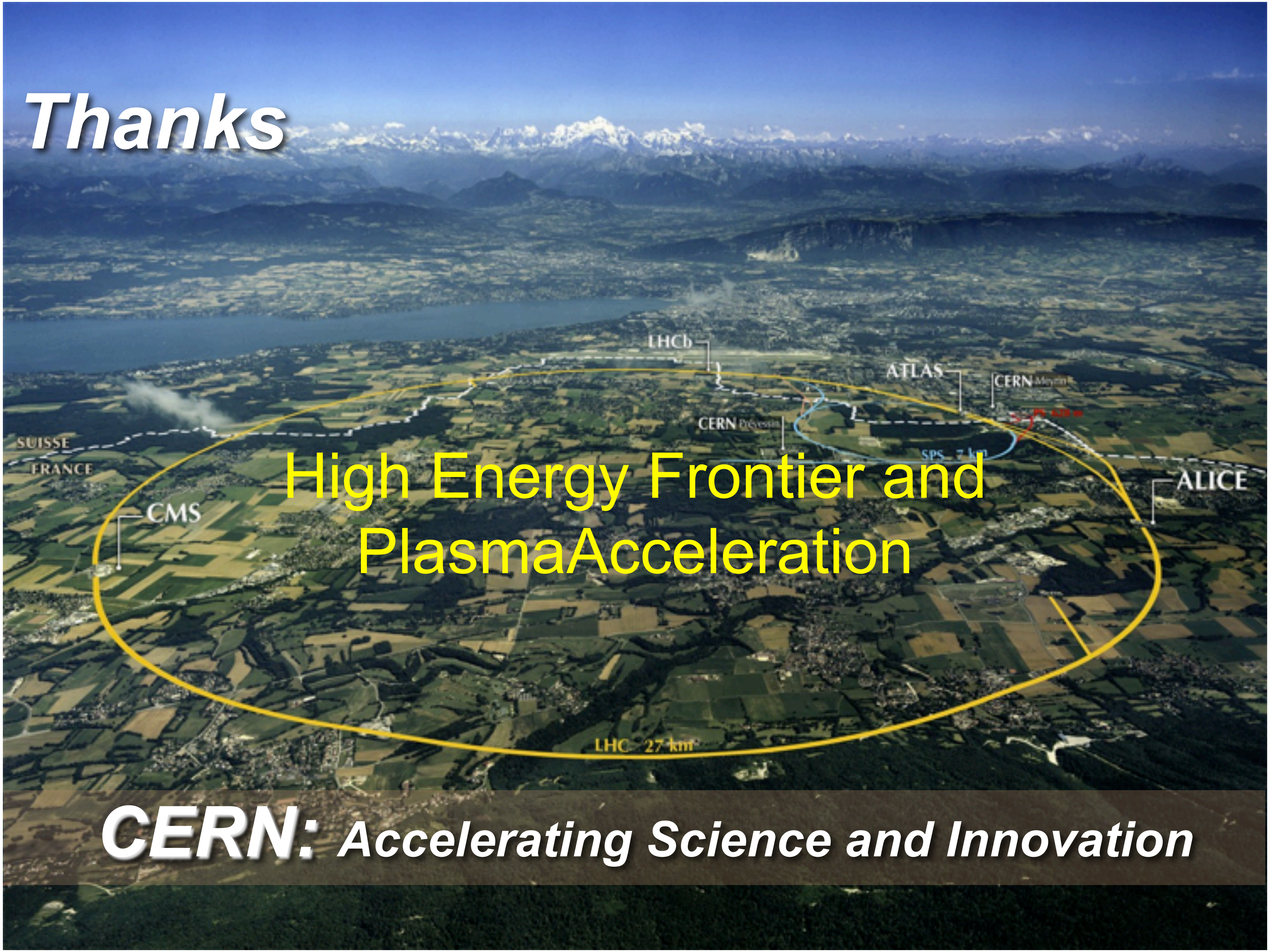
Thanks



High Energy Frontier and PlasmaAcceleration

CERN: ***Accelerating Science and Innovation***

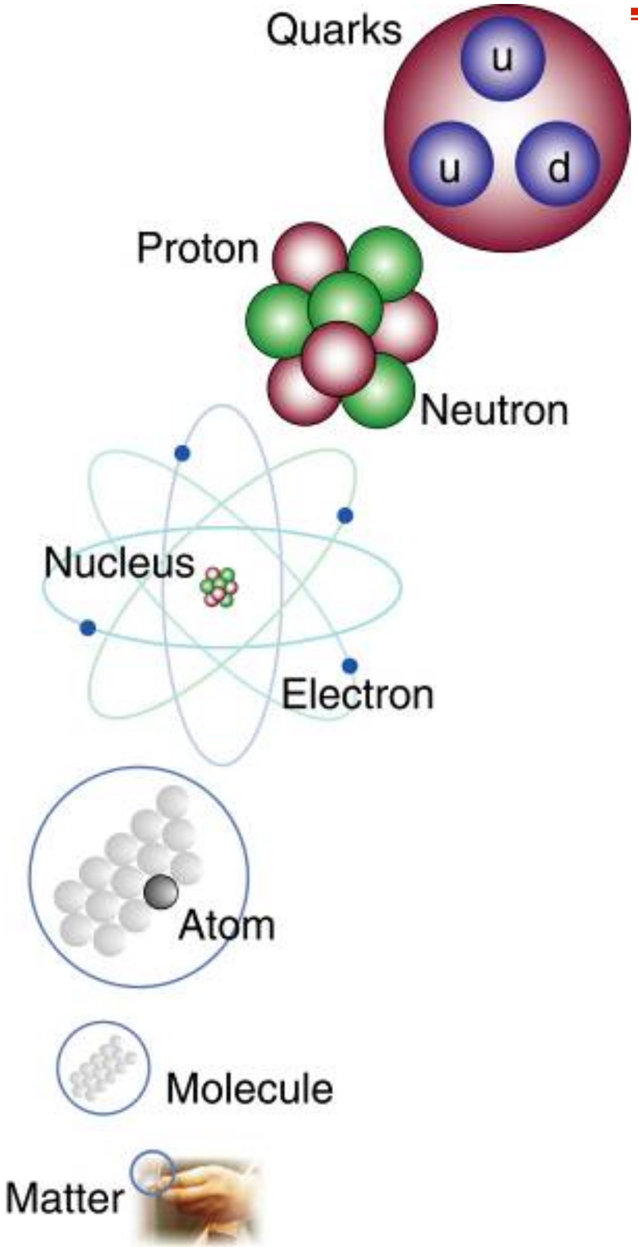
Outline

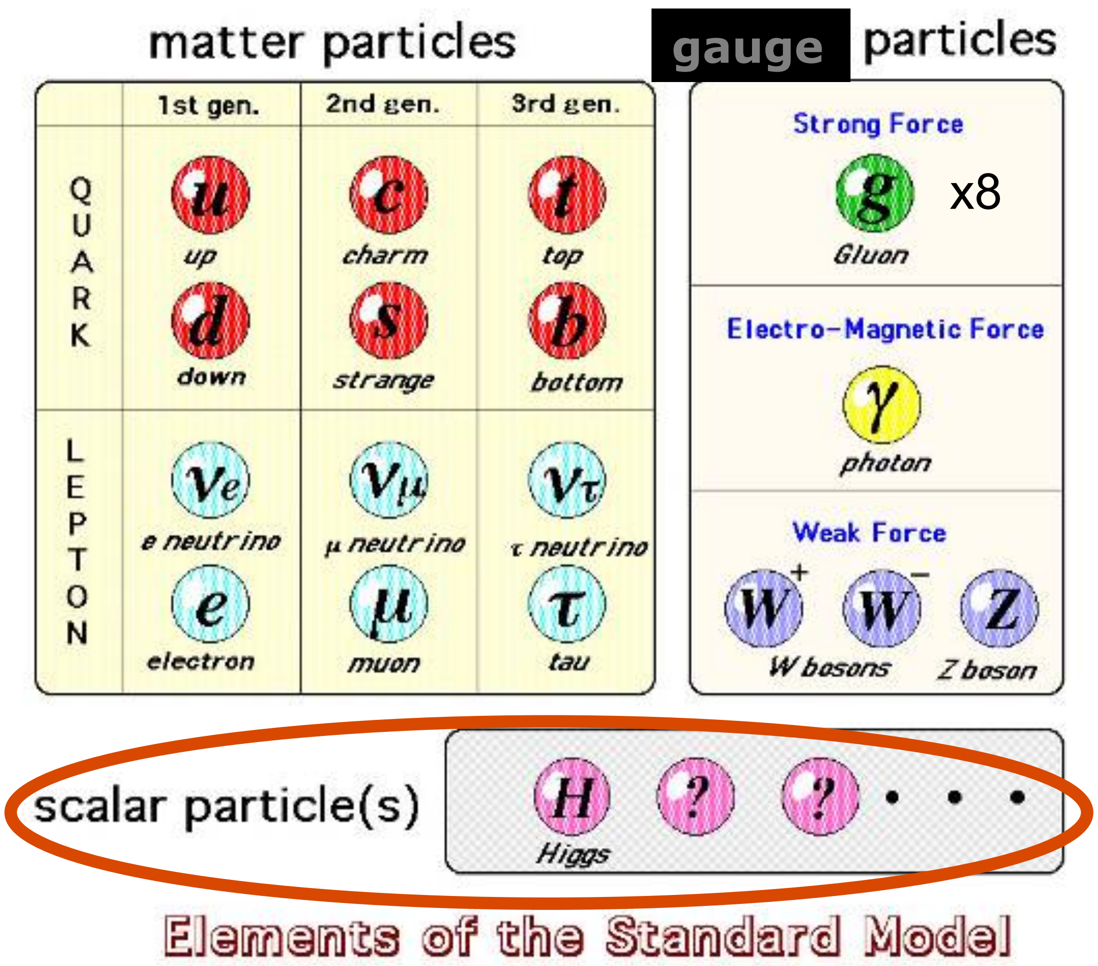
* LHC, the new high energy frontier

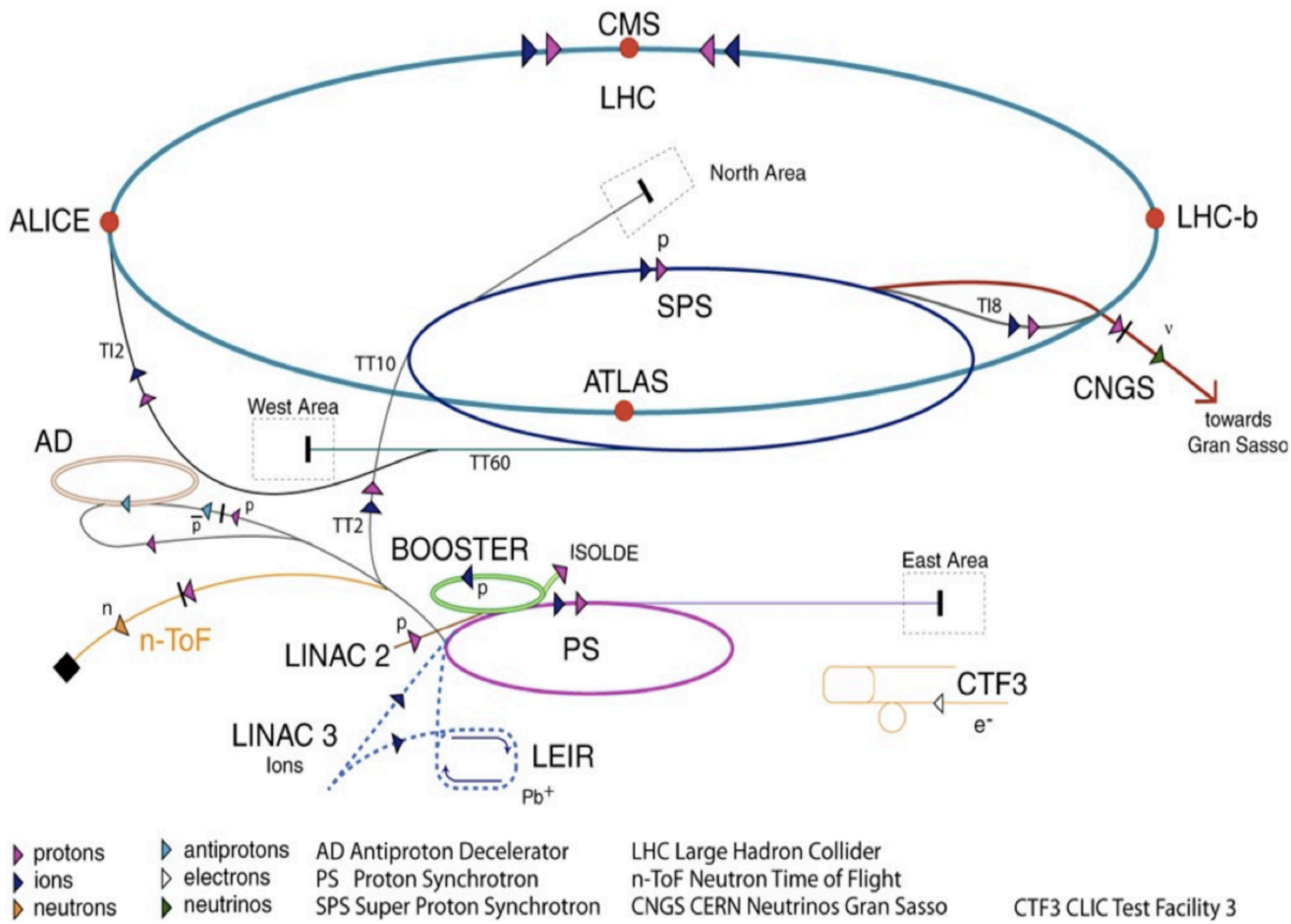
* The energy scale of new physics

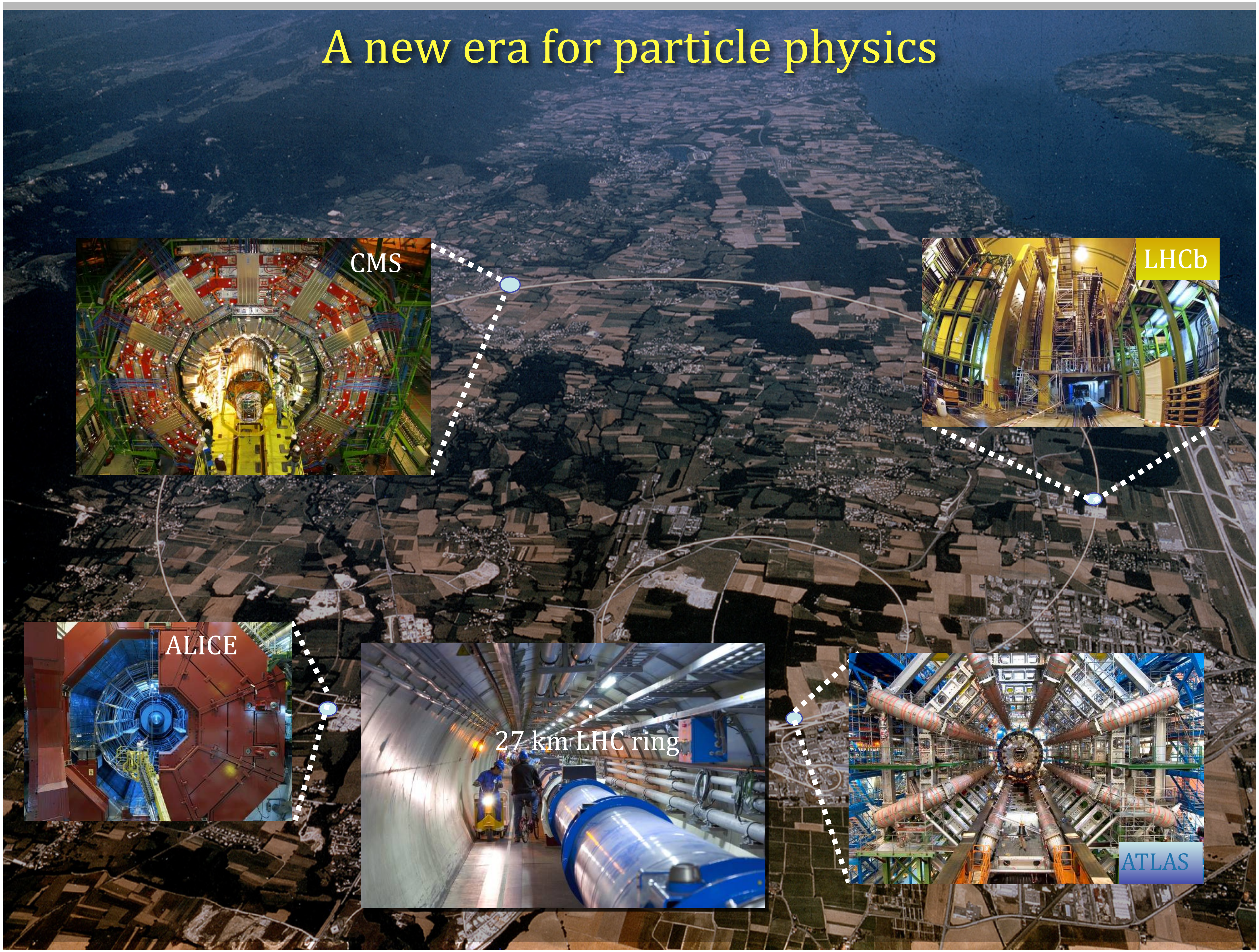
* How to reach it?

The study of elementary particles and fields and their interactions

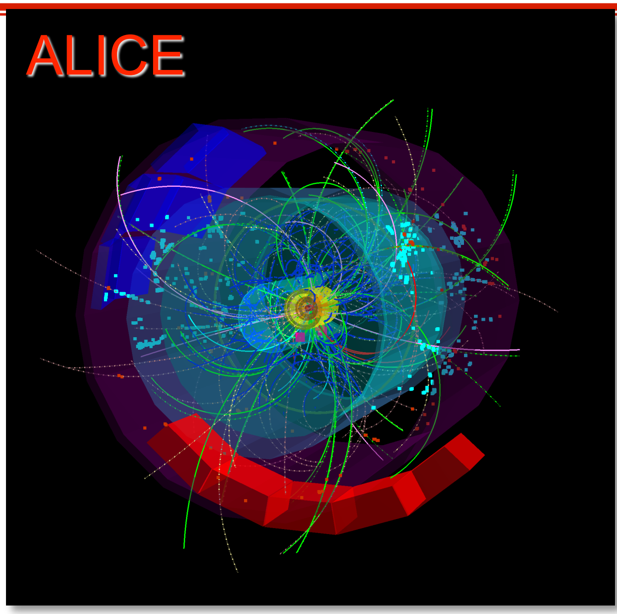




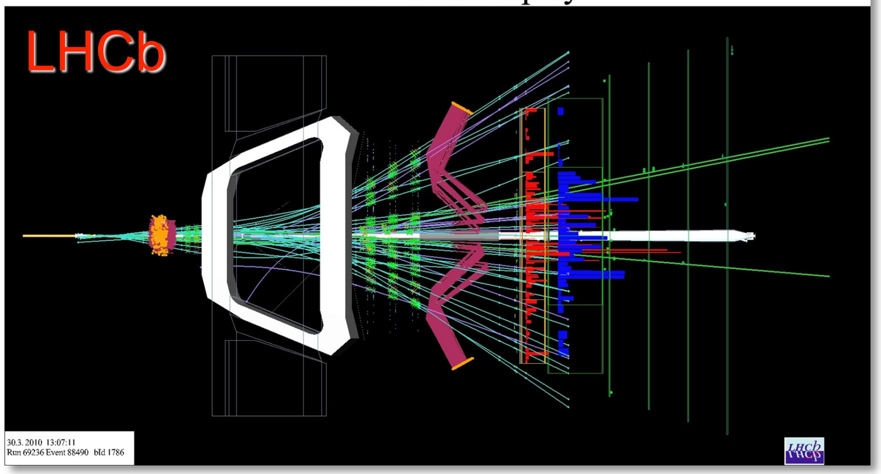

CMS
LHC
North Area
ALICE
LHC-b
p
SPS
TI8
ν
TI2
TT10
ATLAS
CNGS
West Area
towards Gran Sasso
AD
TT60
p̄
p
TT2
BOOSTER
ISOLDE
East Area
p
n
n-ToF
p
LINAC 2
PS
CTF3
e⁻
LINAC 3
Ions
LEIR
Pb+
protons
ions
neutrons
antiprotons
electrons
neutrinos
AD Antiproton Decelerator
PS Proton Synchrotron
SPS Super Proton Synchrotron
LHC Large Hadron Collider
n-ToF Neutron Time of Flight
CNGS CERN Neutrinos Gran Sasso
CTF3 CLIC Test Facility 3

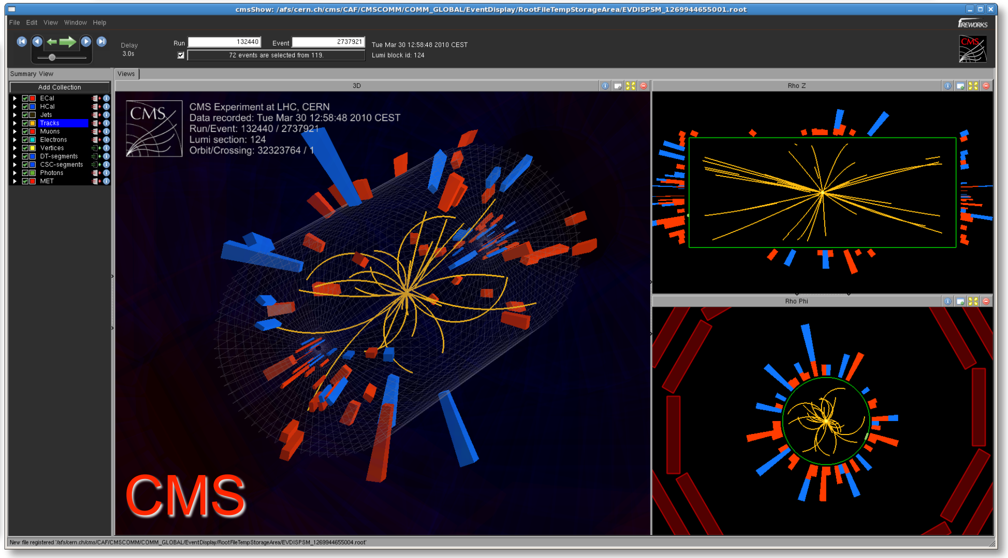

A new era for particle physics
CMS
LHCb
ALICE
27 km LHC ring
ATLAS

LHC: First collisions at 7 TeV on 30 march 2010

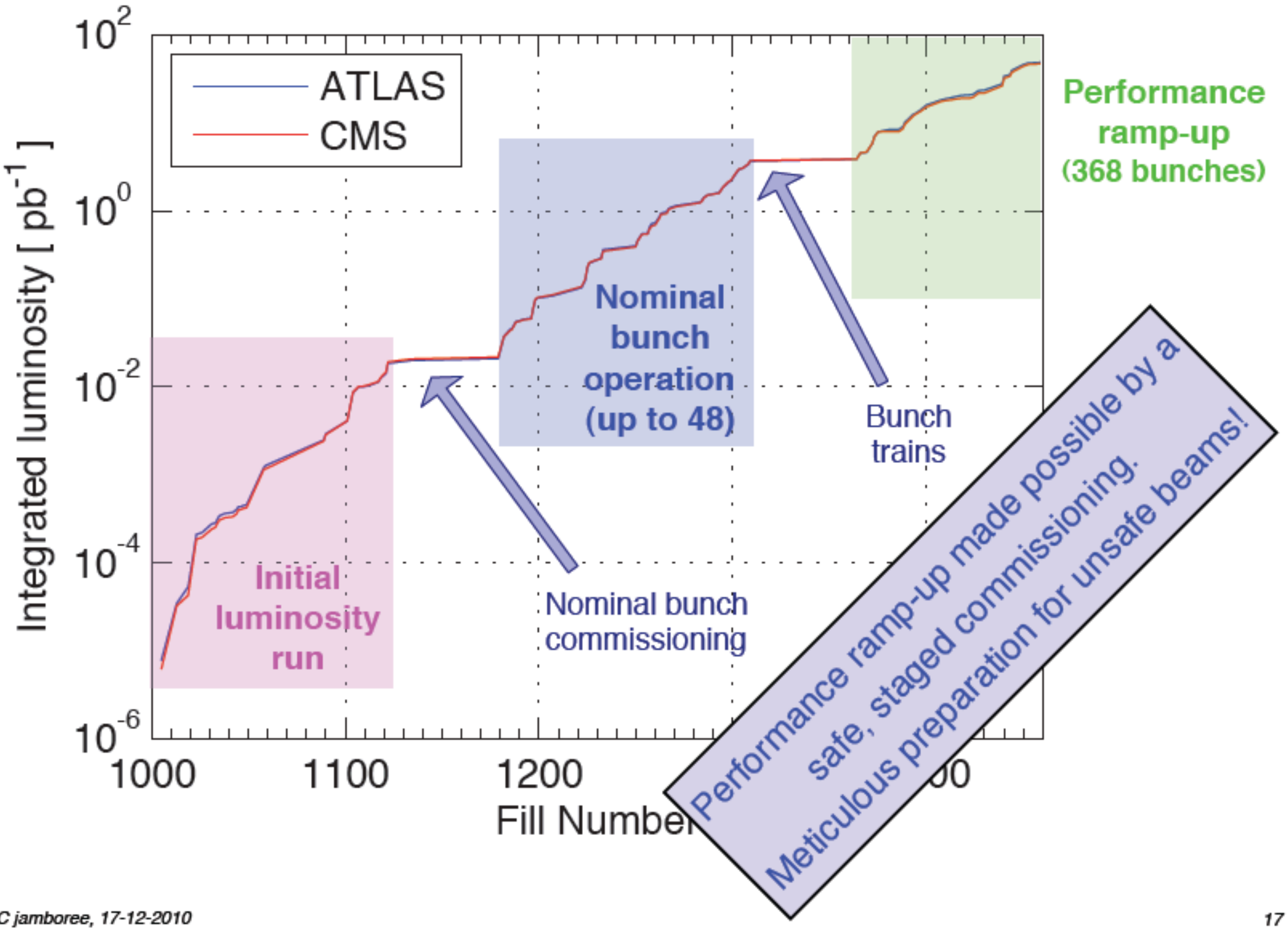


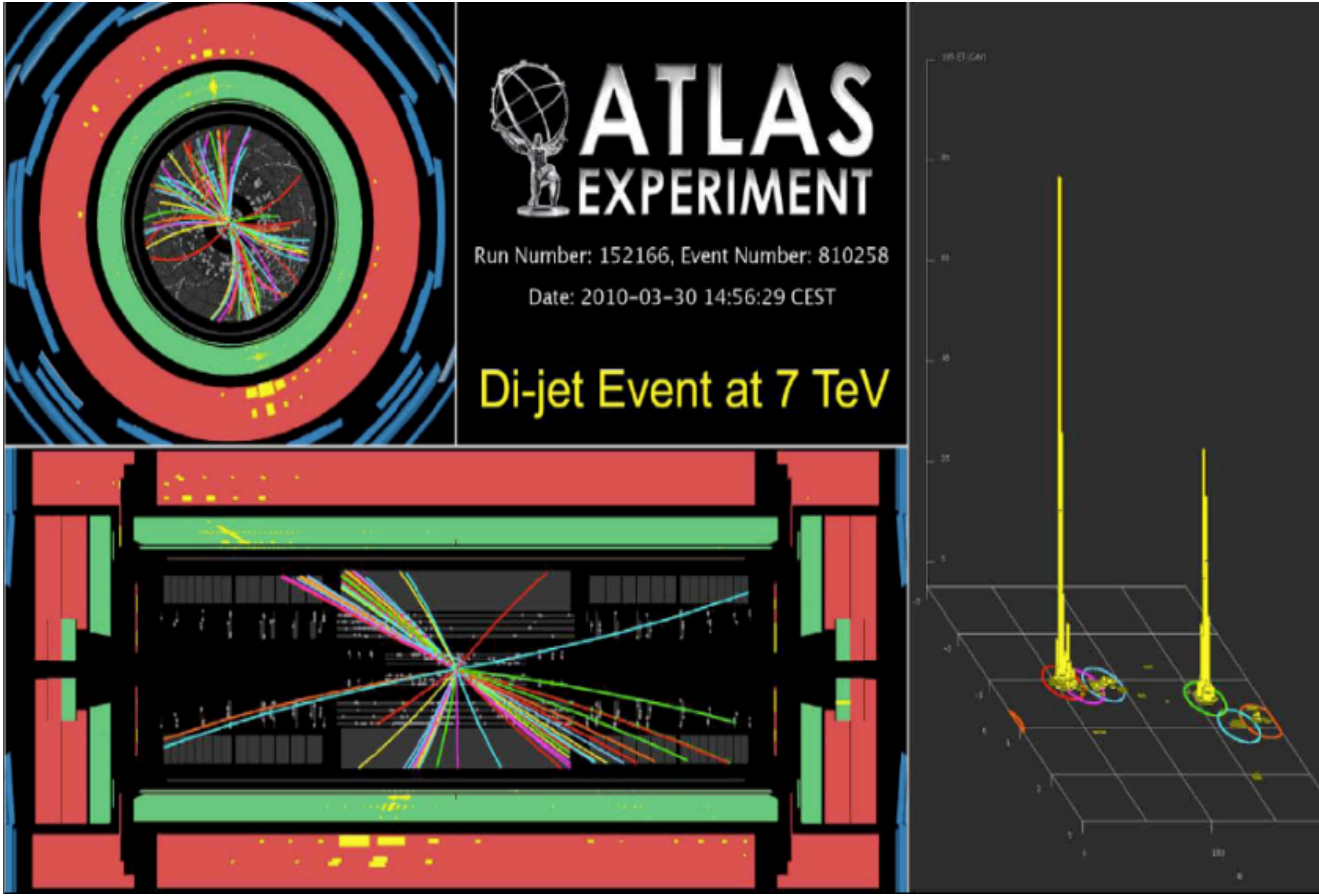
LHCb Event Display



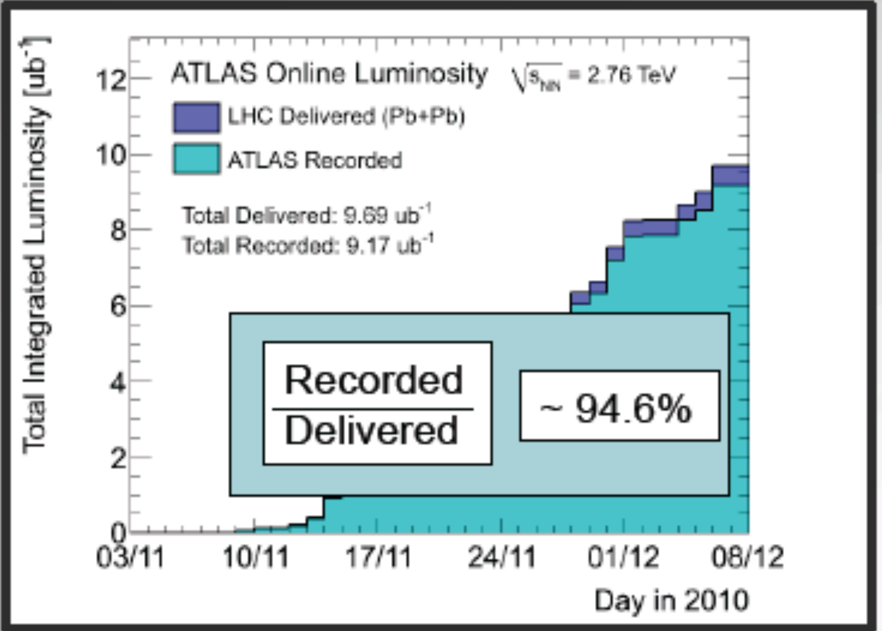


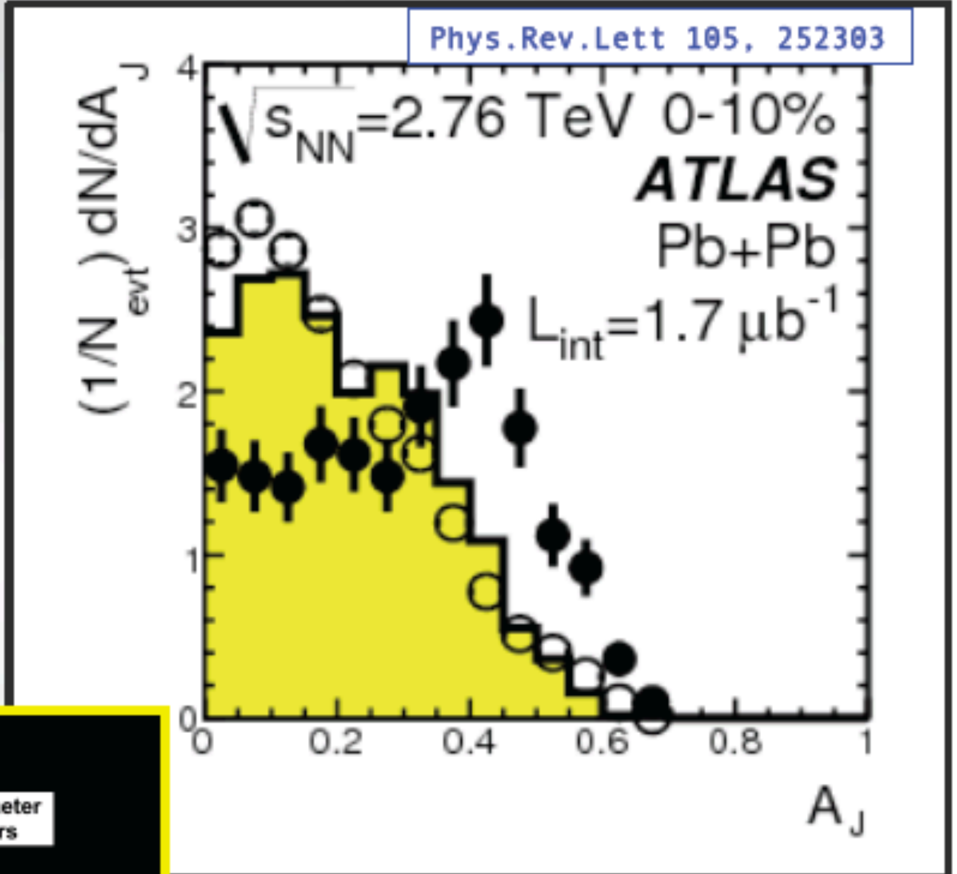
Luminosity: 3 running periods

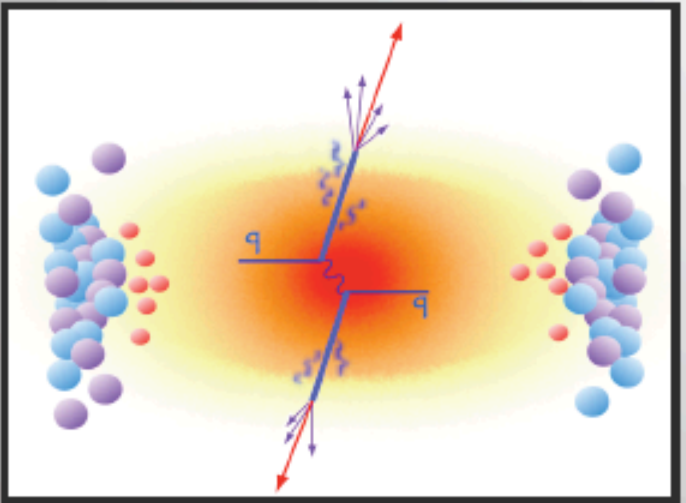


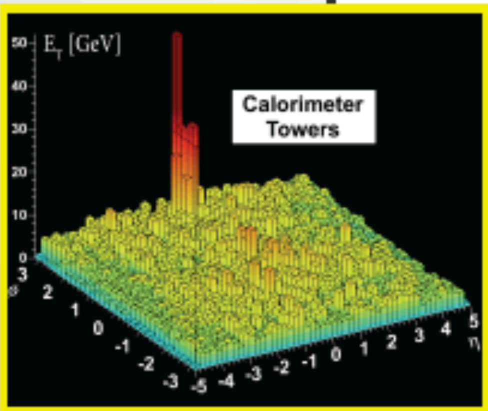

ATLAS
EXPERIMENT
Run Number: 152166, Event Number: 810258
Date: 2010-03-30 14:56:29 CEST
Di-jet Event at 7 TeV

Heavy Ion (lead) collisions









First observation of di-jet asymmetry! : awarded the PRL “viewpoint” label!

The ATLAS detector has performed exceptionally well!

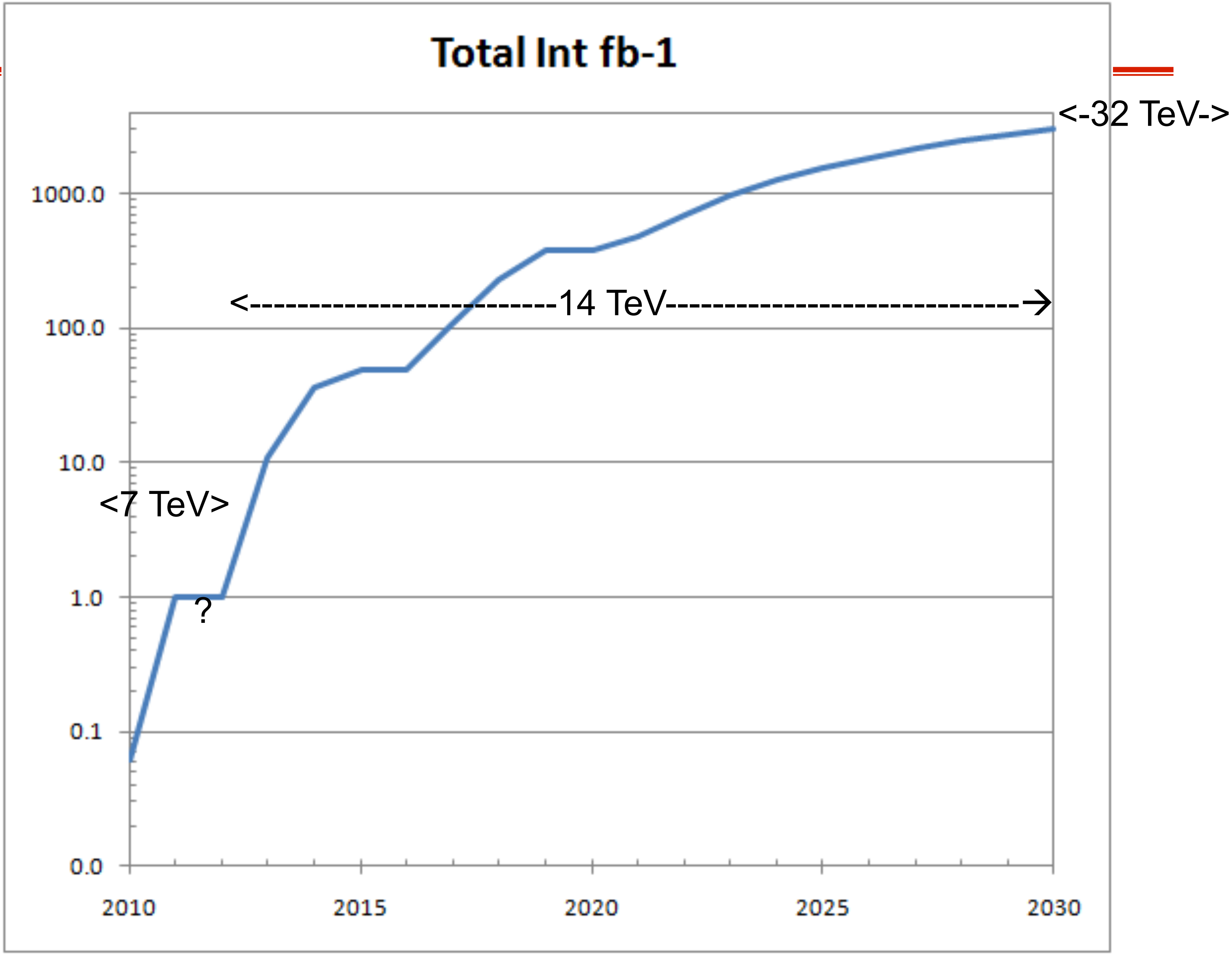
A total of 15 physics papers and 100 conference notes!

A fantastic year for ATLAS!

A huge thanks to the LHC team for delivering such beautiful data to the experiments!

A huge thanks to the collaborating institutes and funding agencies for support for over 20 years!

Preliminary Long Term Predictions



New studies under way (HL-LHC)

- *High Gradient/Large Aperture Quads, with B_{peak} 13-15 T. **(Nb_3Sn)**

–**Higher field quadrupoles translate in** higher gradient/shorter length **or larger aperture/same length or a mix.**

– US-LARP engaged to produce proof by 2013.

–**β^* as small as 22 cm are possible with a** factor ~2.5 **in luminosity by itself,** if coupled with a mechanism to compensate the geometrical reduction

- *Crab Cavities**: this is the best candidate for exploiting small β^***

–**However it should be underlined that today Crab Cavities are not validated for LHC , not even conceptually:** the issue of machine protection will be addressed with priority

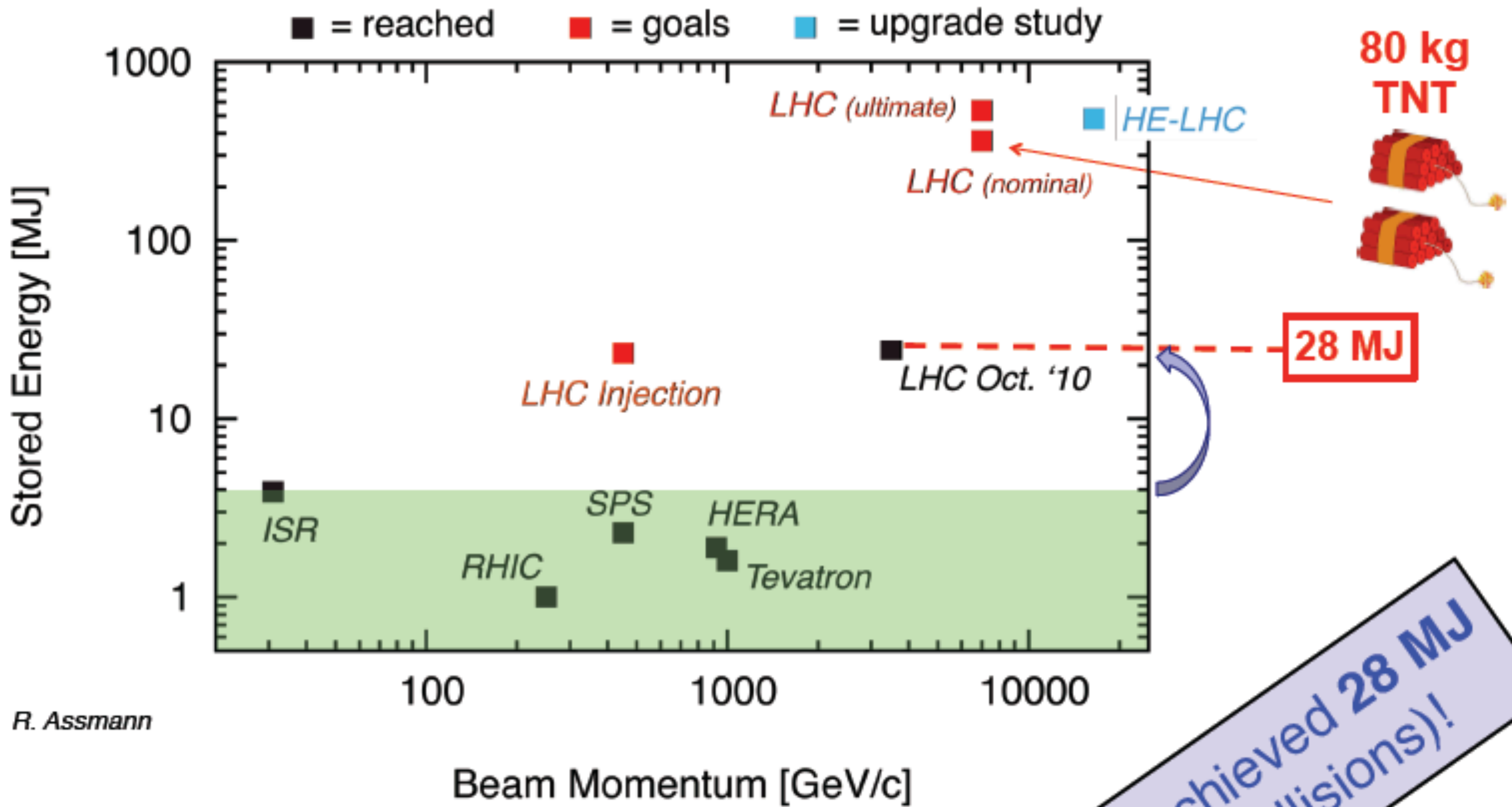
New studies under way (HL-LHC)

* SC links to replace at the surface elecronic equipment today in the tunnel and exposed to high radiation
* New Cryoplants in IP1 & IP5: for power AND to make independent Arc- IR:
* Upgrades in the injector chain (LINAC4, PS Booster, PS, SPS)

32 TeV HE-LHC!!! – main issues and R&D

- high-field 20-T dipole magnets based on Nb_3Sn, Nb_3Al, and HTS
- high-gradient quadrupole magnets for arc and IR
- fast cycling SC magnets for 1-TeV injector
- emittance control in regime of strong SR damping and IBS
- cryogenic handling of SR heat load (first analysis; looks manageable)
- dynamic vacuum

What does this means in practice?



In the first year of operation we needed to achieve:

Factor ~10 above state-of-the-art.

Factor ~15 above the Tevatron.

We made it! Achieved **28 MJ**
(24 MJ with collisions)!

Fit of Mh

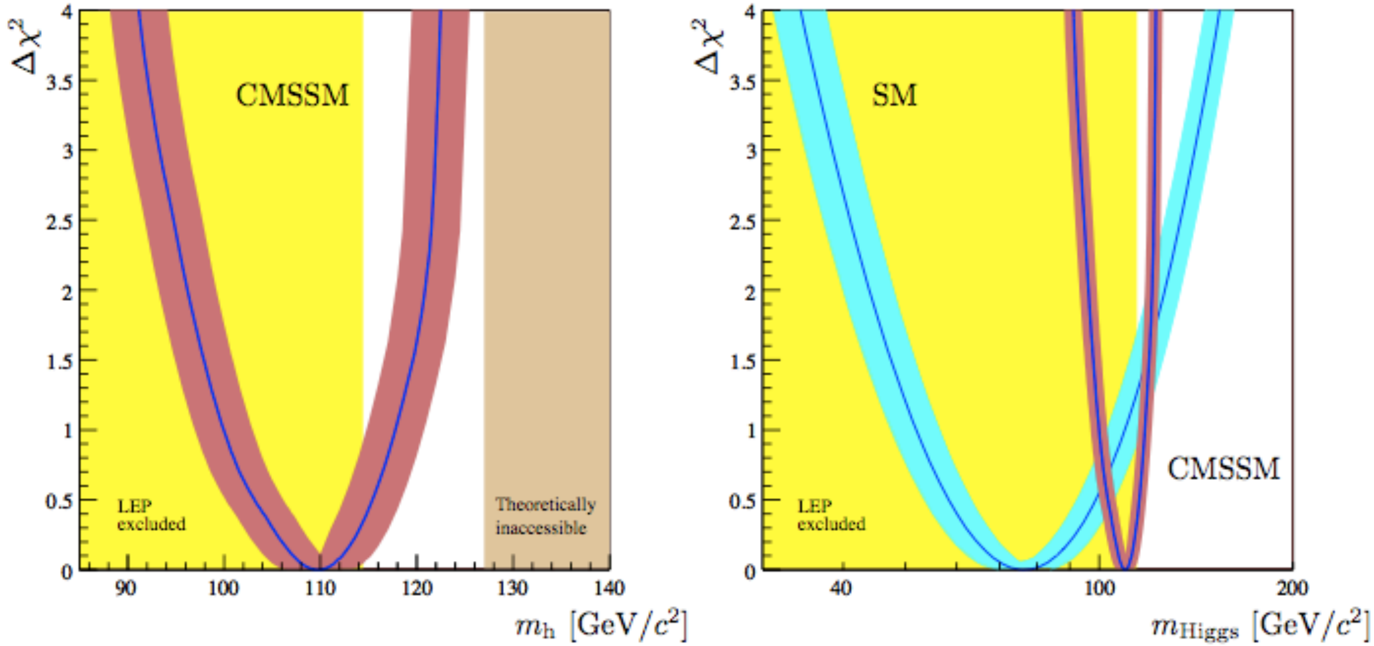
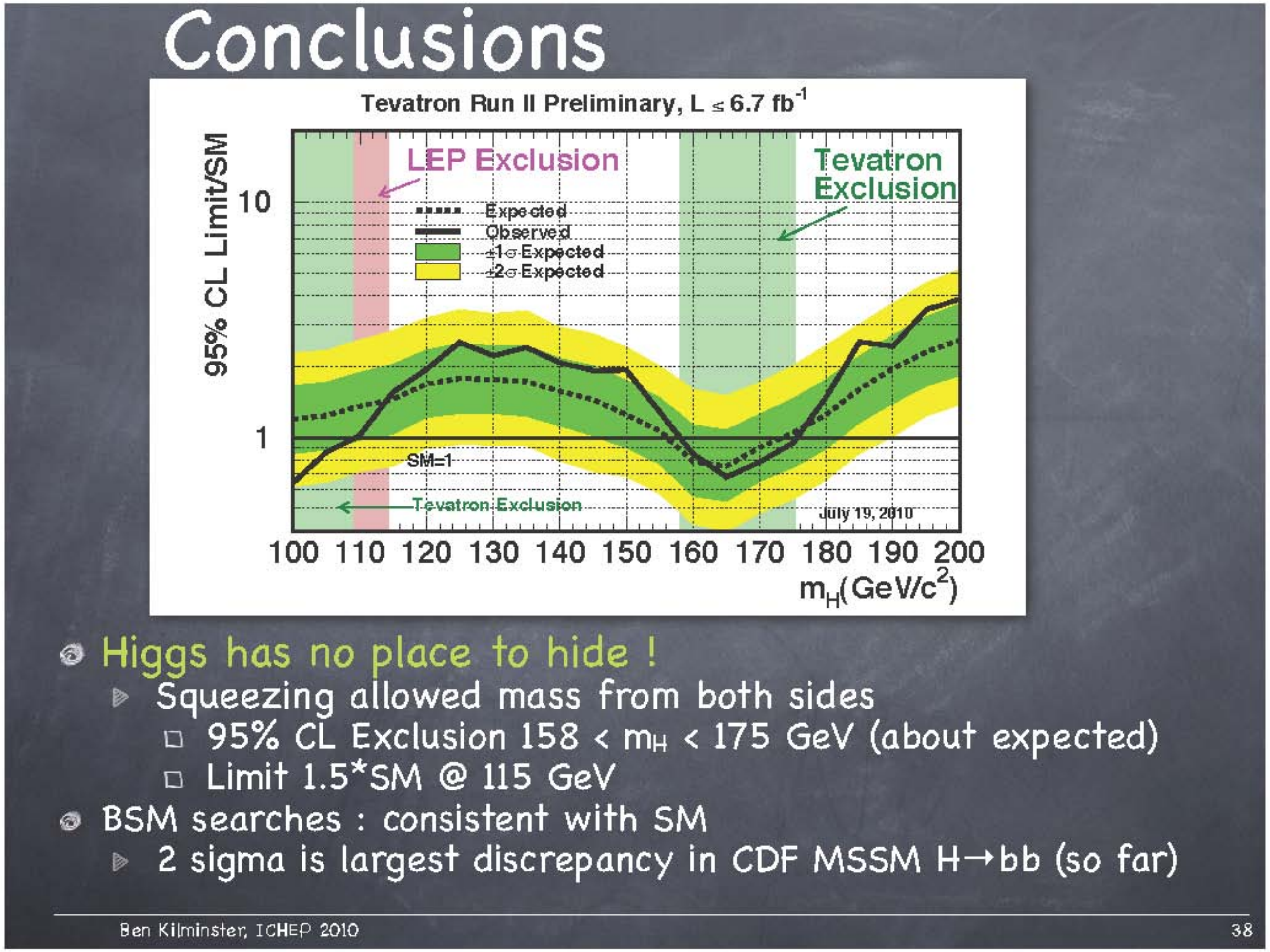


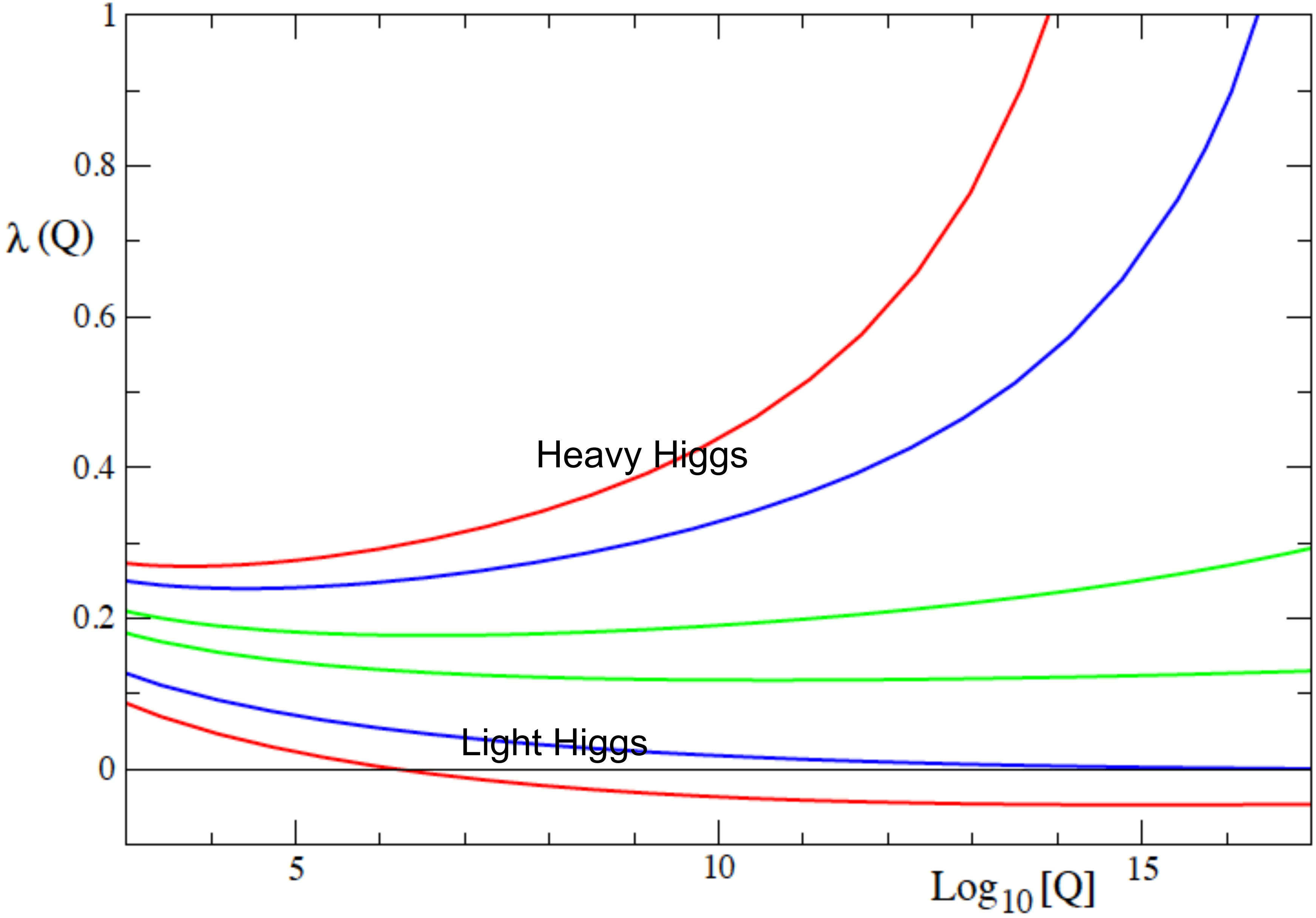
Figure 3. Left: Scan of the lightest Higgs boson mass versus $\Delta\chi^2 = \chi^2 - \chi^2_{min}$. The curve is the result of a CMSSM fit using all of the available constraints listed in Table 1, except the limit on m_h. The red (dark gray) band represents the total theoretical uncertainty from unknown higher-order corrections, and the dark shaded area on the right above 127 GeV/c^2 is theoretically inaccessible (see text). Right: Scan of the Higgs boson mass versus $\Delta\chi^2$ for the SM (blue/light gray), as determined by [45] using all available electroweak constraints, and for comparison, with the CMSSM scan superimposed (red/dark gray). The blue band represents the total theoretical uncertainty on the SM fit from unknown higher-order corrections.

Approaching the moment of truth

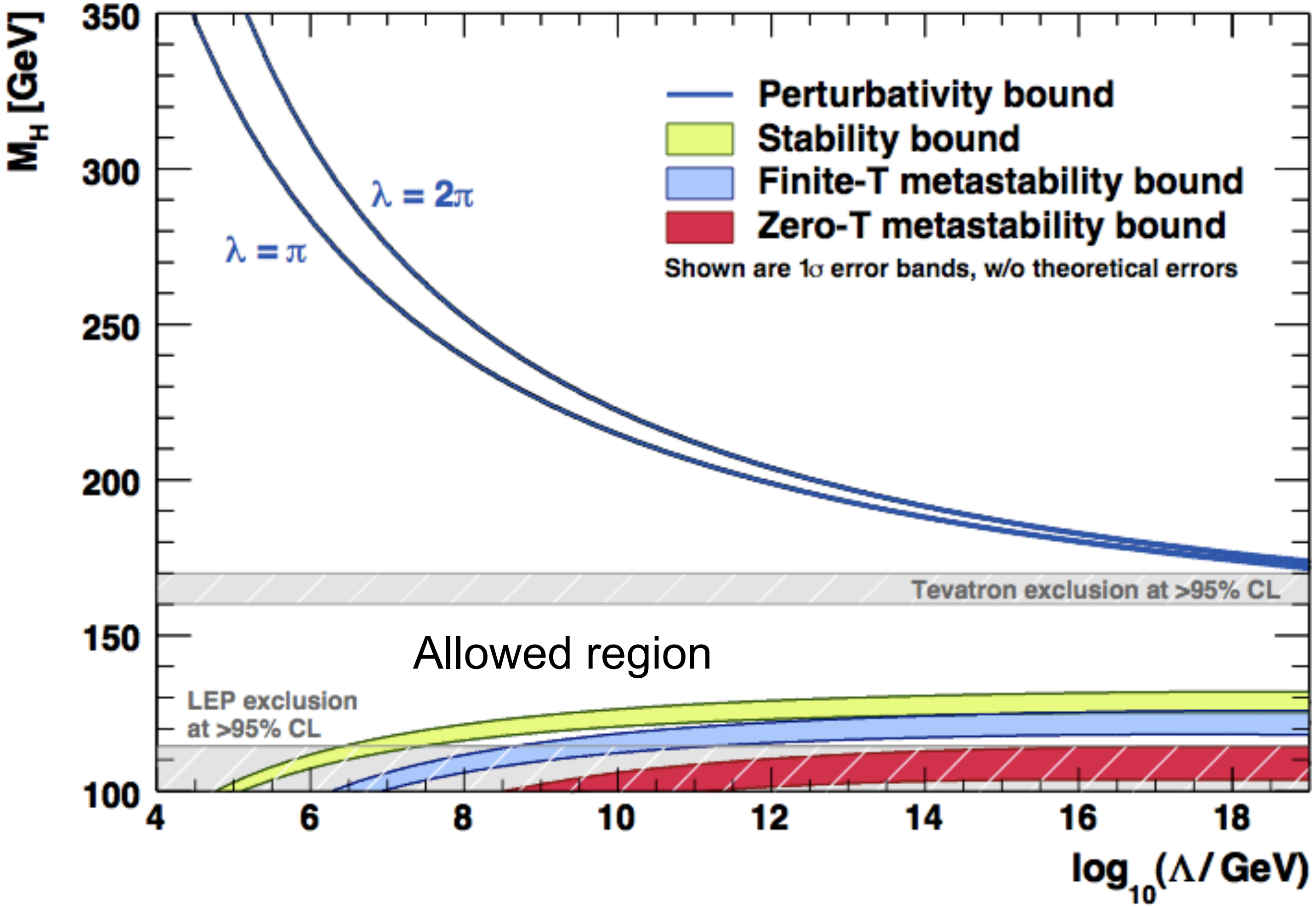


$\Delta\sigma$ th?

$$V = -\mu^2\Phi^2 + \lambda\Phi^4$$



Mh versus Cut-off



At 99% new physics needed below 10 TeV

From $\delta m2_w(\Lambda)/m^2_w$

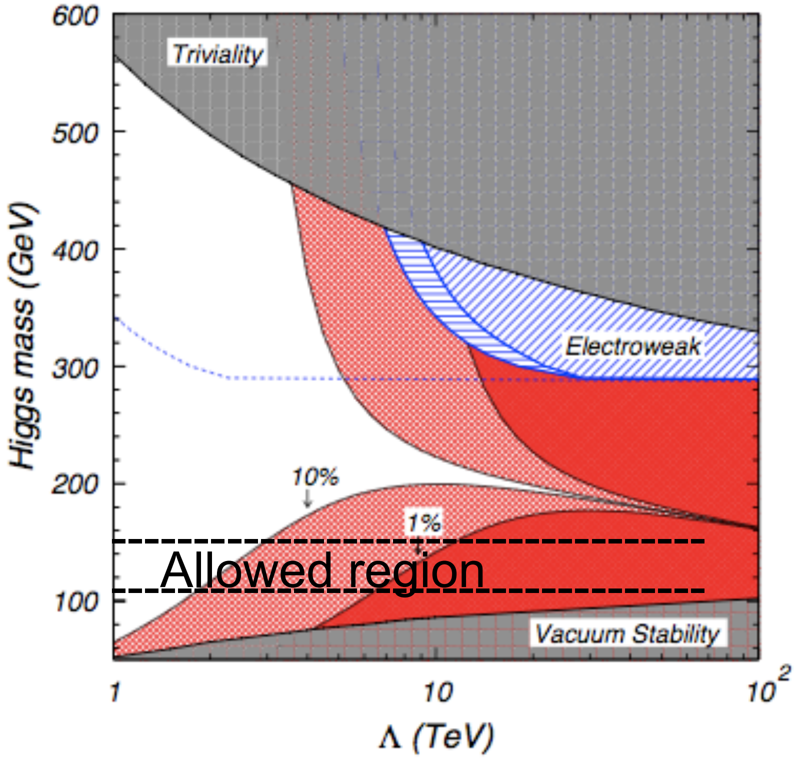
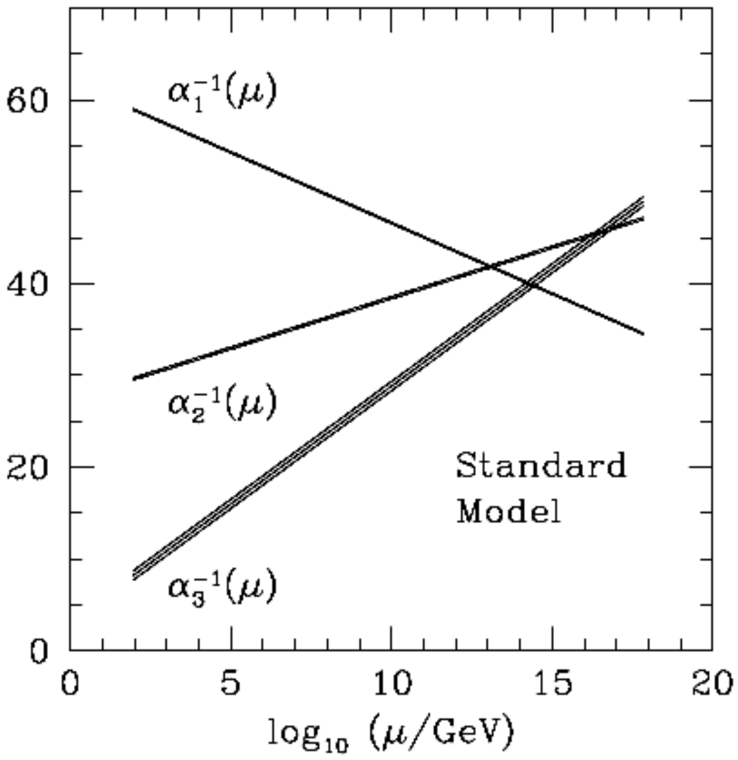
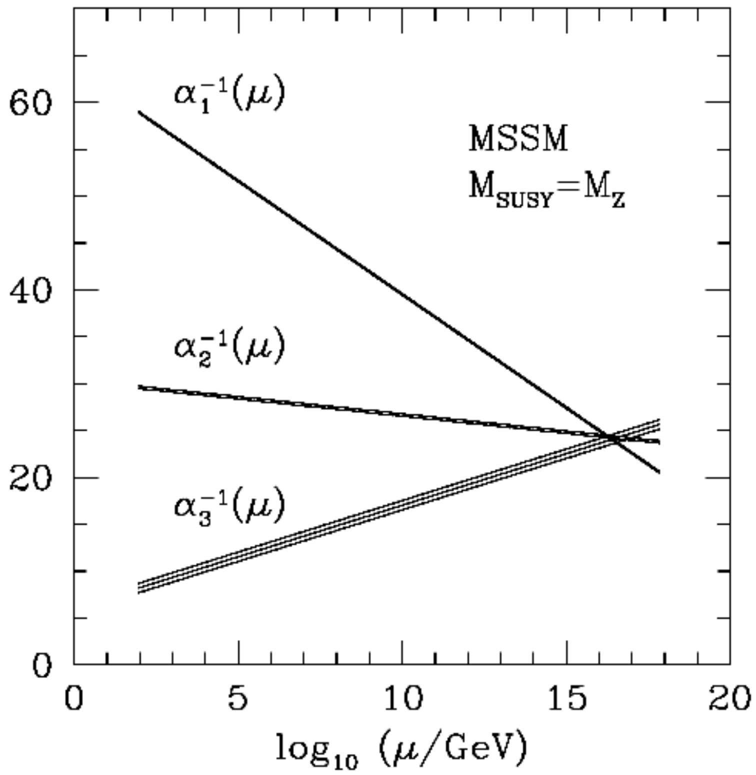


Figure 2: Plot in the $m_h - \Lambda$ plane showing the canonical constraints from Figure 1 as well as the tuning contours. The darkly hatched region marked "1%" represents tunings of greater than 1 part in 100; the "10%" region means greater than 1 part in 10. The empty region is consistent with all constraints and has less than 1 part in 10 finetuning.

Evolution of Gauge Couplings



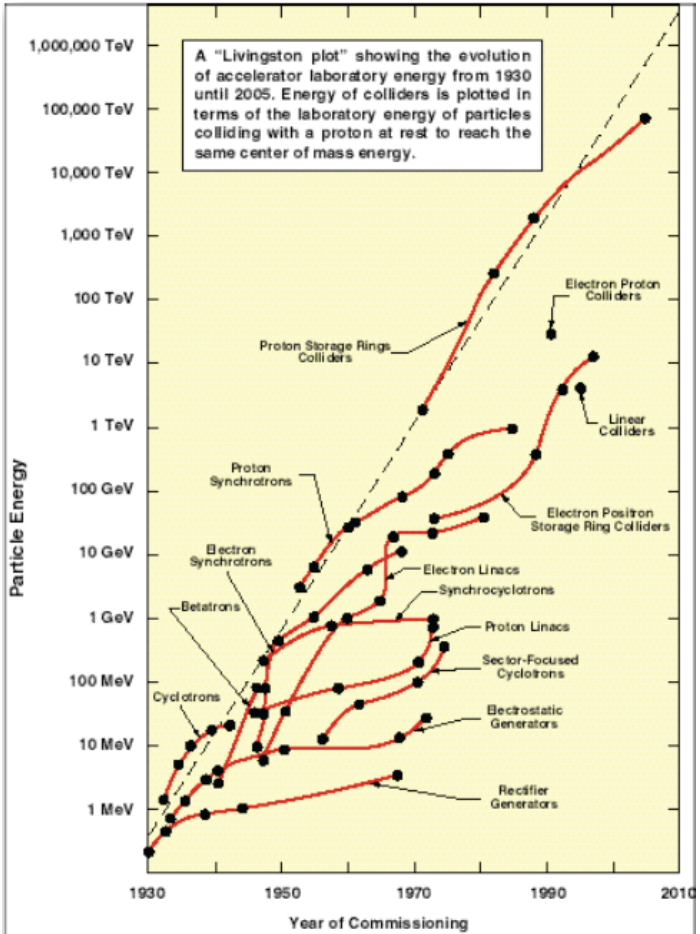
Standard Model



Supersymmetry

Why New Acceleration Techniques?

* Accelerator have been primary tool to advance HEP frontiers
  - But accelerators have continued to increase in size and cost and appear to be approaching the limit that can be supported



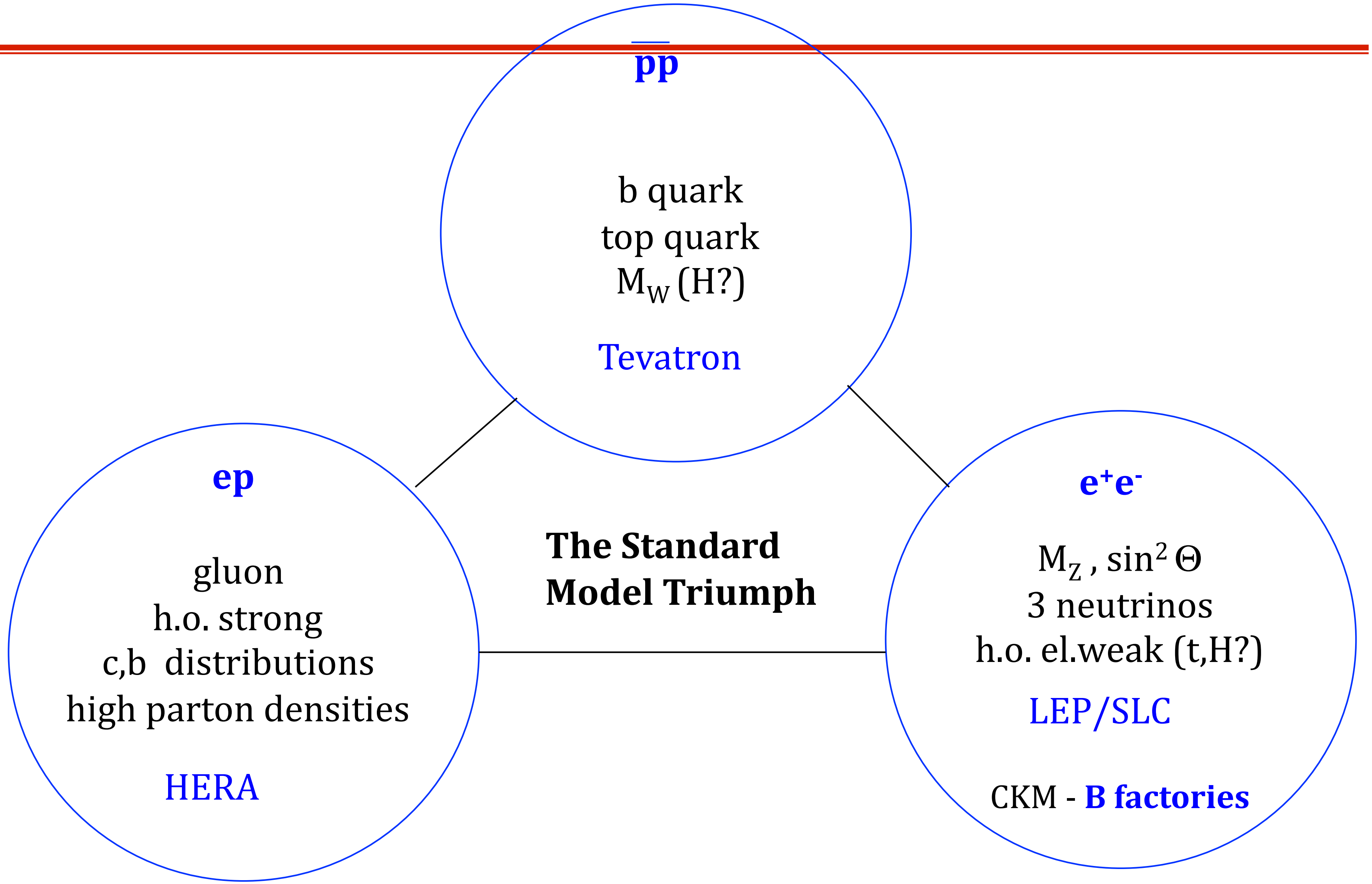
The Evolution of Particle Accelerators & Colliders
by W. K. H. Panofsky

2-017

- Need new technologies that are aimed at cost effective solutions

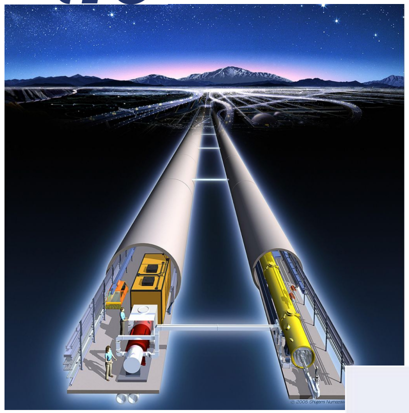
- Accelerator research very broad from materials to rf to nonlinear dynamics
  - Advances come from both fundamental research and directed R&D aimed at applications

The Fermi Scale [1985-2012]

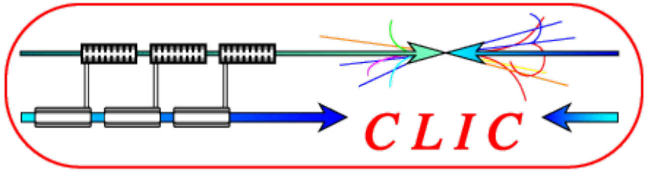


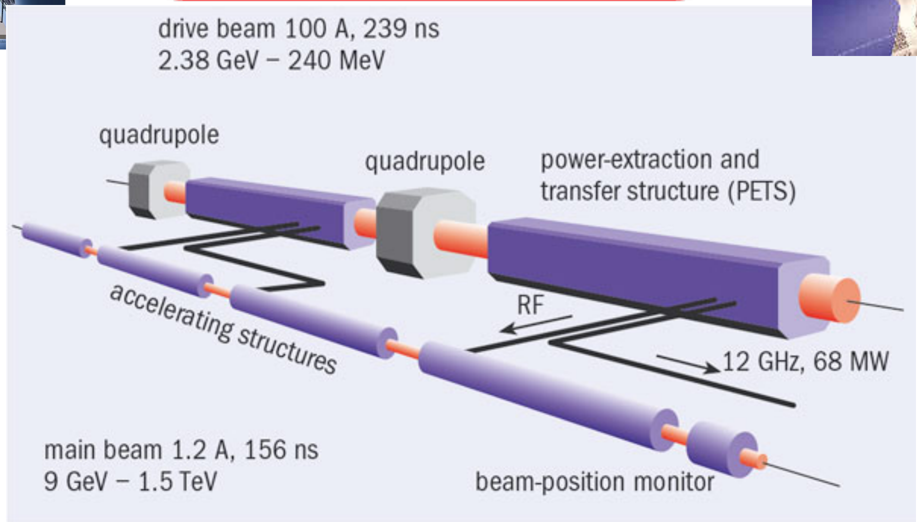
Vision for next machine (2030 ?): 3 avenues

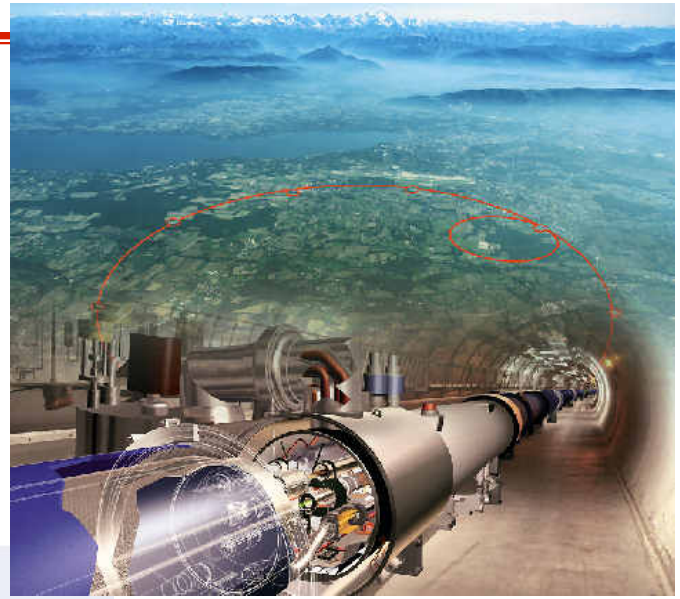
e+e- 500 GeV
Mature



e+e- 3 TeV
Feasibility Study



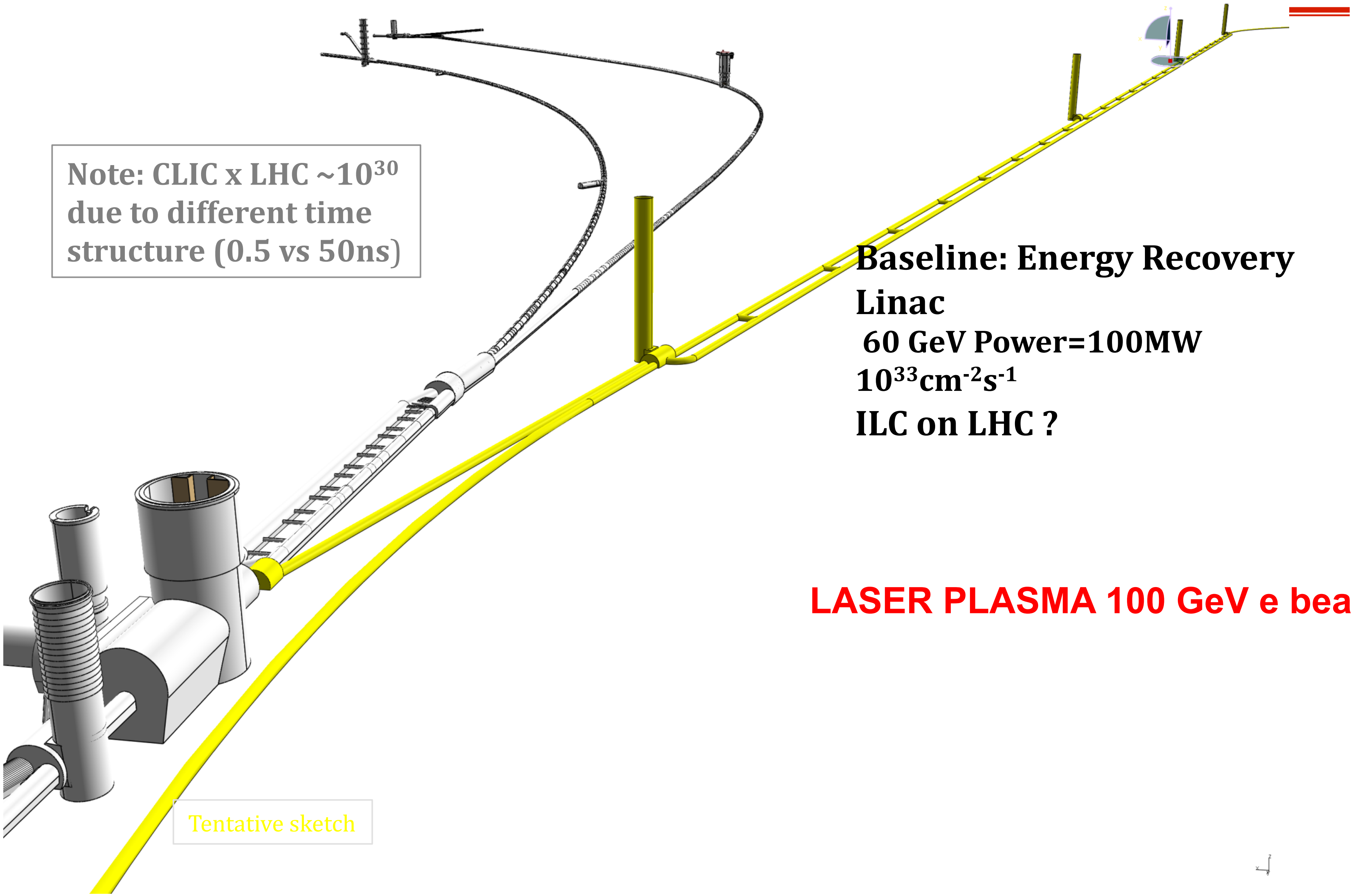




High Energy LHC
≥ 30 TeV
Still a concept

ep Linac-Ring configuration

Note: CLIC x LHC ~10^{30} due to different time structure (0.5 vs 50ns)



Baseline: Energy Recovery Linac

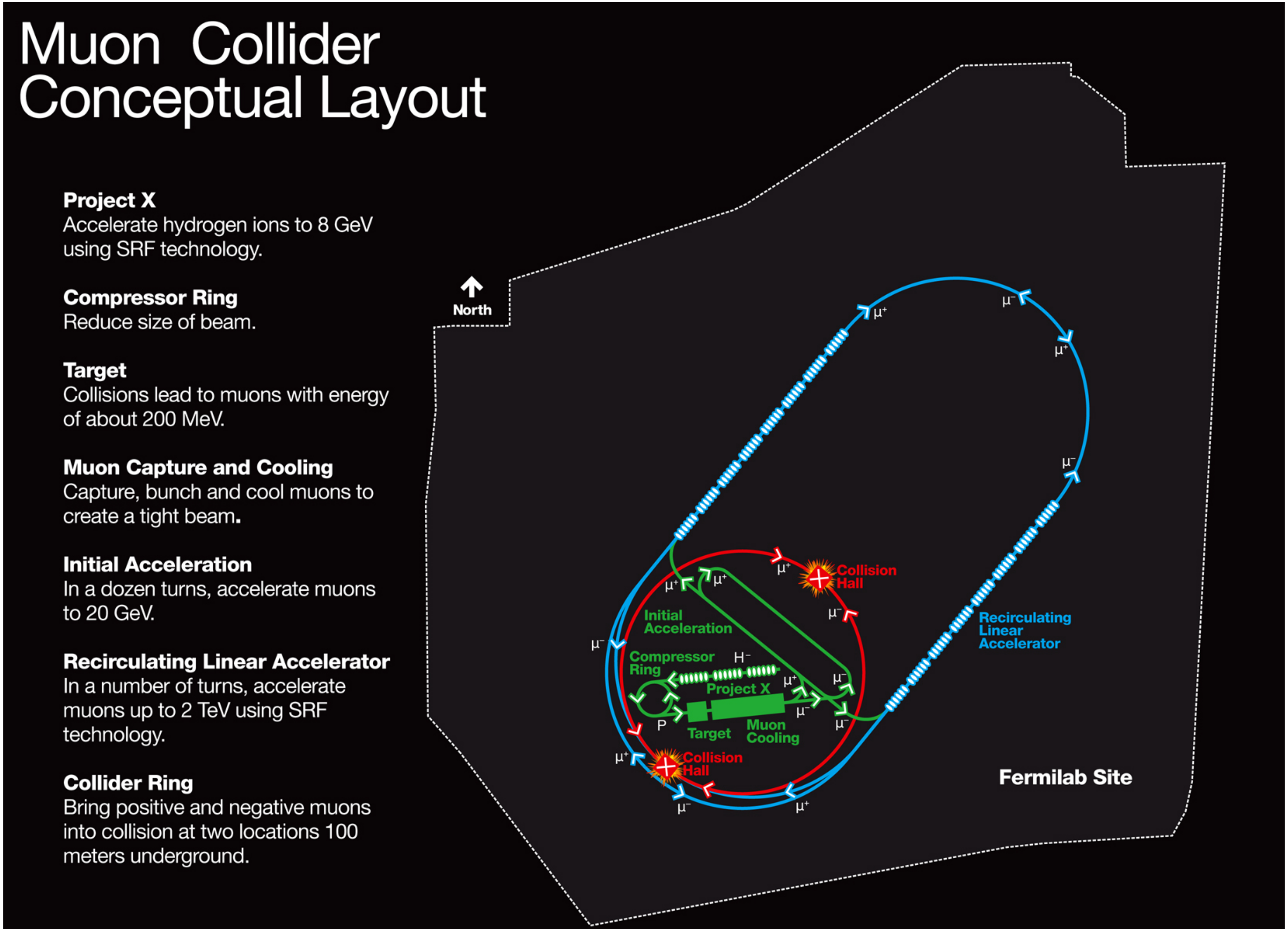
60 GeV Power=100MW

$10^{33}cm^{-2}s^{-1}$

ILC on LHC ?

LASER PLASMA 100 GeV e beam?

Further in time…



Linear →High Gradient Acceleration

- High gradient acceleration requires high peak power and structures that can sustain high fields
  - Beams and lasers can be generated with high peak power
  - Dielectrics and plasmas can withstand high fields

- Many paths towards high gradient acceleration
  - RF source driven metallic structures
  - Beam-driven metallic structures

    } ~30 (ILC) to100 (CLIC) MV/m

  - Laser-driven dielectric structures
  - Beam-driven dielectric structures

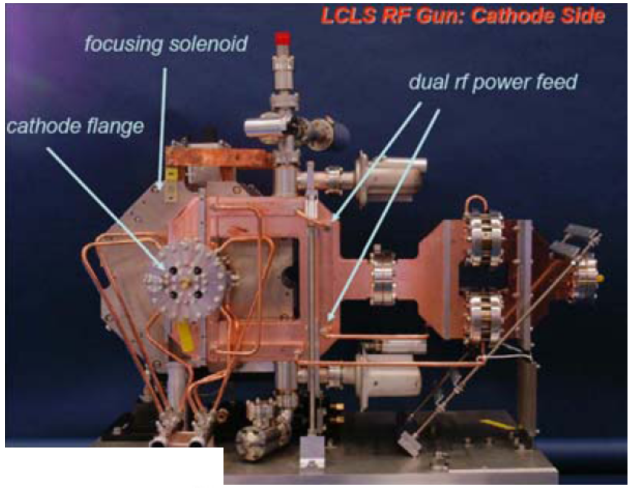
    } ~1 GV/m

  - Laser-driven plasmas
  - Beam-driven plasmas

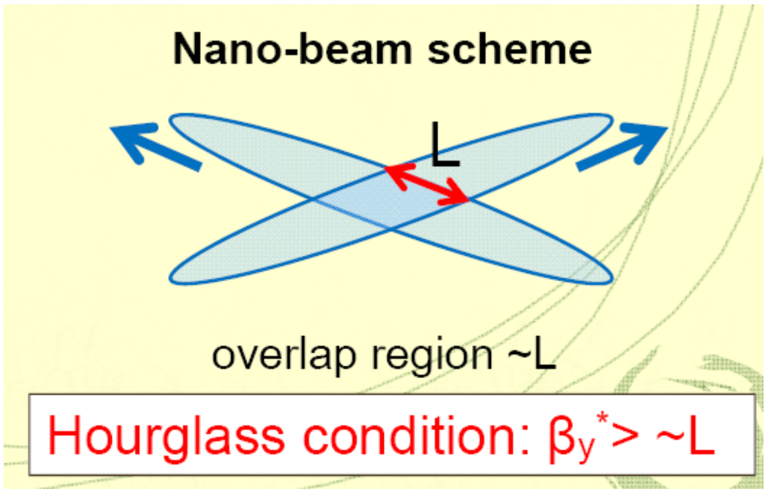
    } ~10 GV/m

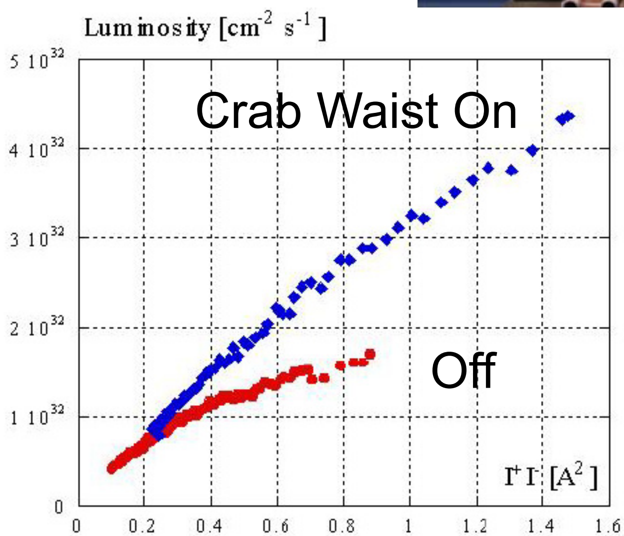
Physics→Beam Brightness Challenge

- Beam brightness most tightly tied to ‘beam physics’
  - Some of the hot topics over the years:
    - Rf guns, final focus systems, emittance preservation, electron cloud, long-range wakefields, emittance exchange, …
- New e- guns 1000 x brighter than best storage/damping rings
  - Development pushed by FEL community
  - How can HEP benefit?



- High luminosity B-factories

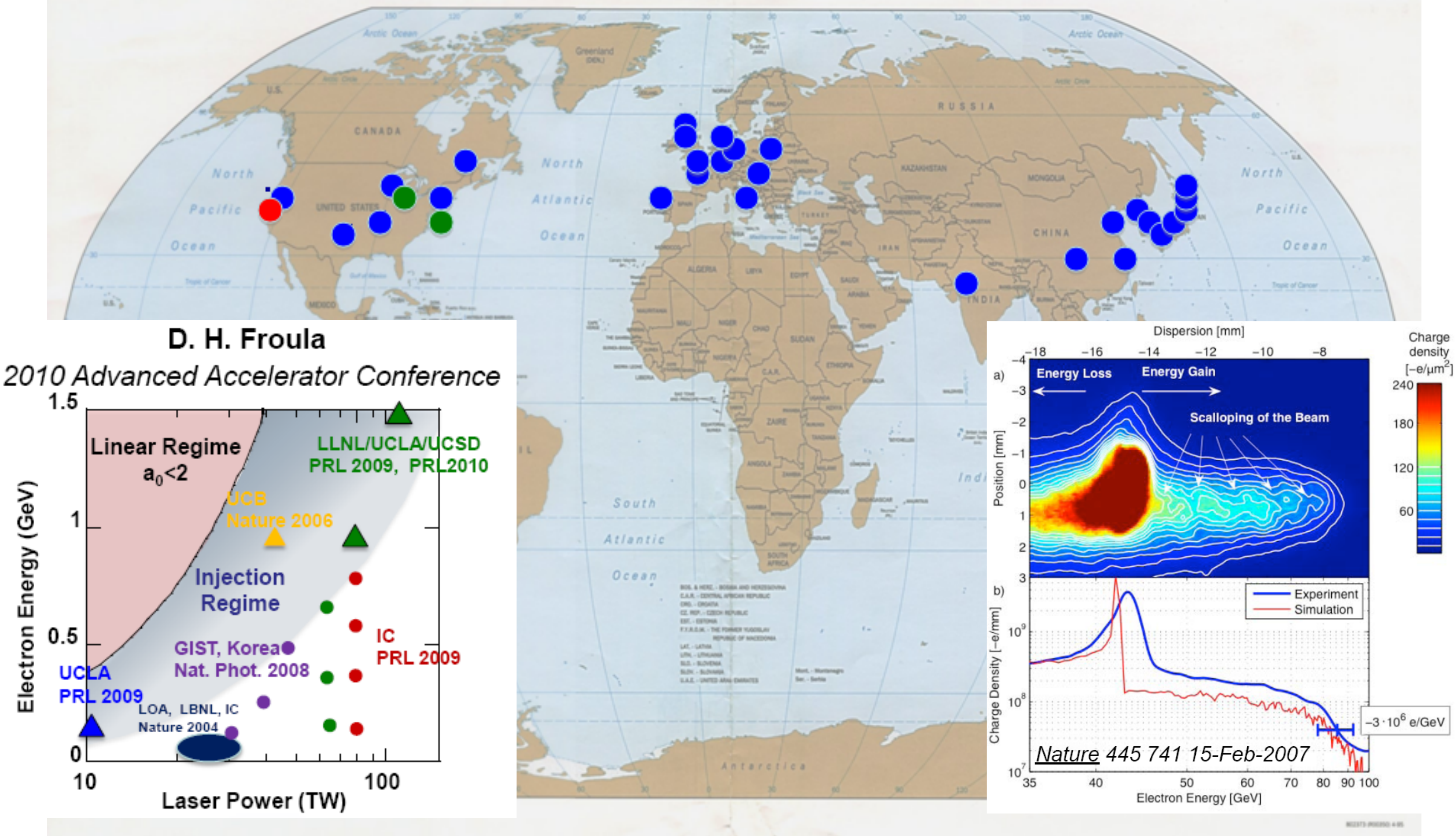




T. Raubenheimer

World-Wide Interest in Plasma Acc.

Plasma Acceleration on the Globe, T. Katsuoleas



● Laser Wake Expts ● Electron Wake Expts ● e-/e+ Wake Expts

Concept of Laser-Driven Plasma Linac

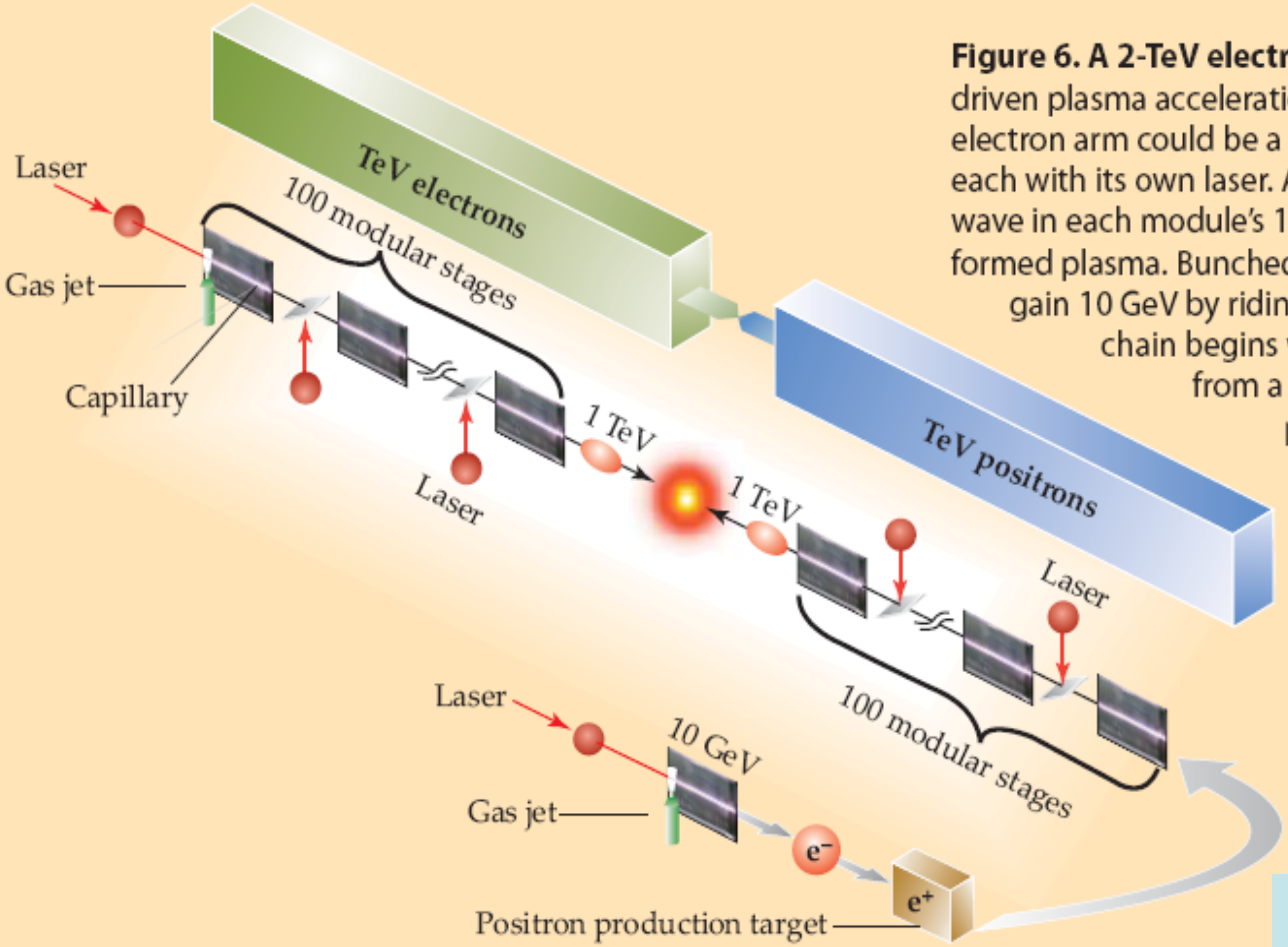
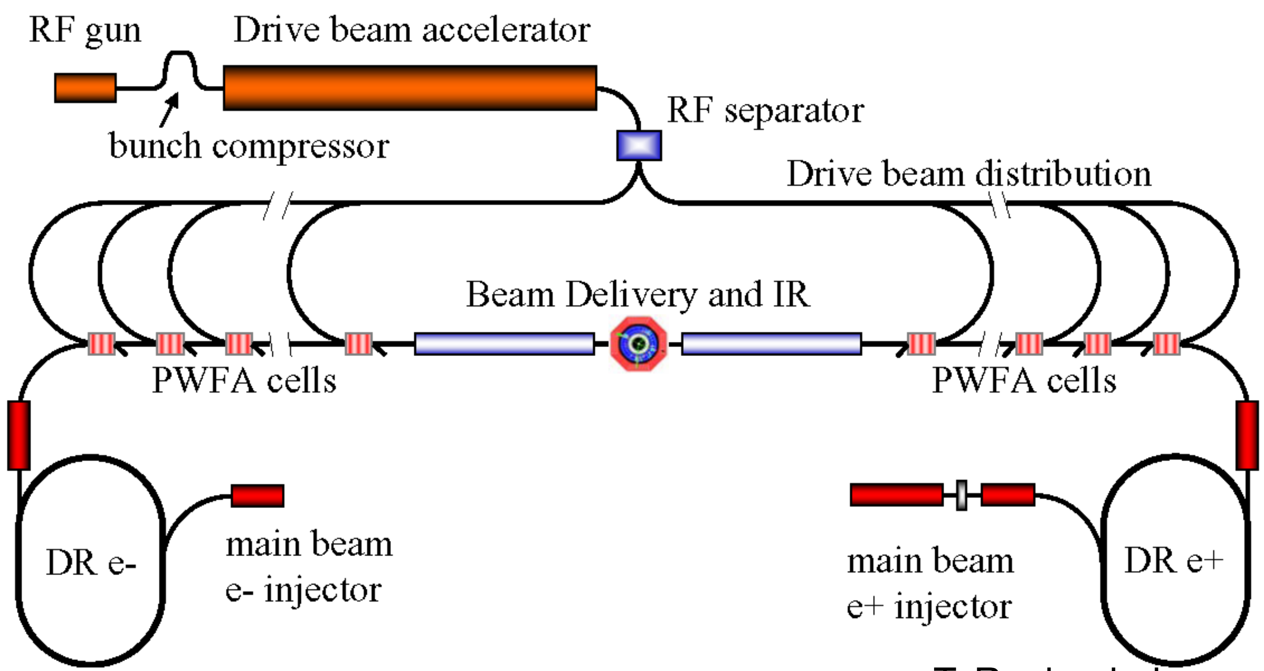


Figure 6. A 2-TeV electron–positron collider based on laser-driven plasma acceleration might be less than 1 km long. Its electron arm could be a string of 100 acceleration modules, each with its own laser. A 30-J laser pulse drives a plasma wave in each module's 1-m-long capillary channel of preformed plasma. Bunched electrons from the previous module gain 10 GeV by riding the wave through the channel. The chain begins with a bunch of electrons trapped from a gas jet just inside the first module's plasma channel. The collider's positron arm begins the same way, but the 10-GeV electrons emerging from its first module bombard a metal target to create positrons, which are then focused and injected into the arm's string of modules and accelerated just like the electrons.

W. Leemans, et al.,
Physics Today, March 2009

Concept of Beam-Driven Plasma Linac

- Concept for a 1 TeV plasma wakefield-based linear collider
  - Use conventional Linear Collider concepts for main beam and drive beam generation and focusing and PWFA for acceleration
    - Makes good use of PWFA R&D and 30 years of conventional rf R&D
  - Concept illustrates focus of PWFA R&D program
    - High efficiency
    - Emittance pres.
    - Positrons
  - Allows study of cost-scales for further optimization of R&D



T. Raubenheimer

Laser Plasma Research & Development

- Timescales for accelerator development will be long
  - Need to maintain pipeline of new ideas
  - Test facilities and infrastructure are critical to enable R&**D (Bridgelab)**
  - Requires support for both fundamental and directed (project) R&D
- Important to connect to other projects**: CLIC and CERN most natural**
- Large-scale projects tend to be conservative
  - Likely will require many systems-level demonstrations (100 GeV?)
  - Important to understand timescales and costs both for the R&D as well as the demonstrations
- Important to consider early applications **(e LHC?)**

T. Raubenheimer


Thank you !
LHCb
ATLAS
CERN
CERN
SUISSE
FRANCE
SPS 7 km
CMS
ALICE
LHC 27 km