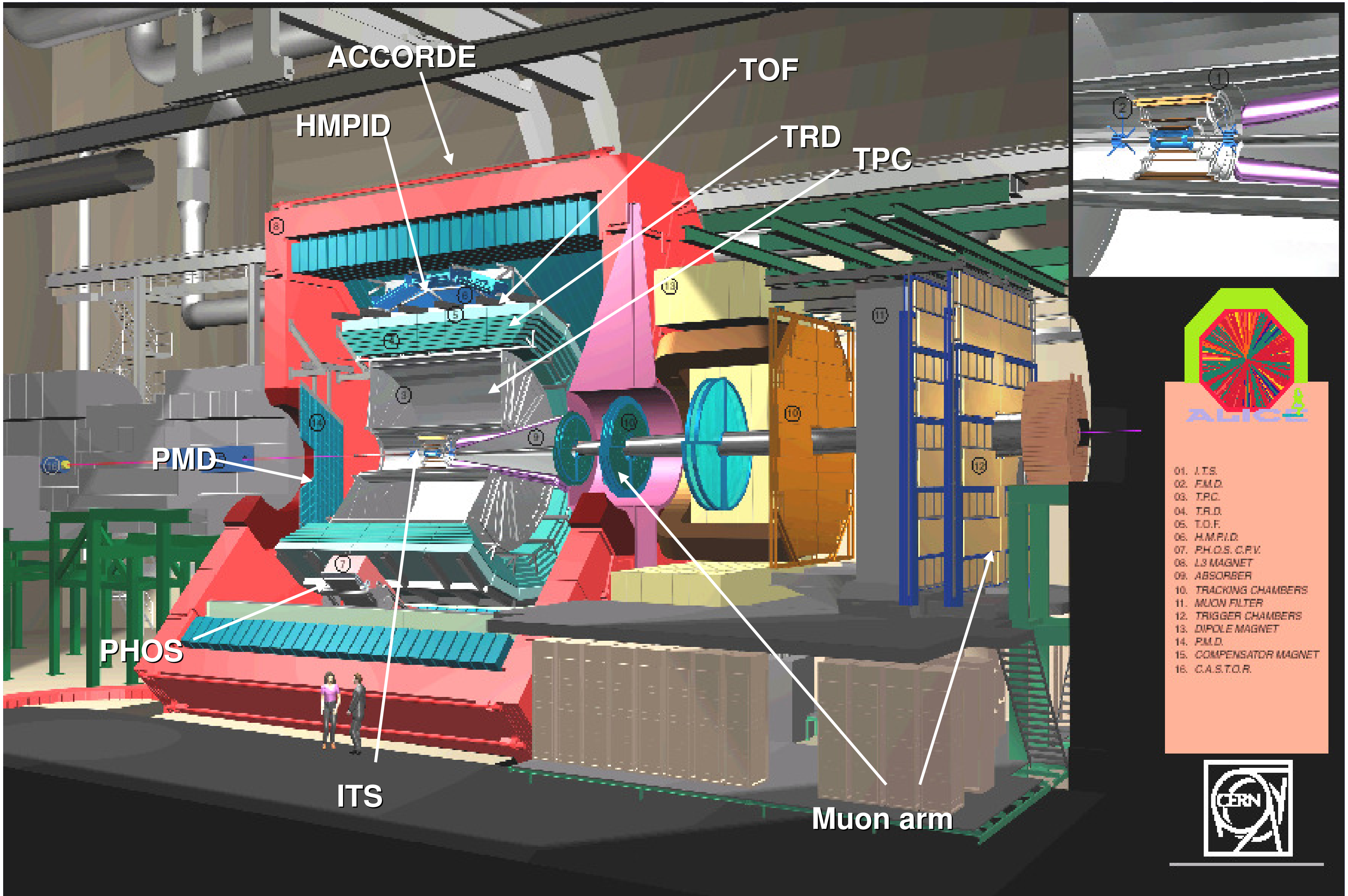




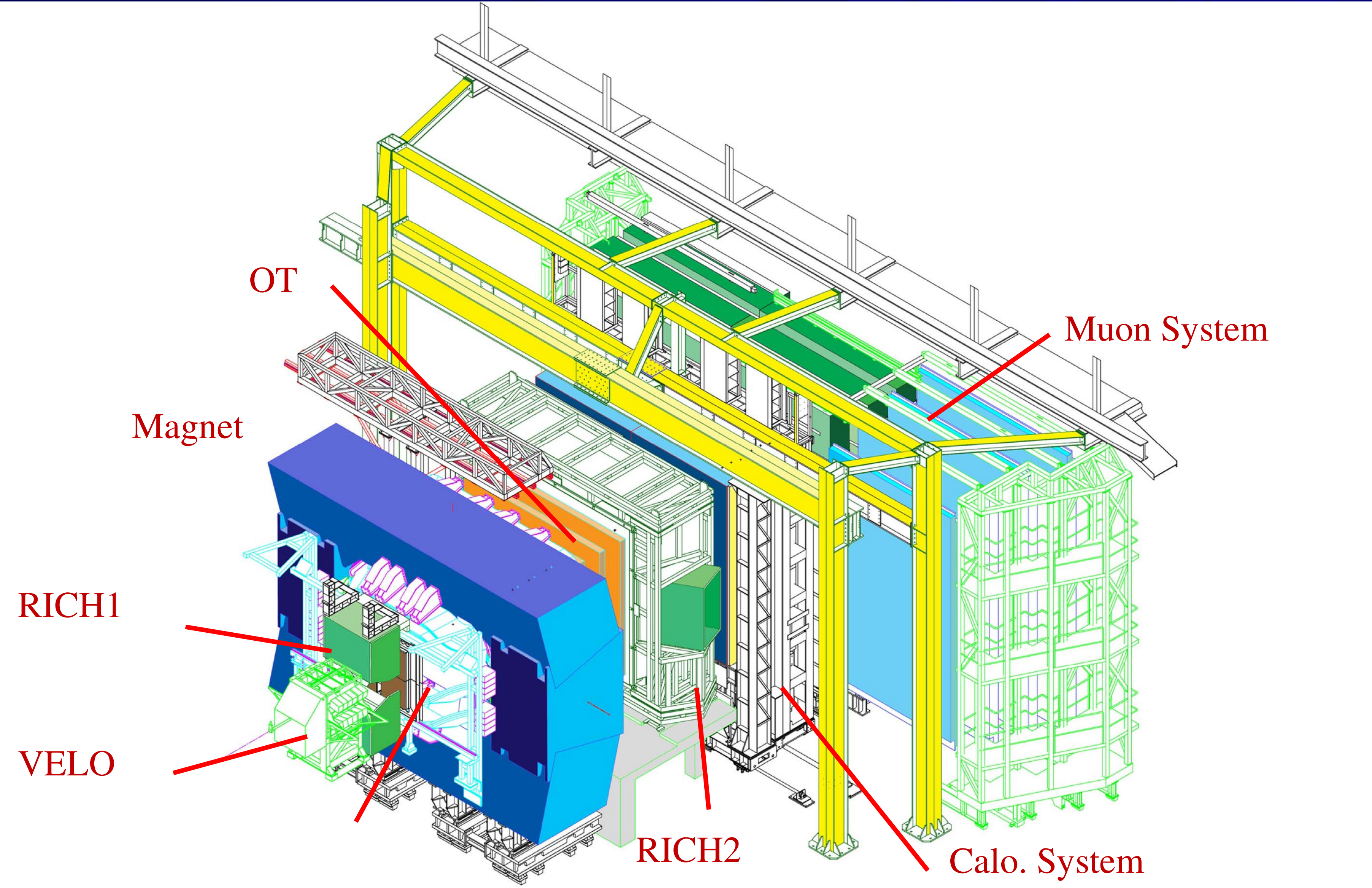
V36 Schedule
2nd ECAL endcap rfi in July

1) Detector Installation, Commissioning & Operation		2) Preparation of Software, Computing & Physics Analysis
	Jan	
Cooldown of Magnet started	Feb	2007 Physics Analyses Results Functional Tests CCRC Combined Computing Readiness Challenge
	Mar	
Tracker Connected		
Magnet Low i Test	Apr	S/w Release 2_0 (CRAFT, Production startup MC samples)
Cosmic Run 0T	May	
Pixels installed,Install EE endcap	Jun	CCRC/CSA08 S/w Release 2_1 (All basic s/w components ready for LHC)
CMS Closed, Cosmic Run 4T & Ready for Beam	Jul	
	Aug	
	Sep	
	Oct	

Comment:
Will need 2 months advance warning of injection of beam.

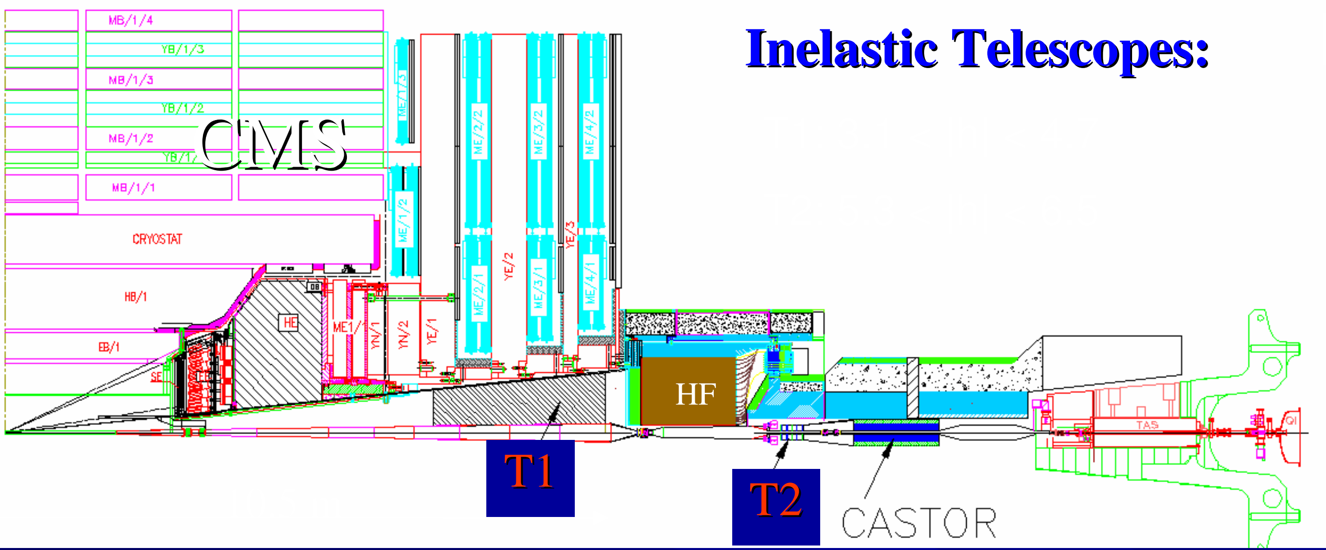

ACCORDE
TOF
HMPID
TRD
TPC
PMD
PHOS
ITS
Muon arm
01. I.T.S.
02. F.M.D.
03. T.P.C.
04. T.R.D.
05. T.O.F.
06. H.M.P.I.D.
07. P.H.O.S. C.P.V.
08. L3 MAGNET
09. ABSORBER
10. TRACKING CHAMBERS
11. MUON FILTER
12. TRIGGER CHAMBERS
13. DIPOLE MAGNET
14. P.M.D.
15. COMPENSATOR MAGNET
16. C.A.S.T.O.R.
CERN

LHCb Spectrometer



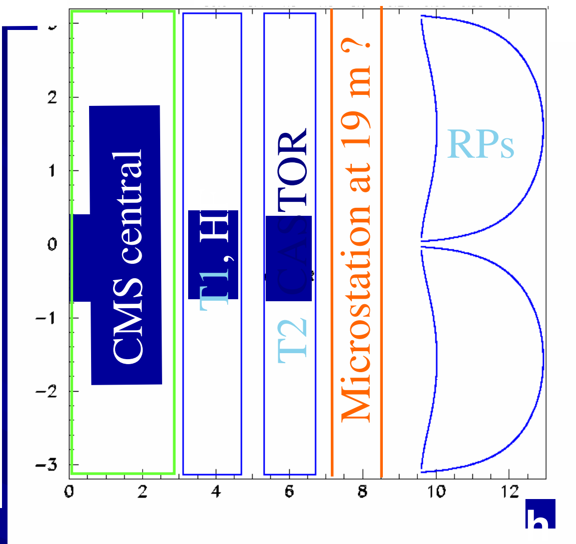
TOTEM

Inelastic Telescopes:

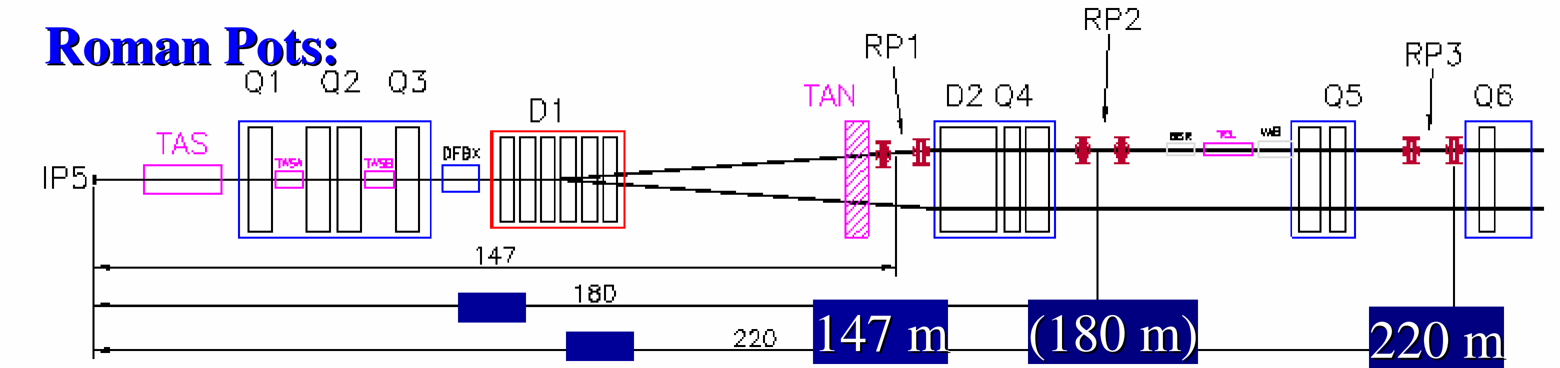


~14 m

Acceptance:



Roman Pots:



?

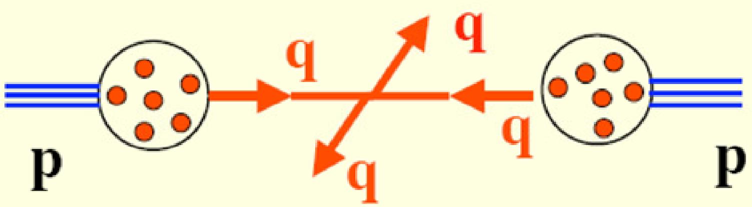
(420 m)

Overall Conclusion

- Good progress – there have been small delays, but no major issues anymore
- Still much work to do in coming months – tasks and schedules are understood
- Closing the experiments, in particular ATLAS and CMS, and subsequent turn on of magnets (in particular ATLAS: first operation of all magnets together) are major operations (two months foreseen in schedules)
- Detector-, readout-, trigger-, data acquisition-, off line software commissioning progressing very well in parallel

What Experimental Signatures Can Be Used?

Quark-quark scattering:

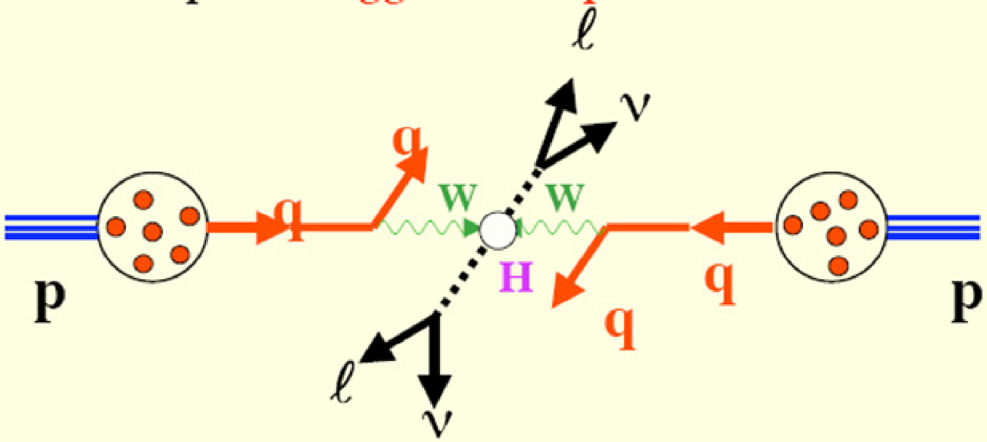


No leptons / photons in the initial and final state

If leptons with large transverse momentum are observed:

⇒ **interesting physics !**

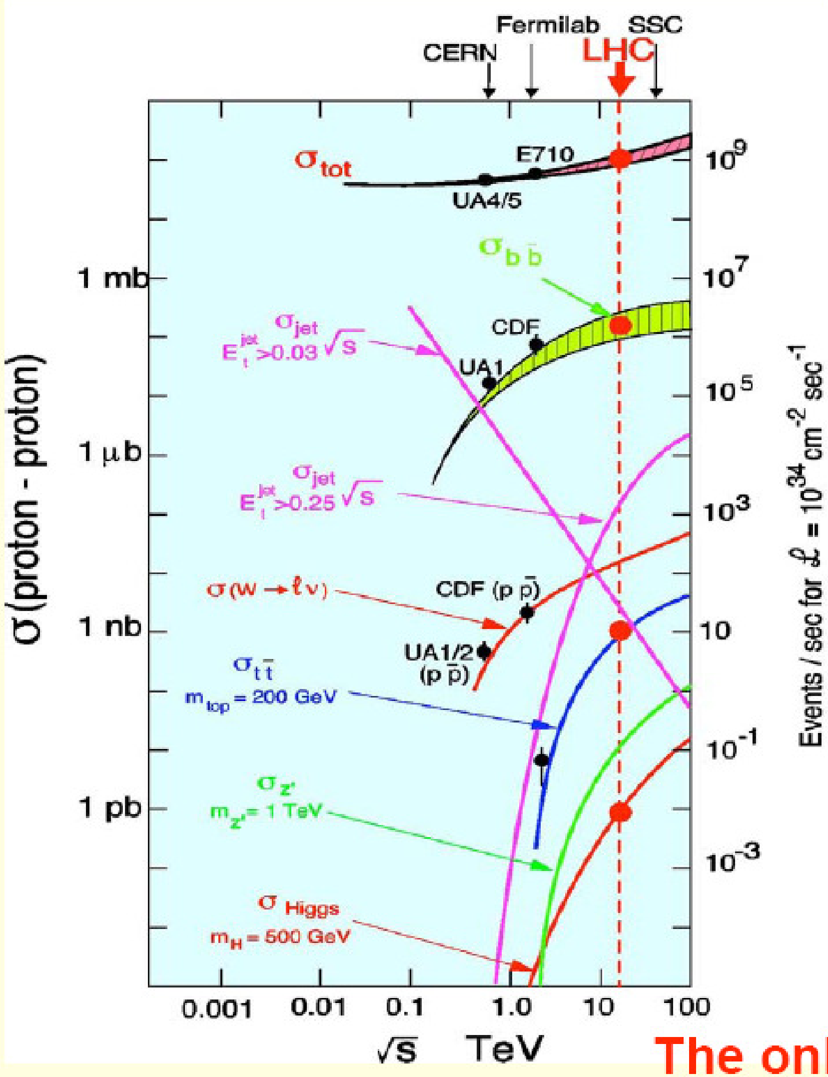
Example: Higgs boson production and decay



Important signatures:

- **Leptons und photons**
- **Missing transverse energy**

Cross Sections and Production Rates



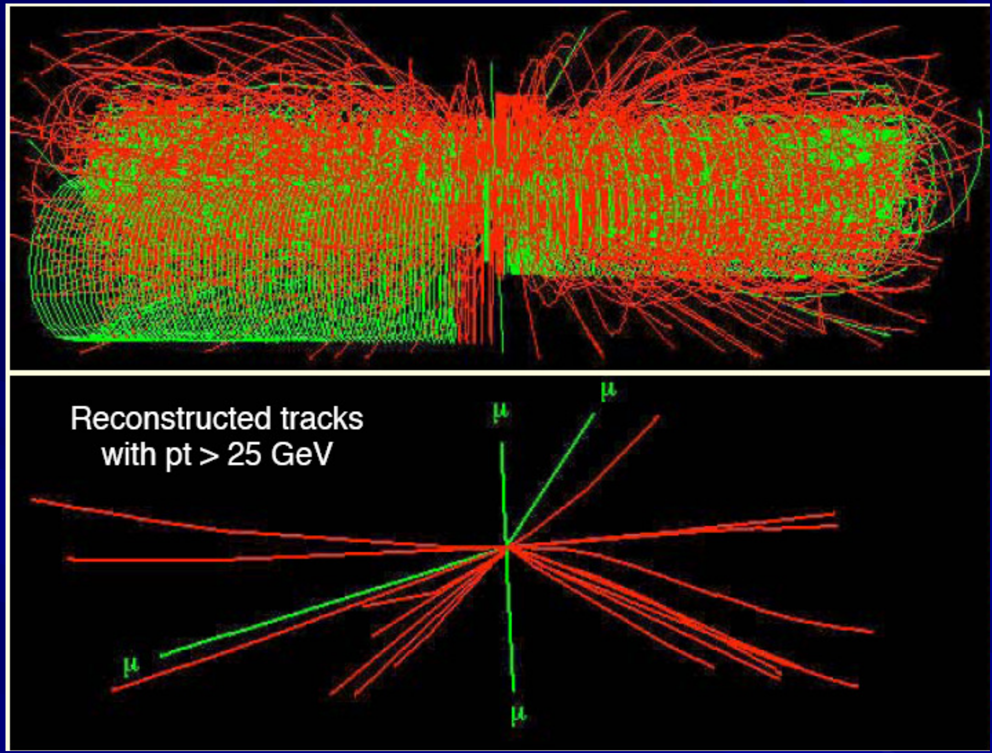
Rates for $L = 10^{34}$ cm^{-2} s^{-1}: (LHC)
Number of Events = $L \cdot \sigma$

• Inelastic proton-proton reactions:	10^9 / s
• bb pairs	5 10^6 / s
• tt pairs	8 / s
• W → e ν	150 / s
• Z → e e	15 / s
• **Higgs (150 GeV)**	**0.2 / s**
• **Gluino, Squarks (1 TeV)**	**0.03 / s**

LHC is a factory for:
top-quarks, b-quarks, W, Z, ……. Higgs, ……

The only problem: you have to detect them !

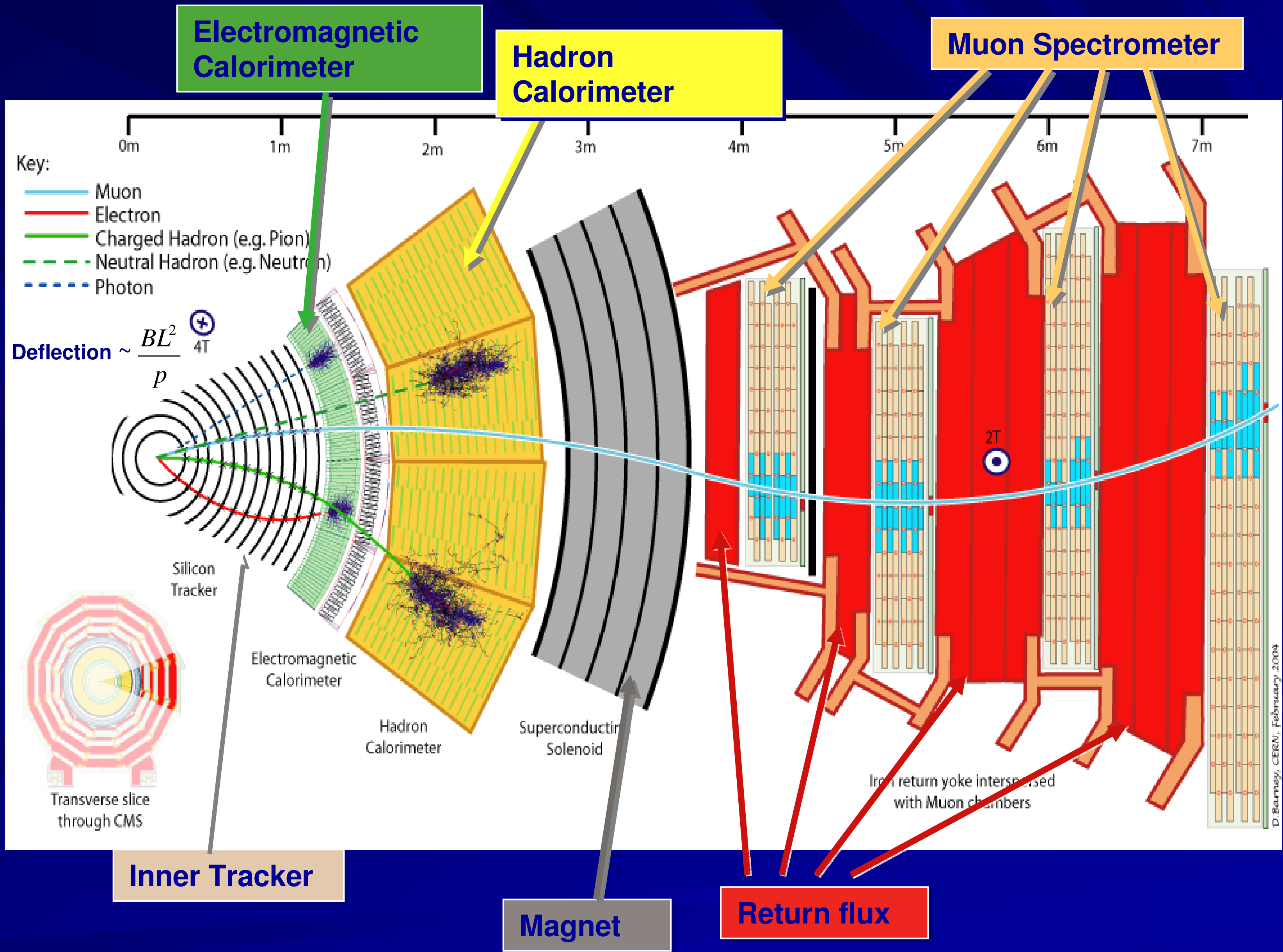
Suppression of background: Reconstruction of objects with large transverse momentum

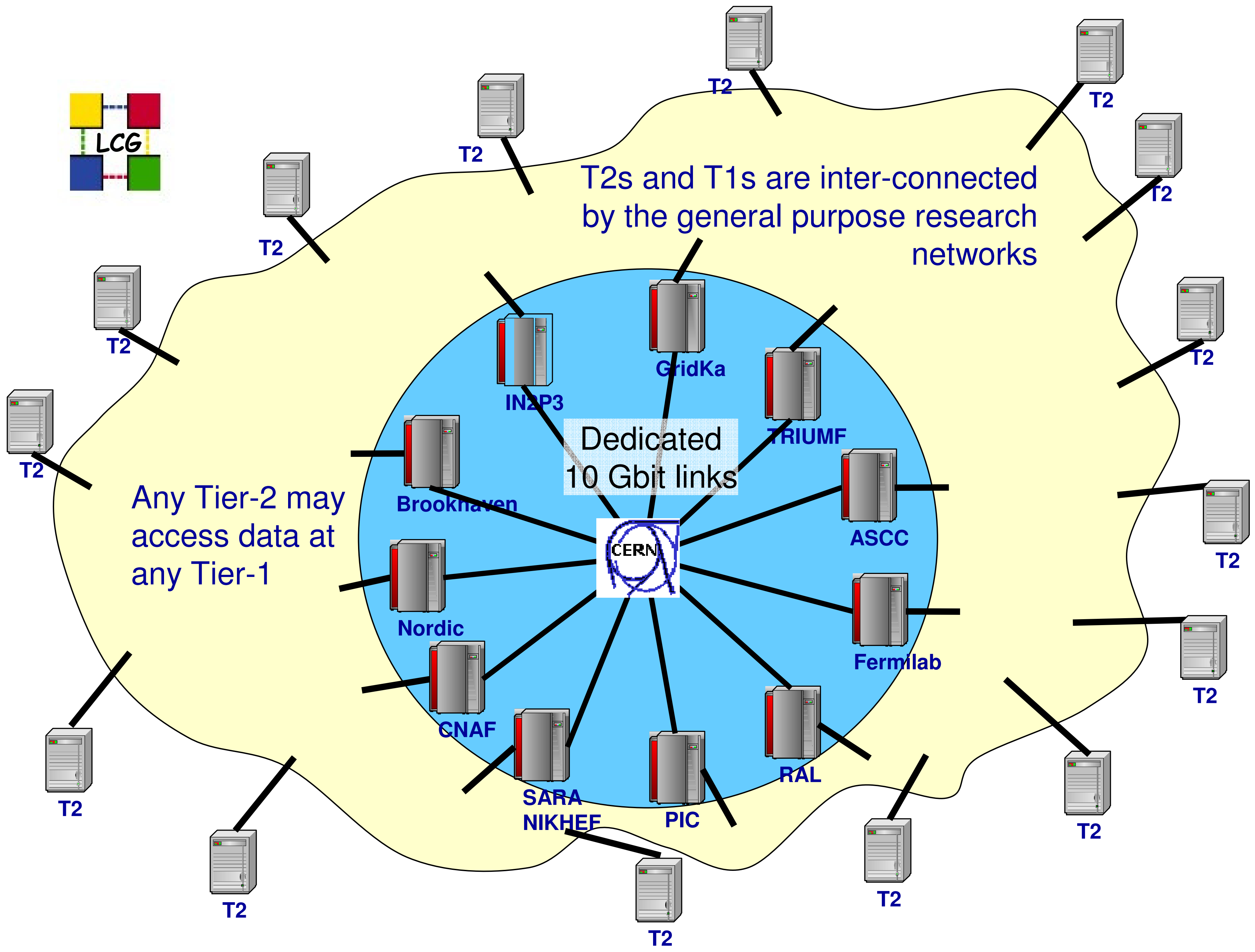


Impact of pile-up on detector requirements and performance

- Fast response: ~50ns
- Granularity: >10^8 channels
- Radiation resistance (up to 10^{16}n/cm^2/year in forward calorimeters)
- Event reconstruction much more challenging than at previous colliders

With some more details (CMS case)





T2s and T1s are inter-connected by the general purpose research networks
Any Tier-2 may access data at any Tier-1
Dedicated 10 Gbit links
CERN
GridKa
IN2P3
TRIUMF
Brookhaven
ASCC
Nordic
Fermilab
CNAF
SARA NIKHEF
PIC
RAL
T2

The Worldwide LHC Computing Grid

- The LHC physics data analysis service distributed across the world
  - CERN, 11 large *Tier-1* centres, over 100 *Tier-2* centres

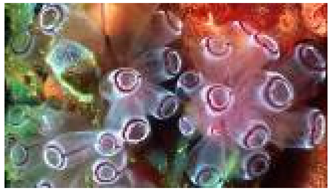
- What has been achieved?
  - Established the 10 Gbit/sec optical network that interlinks CERN and the Tier-1 centres
  - Demonstrated data distribution from CERN to the Tier-1 centres at 1.6 GByte/sec – the rate that will be needed in 2008

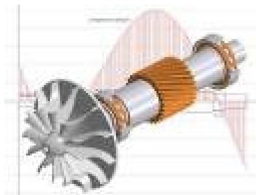
  - Regularly running a million jobs each month across the grid
  - All of the Tier-1s and most of the Tier-2 centres took part in the service during the experiment "data challenges"

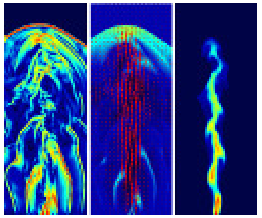
  - **The performance and reliability targets have been achieved**
  - **The distributed grid operation, set up during 2005, has reached maturity**

The EGEE project

- EGEE
  - 1 April 2004 – 31 March 2006
  - 71 partners in 27 countries, grouped into regional federations
- EGEE-II
  - 1 April 2006 – 31 March 2008
  - 91 partners in 32 countries
  - 13 federations
- Objectives
  - Large-scale, production-quality grid infrastructure for e-Science
  - Attracting new resources and users from industry as well as science
  - Maintain and further improve “gLite” Grid middleware

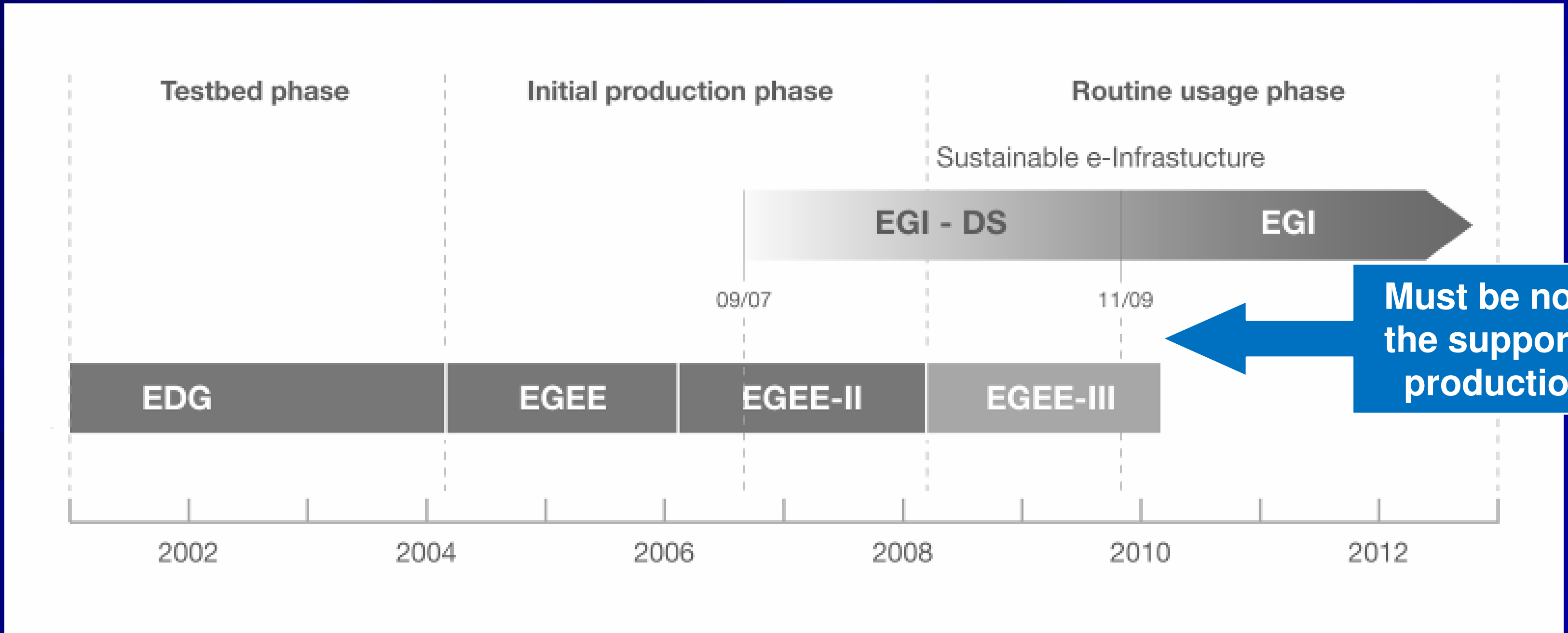






European Grid Initiative

- Need to prepare permanent, common Grid infrastructure
- Ensure the long-term sustainability of the European e-Infrastructure independent of short project funding cycles
- Coordinate the integration and interaction between National Grid Infrastructures (NGIs)
- Operate the production Grid infrastructure on a European level for a wide range of scientific disciplines



Must be no gap in the support of the production grid

The various steps toward design luminosity

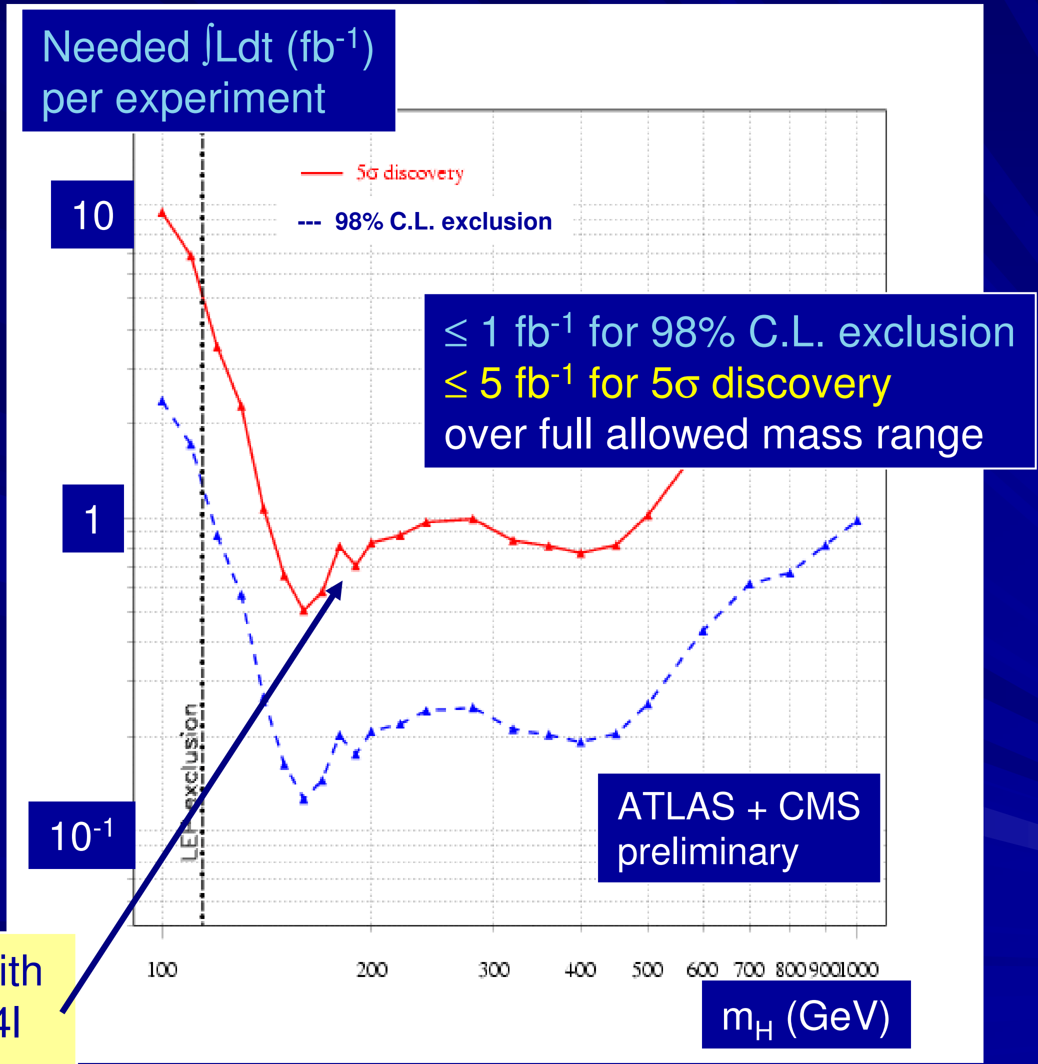
Beam commissioning

Beam commissioning will proceed in phases with increased complexity:

- Number of bunches and bunch intensity.
- Crossing angle (start without crossing angle !).
- Less focusing at the collision point (larger 'β^*').

Parameter	Phase A	Phase B	Phase C	Nominal
k / no. bunches	43-156	936	2808	2808
Bunch spacing (ns)	2021-566	75	25	25
N (10^{11} protons)	0.4-0.9	0.4-0.9	0.5	1.15
Crossing angle (μrad)	0	250	280	280
$\sqrt{(\beta^*/\beta^*_{nom})}$	2	$\sqrt{2}$	1	1
σ^* (μm, IR1&5)	32	22	16	16
L ($cm^{-2}s^{-1}$)	6×10^{30}-10^{32}	10^{32}-10^{33}	$(1-2)\times10^{33}$	10^{34}

SM Higgs in ATLAS and CMS



here discovery easier with gold-plated $H \to ZZ \to 4l$

$\to$ **by end 2009 ?**

General Schedule

- Engineering run with two beams colliding at the injection energy (450 Gev) originally foreseen at end 2007 now precluded by delays in installation and equipment commissioning.
- 450 GeV operation now part of normal setting up procedure for beam commissioning to high-energy
- General schedule being reassessed, accounting for inner triplet repairs and their impact on sector commissioning
  - All technical systems commissioned to 5 TeV operation, and beam pipe closed April 2008
  - Beam commissioning starts June2008
  - First collisions at 10 TeV c.m. Summer 2008
  - Pilot run pushed to 156 bunches for reaching 10^{32} $cm^{-2}.s^{-1}$ by end 2008
  - Commissioning to 7 TeV to be done during the winter shutdown.
- No provision in success-oriented schedule for major mishaps, e.g. additional warm-up/cooldown of sector

The various steps toward design luminosity

Beam commissioning

Beam commissioning will proceed in phases with increased complexity:

- Number of bunches and bunch intensity.
- Crossing angle (start without crossing angle !).
- Less focusing at the collision point (larger 'β^*').

Parameter	Phase A	Phase B	Phase C	Nominal
k / no. bunches	43-156	936	2808	2808
Bunch spacing (ns)	2021-566	75	25	25
N (10^{11} protons)	0.4-0.9	0.4-0.9	0.5	1.15
Crossing angle (μrad)	0	250	280	280
$\sqrt{(\beta^*/\beta^*_{nom})}$	2	$\sqrt{2}$	1	1
σ^* (μm, IR1&5)	32	22	16	16
L ($cm^{-2}s^{-1}$)	6×10^{30}-10^{32}	10^{32}-10^{33}	$(1-2)\times10^{33}$	10^{34}

First Phase of LHC Operation

So, **in about 1 year from now, particle physics will enter a new epoch, hopefully the most glorious and fruitful of its history.**

We can anticipate a profusion of exciting results from a machine able to explore in detail the highly-motivated TeV-scale with a direct discovery potential up to m ≈ 5-6 TeV

- **if New Physics is there, the LHC should find it (SUSY could be found quickly, light Higgs requires a bit more time, … and what about early surprises ?)**
- **it will say the final word about the SM Higgs mechanism and many TeV-scale predictions**
- **it may add crucial pieces to our knowledge of fundamental physics → impact also on astroparticle physics and cosmology**
- **most importantly, it will tell us how to go on …**

Contents

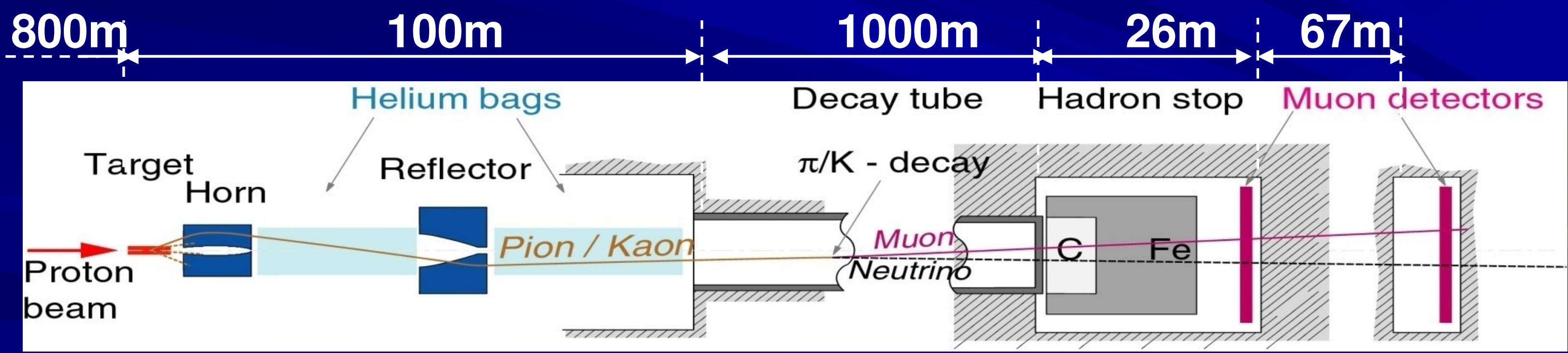
- about CERN: a facility for the benefit of the European Particle Physics Community
- the LHC project: completion of installation, start of commissioning for accelerator, experiments and computing,
- the CNGS: start of operations and the CLIC scheme for multi Tev e^+e^- Linear Collider
- plans for CERN in the next decade

CNGS - CERN Neutrinos to Gran Sasso

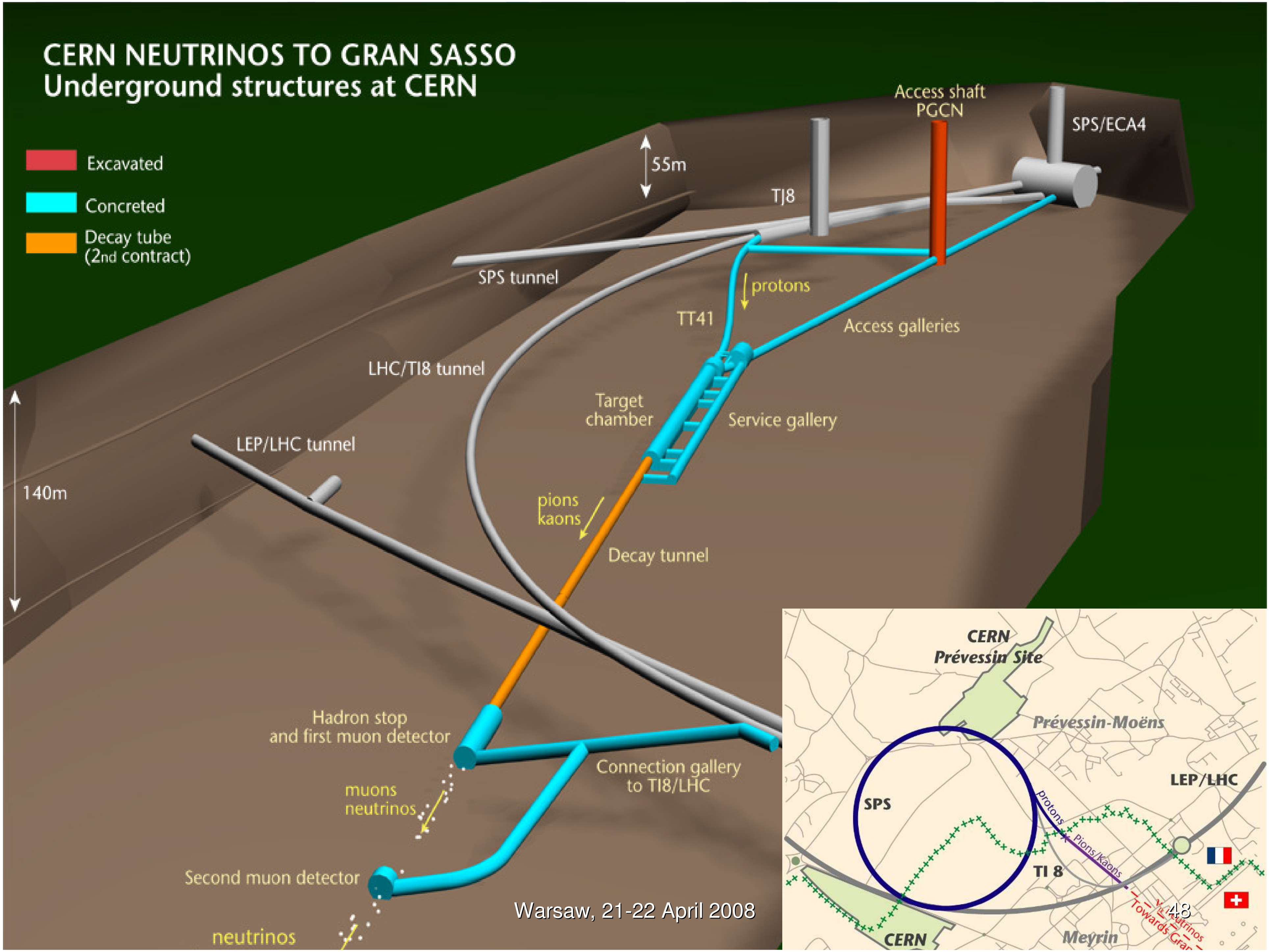
Physics goal:
search for oscillation

$$\nu_\mu - \nu_\tau$$

Task for CERN:
produce intense ν_μ beam
towards Gran Sasso

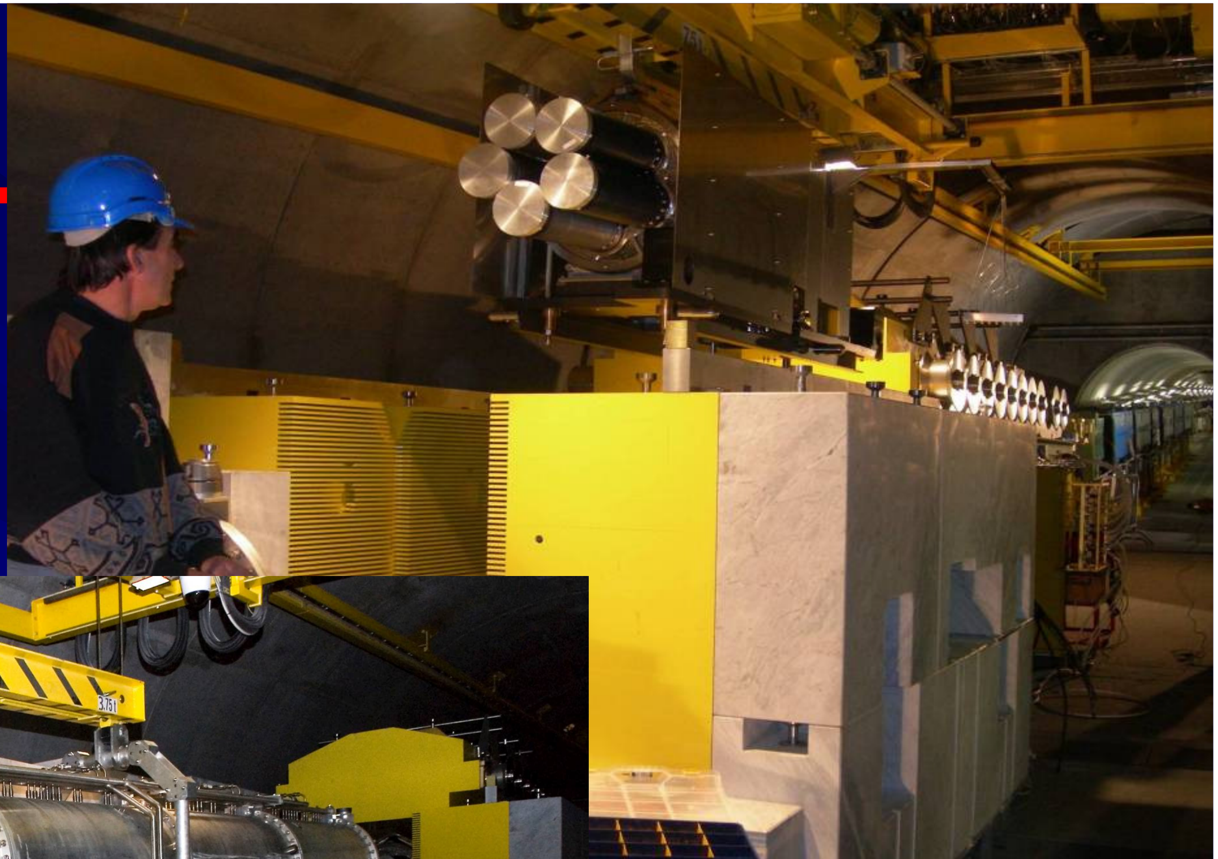


p + C → (interactions) → π^+, K^+ → (decay in flight) → $\mu^+ + \nu_\mu$

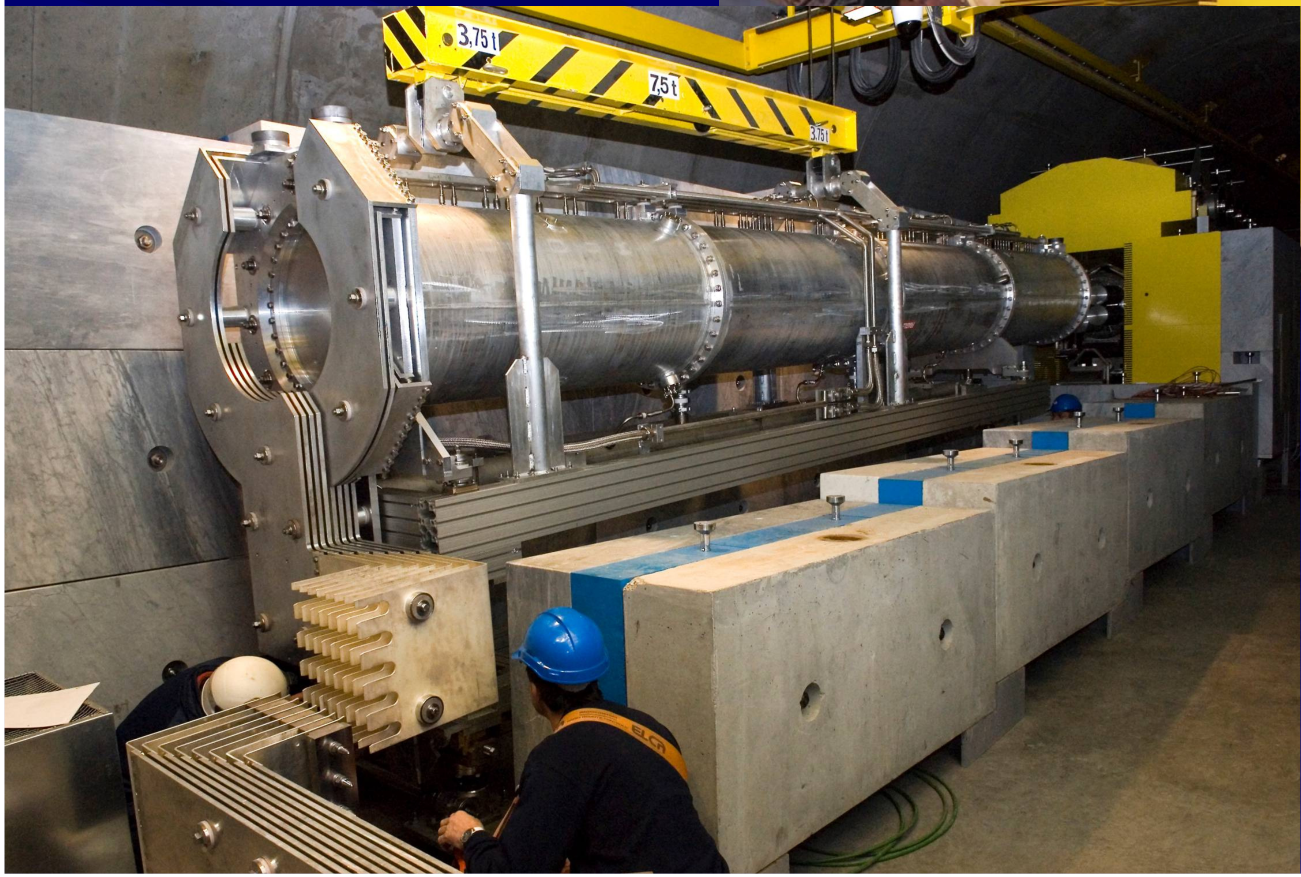


CERN NEUTRINOS TO GRAN SASSO
Underground structures at CERN
Excavated
Concreted
Decay tube
(2nd contract)
55m
140m
TJ8
Access shaft
PGCN
SPS/ECA4
SPS tunnel
protons
TT41
Access galleries
LHC/TI8 tunnel
Target
chamber
Service gallery
LEP/LHC tunnel
pions
kaons
Decay tunnel
Hadron stop
and first muon detector
Connection gallery
to TI8/LHC
muons
neutrinos
Second muon detector
neutrinos
CERN
Prévessin Site
Prévessin-Moëns
SPS
LEP/LHC
protons
Pions/Kaons
TI 8
CERN
Meyrin

CNGS Target Chamber



Installation of
target magazine
(4 in-situ spares)

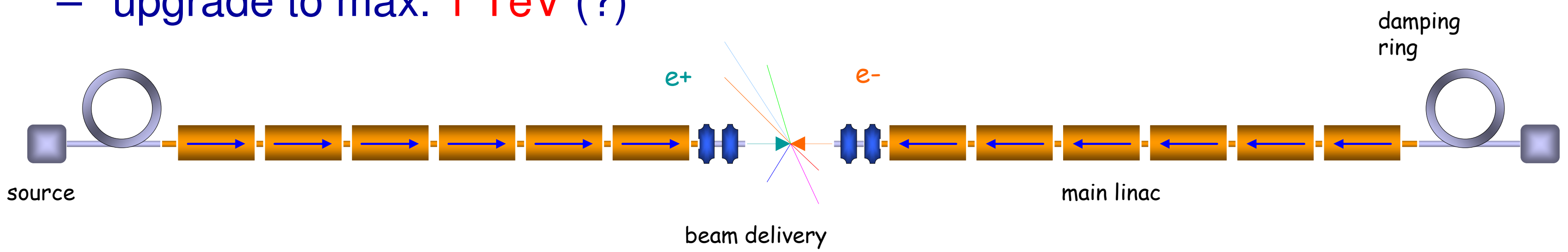


Installation of horn
(focusing element)

Linear Collider projects

New physics expected in TeV energy range.
LHC will indicate what physics, and at which energy scale.
Experiments probing physics beyond the Standard Model may be best done with e^+e^- Linear Collider. Depending on energy scale of new physics, there are two options:

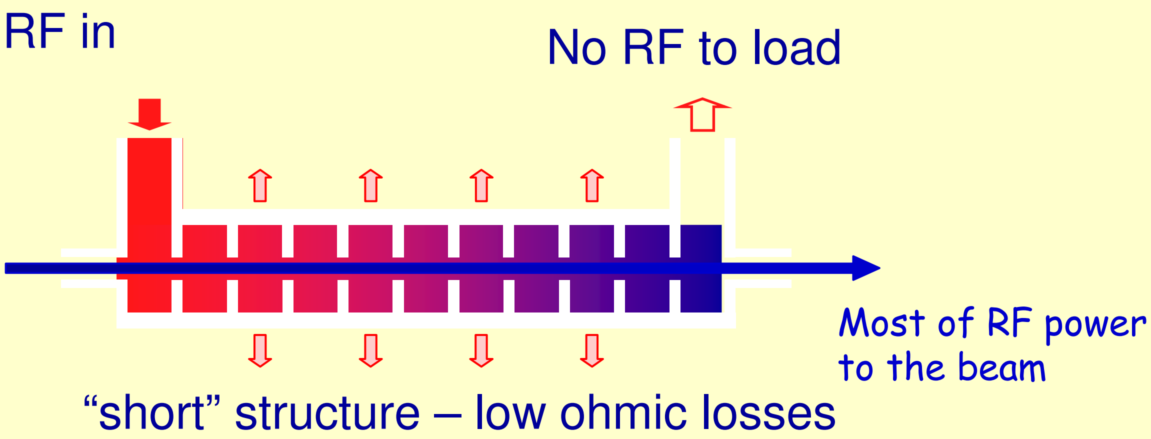
up to 1 TeV	multi TeV
ILC (International Linear Collider)	**CLIC (Compact Linear Collider)**
– superconducting technology	• normal conducting technology
– 1.3 GHz RF frequency	• 12 GHz
– ~31 MV/m accelerating gradient	• ~100 MV/m
– 500 GeV centre-of-mass energy	• multi-TeV energy range (nom. 3 TeV)
– upgrade to max. 1 TeV (?)	



Drive beam generation basics

- Efficient acceleration

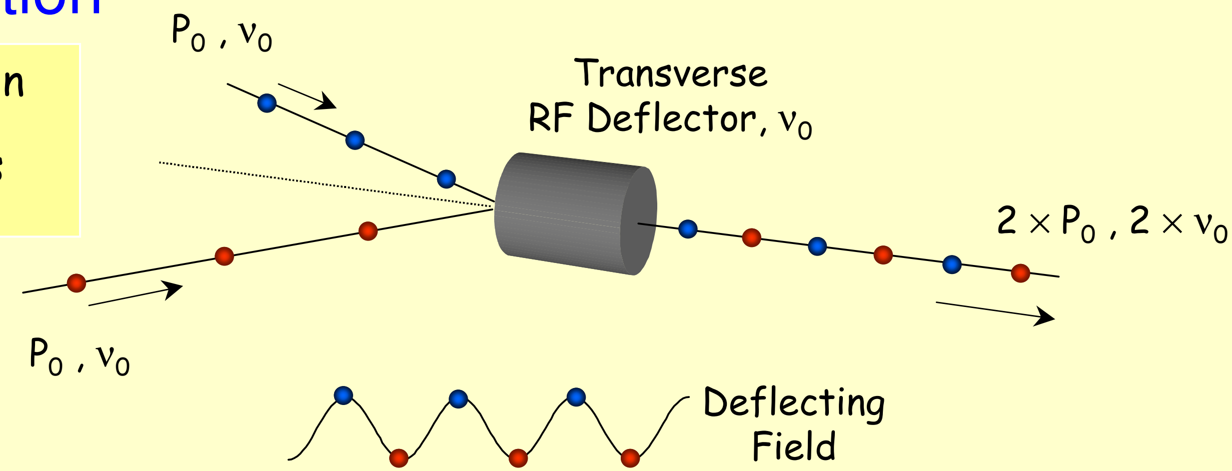
Full beam-loading acceleration in traveling wave sections



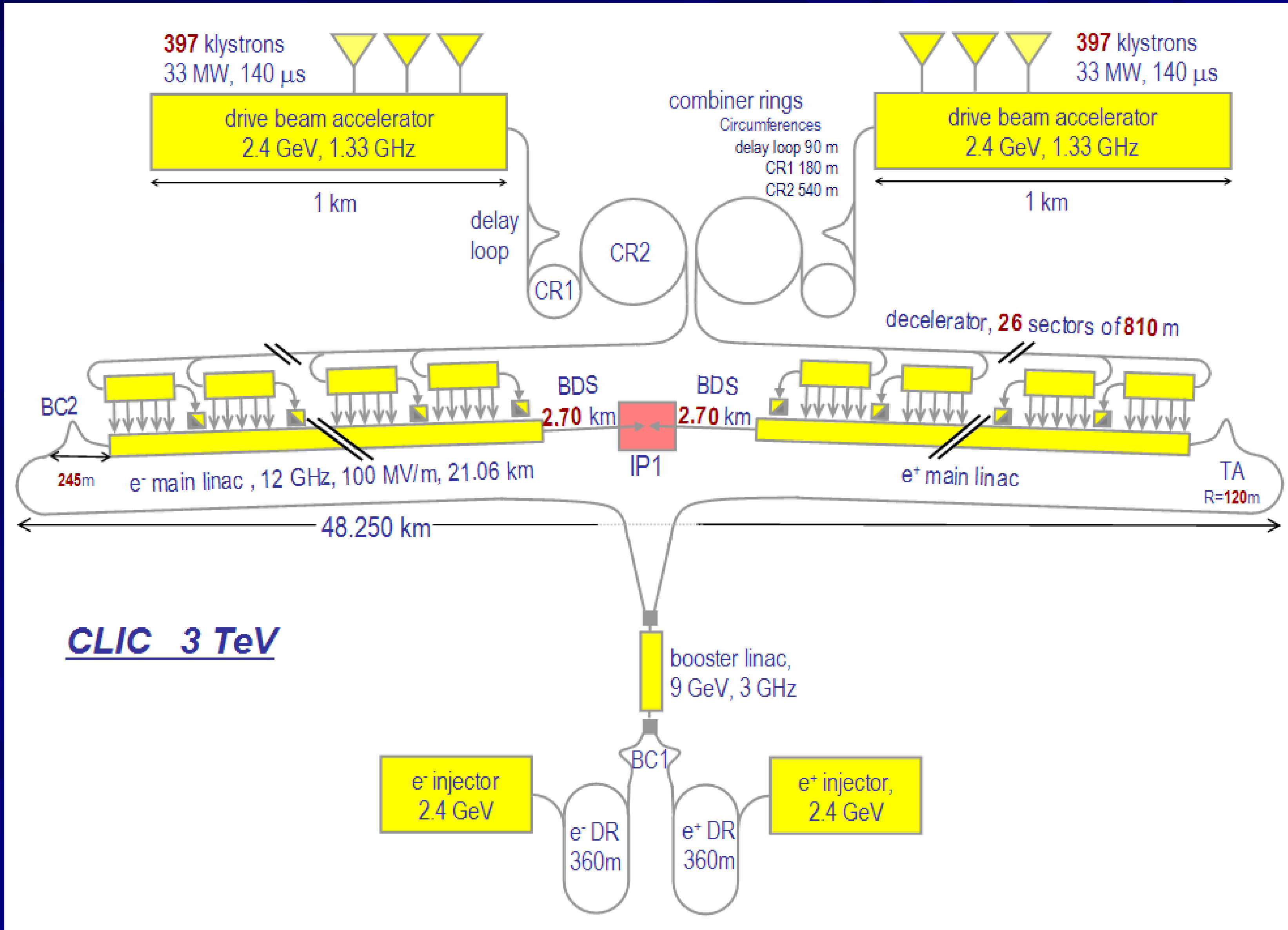
- Frequency multiplication

Beam combination/separation

by transverse RF deflectors



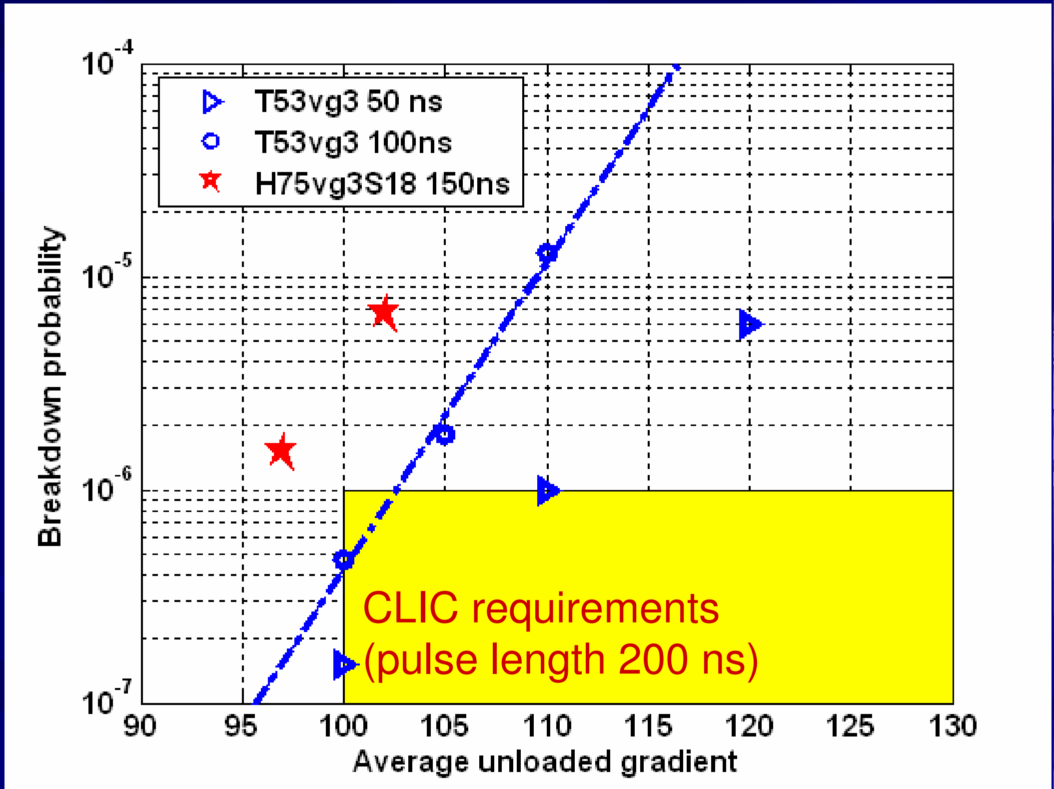
CLIC – overall layout

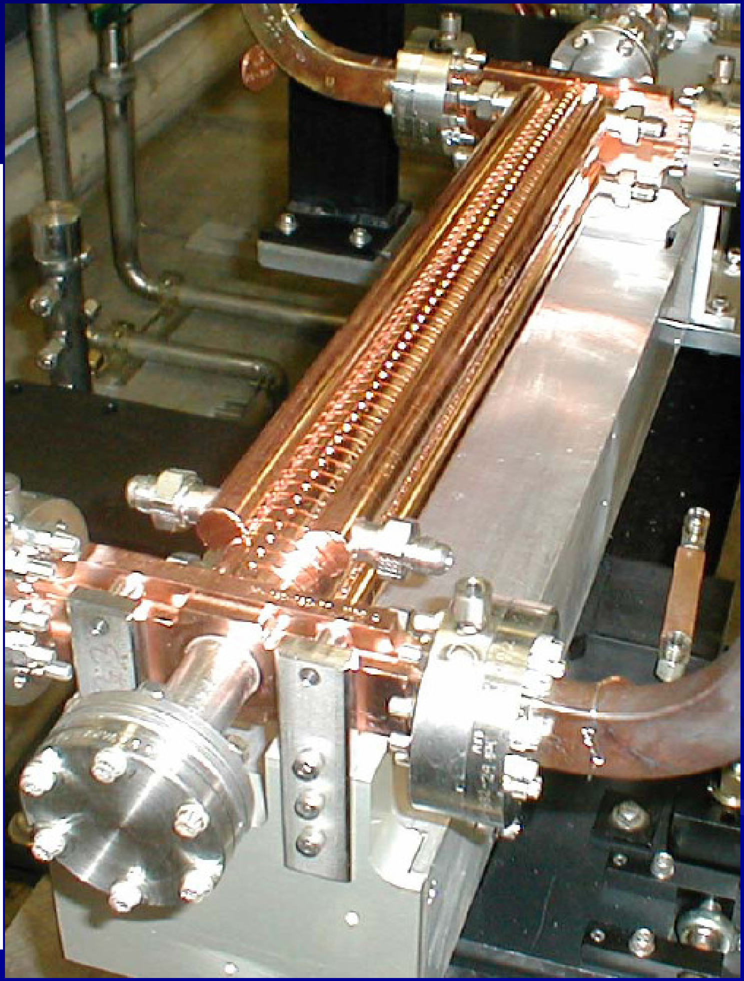


CLIC Challenges 1

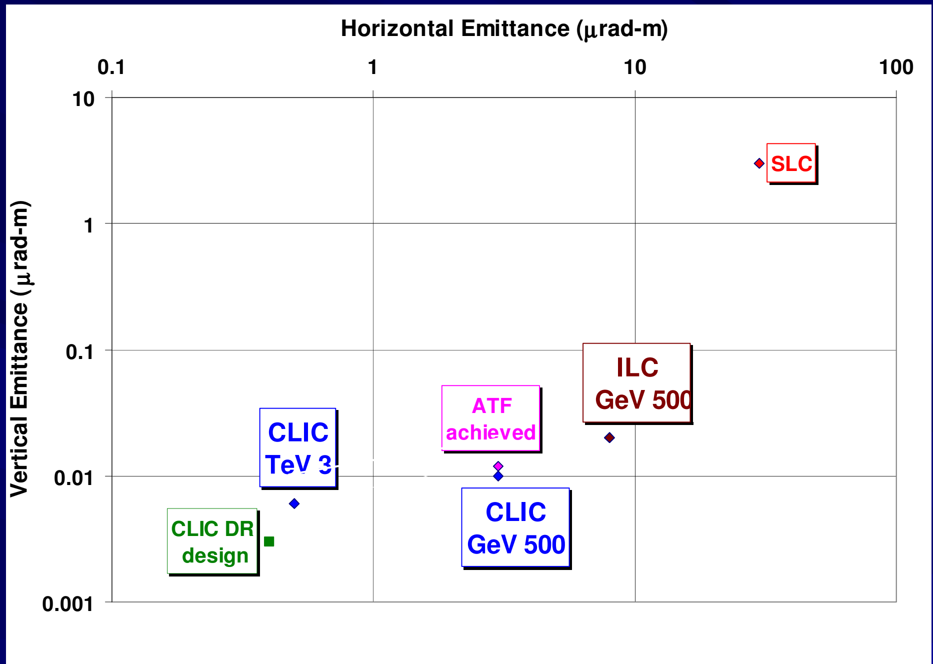
Accelerating structure

Recent High-Power test results @SLAC (11.4 GHz)





CLIC Challenges II



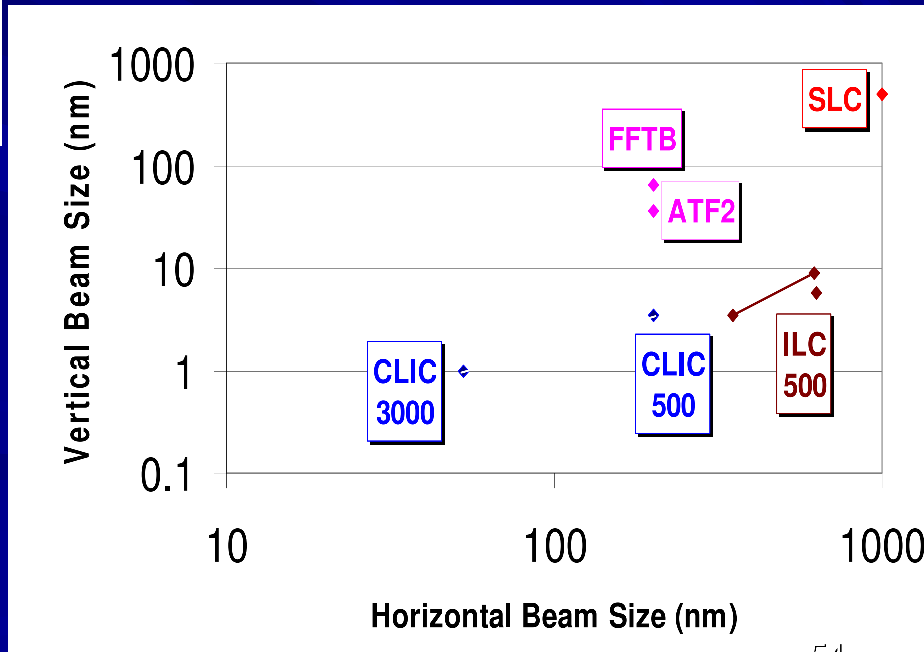
Beam emittances at Damping Rings

Hor./vert. : ~0.6/0.01 μrad m

SLC@SLAC
Test Facilities:
ATF@KEK
FFTB@SLAC

Beam sizes at Collisions

Hor./vert. size : 53 nm/ ~1 nm

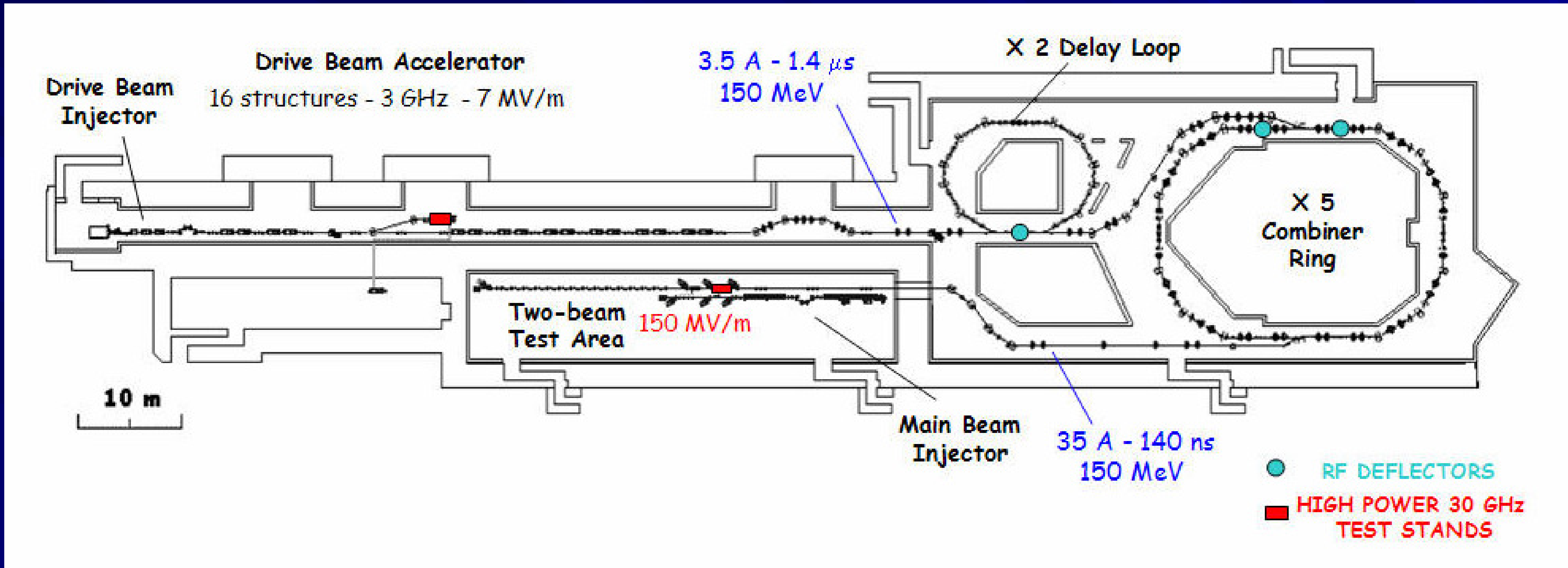


54

CLIC Test Facility, CTF3

all major CLIC technology key issues are addressed in CTF3

Goal: prove of CLIC concept by 2010



Key issues

- ***From 2005: Accelerating structures (bi-metallic) Development & Tests***
- ***2007- 2008: Drive beam generation scheme***
- ***2008- 2009: Damped accelerating structure with nominal parameters***
  ON/OFF Power Extraction Structure
  Drive beam stability bench marking
  CLIC sub-unit

Contents

- about CERN: a facility for the benefit of the European Particle Physics Community
- the LHC project: completion of installation, start of commissioning for accelerator, experiments and computing,
- the CNGS: start of operations and the CLIC scheme for multi Tev e^+e^- Linear Collider
- plans for CERN in the next decade

The European Strategy for Particle Physics
Scientific activities

In 2006, an ad hoc scientific advisory group has organized the definition of a strategy document.
A special meeting of the Council in Lisbon (14 July 2006) has approved unanimously the new European Strategy for Particle Physics

- **The highest priority is to fully exploit the physics potential of the LHC. Resources for completion of the initial programme have to be secured such that machine and experiments can operate optimally at their design performance.**
- **R&D for machine and detectors has to be vigorously pursued now and centrally organized towards a luminosity upgrade by around 2015.**
- **A coordinated programme should be intensified, to develop the CLIC technology and high performance magnets for future accelerators, and to play a significant role in the study and development of a high-intensity neutrino facility.**
- **There should be a strong well-coordinated European activity, including CERN, through the Global Design Effort, for its design and technical preparation towards the construction decision, to be ready for a new assessment by Council around 2010.**
- **Council will play an active role in promoting a coordinated European participation in a global neutrino programme.**

Plans for 2008-2011 to start implementing, at CERN, the European Strategy for Particle Physics Programme

- **First Theme - Highest priority programme: completion of LHC machine and experiments and optimal operation at design energy over the years 2008-2010**
  - CERN contribution to completing four experiments
  - Enhancement of the capabilities of data analysis
  - Consolidation and improvements to enhance LHC luminosity short-term (towards $10^{34}/cm^2s$), in particular:
    - building the second phase - collimators and the dilution kickers
    - improvements in LHC beam controls
    - New power supply for the PS
    - Multiturn extraction for PS

- **Second Theme - Second highest priority**: renovation of entire injector complex **to ensure reliability of LHC operation (2011)**:
  - replacement of PS by a **50 GeV machine**; to be designed, construction decided in 2010, and available in 2016.
  - replacement of Linac 2 and Booster with a new injector, **Linac 4** at 160 MeV to be built immediately**,** and a superconducting proton linac (SPL) at 3-5 GeV, to be designed, construction decided in 2010, and available in 2016..

Plans for 2008-2011 to start implementing, at CERN, the European Strategy for Particle Physics Programme

- **Third Theme - accelerator and detector R&D - LHC luminosity upgrade**
  - R&D on **high-field superconducting magnets**, a **pulsed field magnet** for a possible superconducting version of PS and on **superconducting quadrupoles** for a neutrino facility.
  - Development: tracking detectors and calorimeters (LHC and CLIC), microelectronics and opto-electronics. Improved triggering, DAQ and controls
  - Enhancement of CLIC qualifying programme with CTF3

- **Fourth Theme -** (To be partly funded by CERN with important external contributions.)
  - multipurpose SC cavity test facility
  - R&D on high-power targets for neutrino production
  - High Intensity and Energy Isolde project (HIE - Isolde)

Stage 1: Linac4

Direct benefits of the new linac

Stop of Linac2:

- End of recurrent problems with Linac2 (vacuum leaks, etc.)
- End of use of obsolete RF triodes (hard to get + expensive)

Higher performance:

- Space charge decreased by a factor of 2 in the PSB

  => potential to double the beam brightness and fill the PS with the LHC beam in a single pulse,

  => easier handling of high intensity. Potential to double the intensity per pulse.
- Low loss injection process (Charge exchange instead of betatron stacking)
- High flexibility for painting in the transverse and longitudinal planes (high speed chopper at 3 MeV in Linac4)

First step towards the SPL:

- Linac4 will provide beam for commissioning LPSPL + PS2 without disturbing physics.

Benefits for users of the PSB

Good match between space charge limits at injection in the PSB and PS

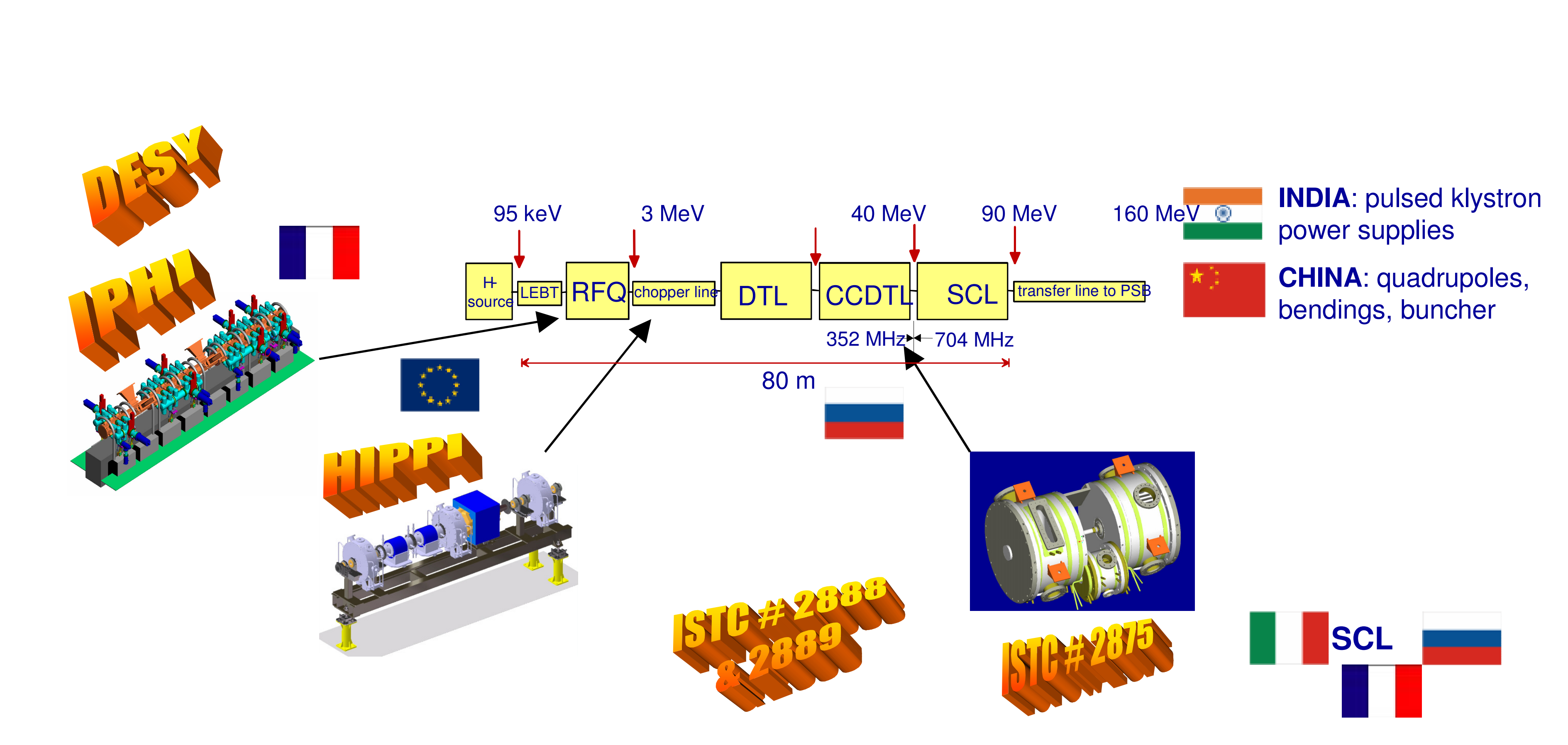
=> for LHC, no more long flat bottom at PS injection + shorter flat bottom at SPS injection: easier/ more reliable operation / potential for ultimate beam from the PS

More intensity per pulse available for PSB beam users (ISOLDE) – up to 2´

More PSB cycles available for other uses than LHC

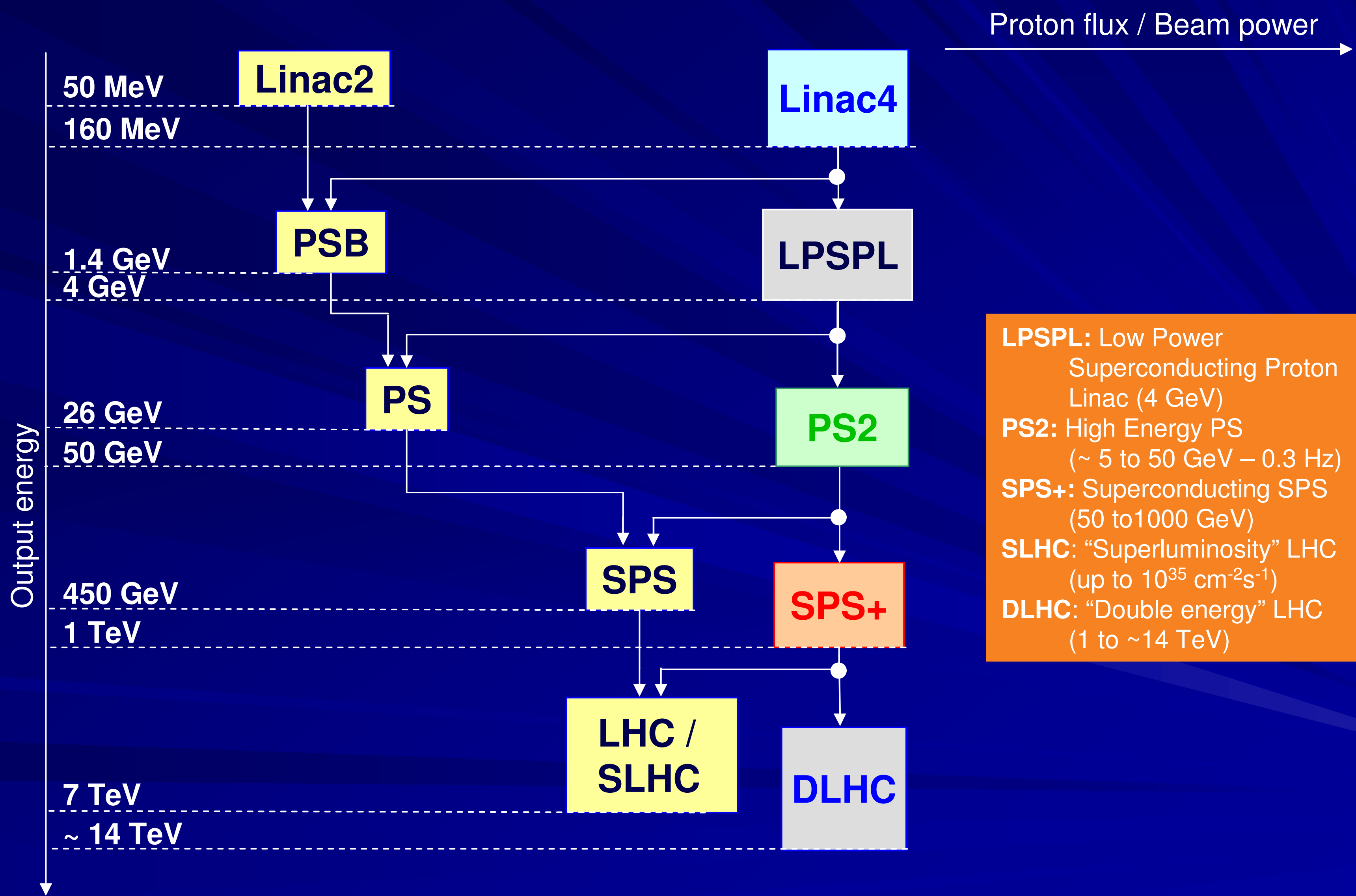
Linac4: Collaborations for construction

(tentative)



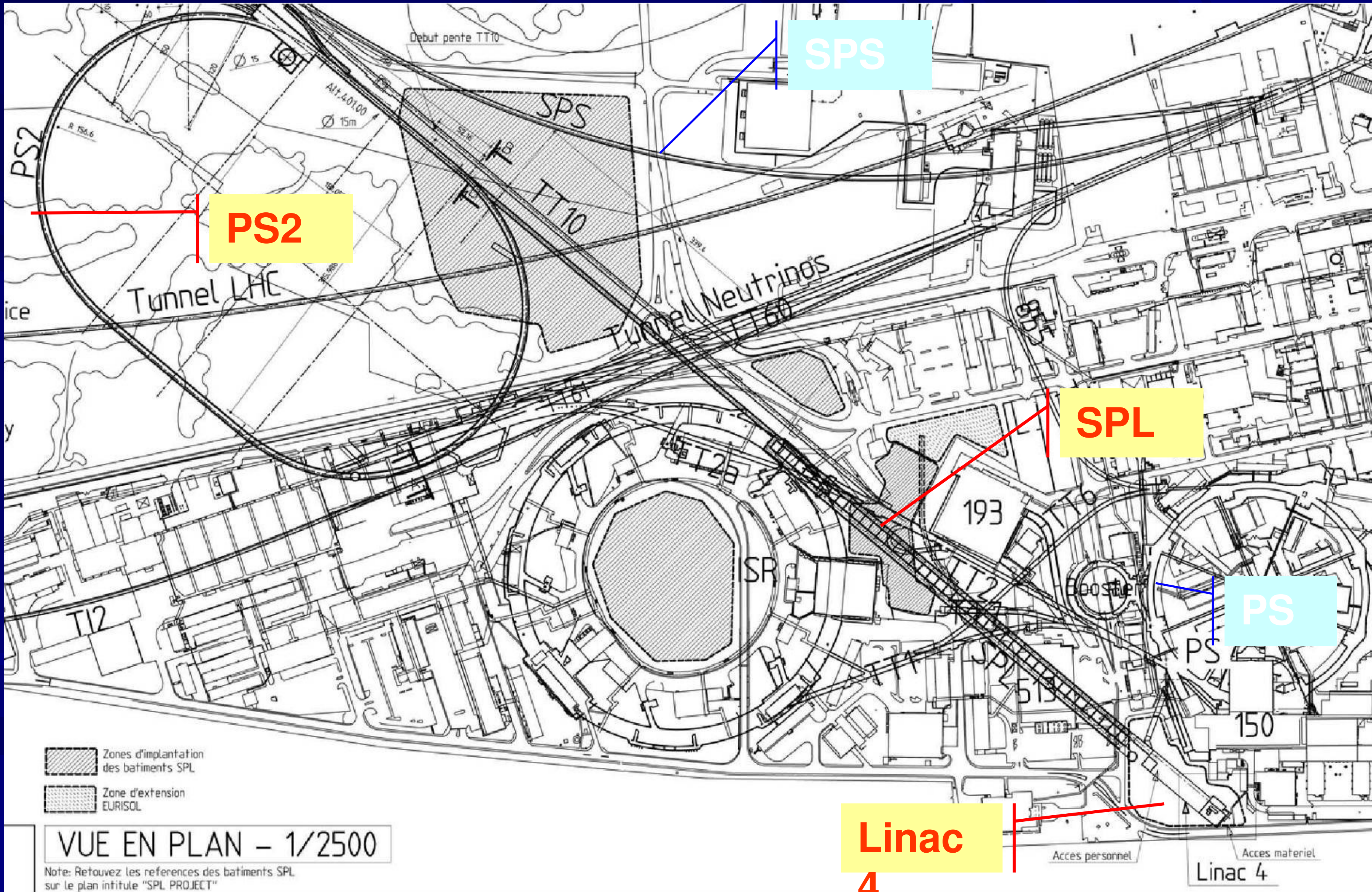
Network of collaborations for the R&D phase, via EU-FP6, CERN-CEA/IN2P3, ISTC, CERN-India and CERN-China agreements.

Upgrade components



LPSPL: Low Power Superconducting Proton Linac (4 GeV)
PS2: High Energy PS (~ 5 to 50 GeV – 0.3 Hz)
SPS+: Superconducting SPS (50 to1000 GeV)
SLHC: "Superluminosity" LHC (up to 10^{35} $cm^{-2}s^{-1}$)
DLHC: "Double energy" LHC (1 to ~14 TeV)

Layout of the new injectors



The LHC programme upgrade (SLHC)

1. The use/need for the SLHC will obviously depend on how EW symmetry breaking and/or the new physics will manifest itself at the LHC

2. A next step at the energy frontier could be a very high luminosity hadron collider at LHC energy (SLHC)
    - Higher statistics
    - Higher mass reach

    This requires major modifications of the injector complex and the LHC hardware and new R&D on detectors (higher irradiation on trackers).

3. Efficient running of the LHC complex requires consolidation of the injectors, in particular of the Proton Synchrotron (1959)

Prospects for scientific activities over the period 2011-2016

To be decided in 2010-2011 in light of first physics results from LHC, and designed and R&D results from the previous years. This programme could most probably comprise:

- An **LHC luminosity increase requiring a new injector (SPL and PS)**.

  The total cost of the investment over 6 years (2011-2016: 1000-1200 MCHF + a staff of 200-300 per year. Total budget: ~ 200-250 MCHF per year.

- P**reparation of a Technical Design for the CLIC programme, for a possible construction decision in 2016 after the LHC upgrade (depending on the ILC future).**

  Total CERN M + P contribution = ~ 250 MCHF + 1000 - 1200 FTE over 6 years.

- **Enhanced infrastructure consolidation** : **30 MCHF + 40 FTEs from 2011**.

NB: Over the period 2011-2016, effective participation of CERN in another large programme (ILC or a neutrino factory) will not be possible within the expected resources if positive decisions taken on LHC upgrade and CLIC Technical Design.

This situation could totally change *if none of the above programmes is approved* or if a new, more ambitious level of activities and support is envisaged in the European framework.