On the Large Hadron Collider

- Collider

- Experiments

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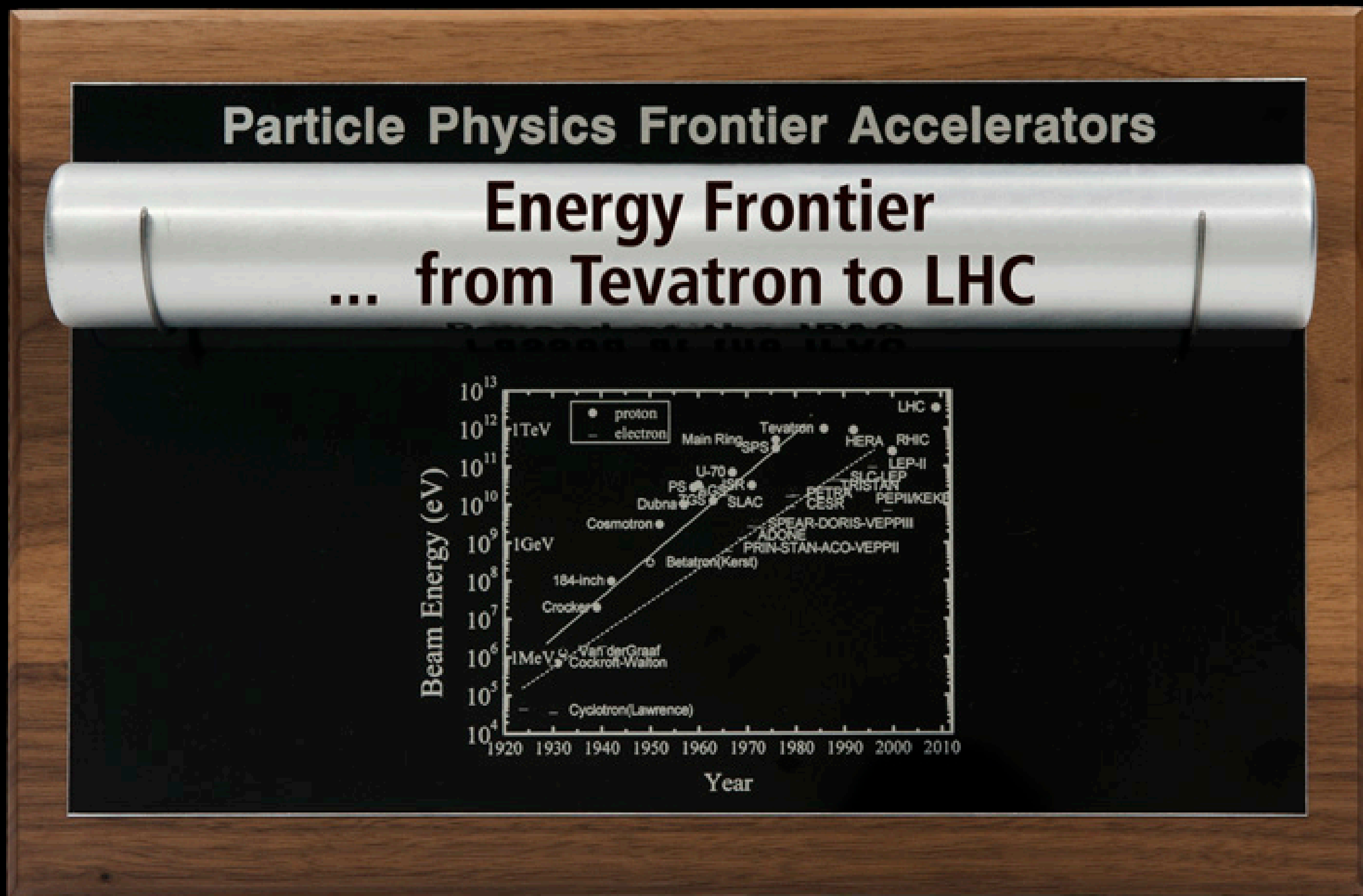
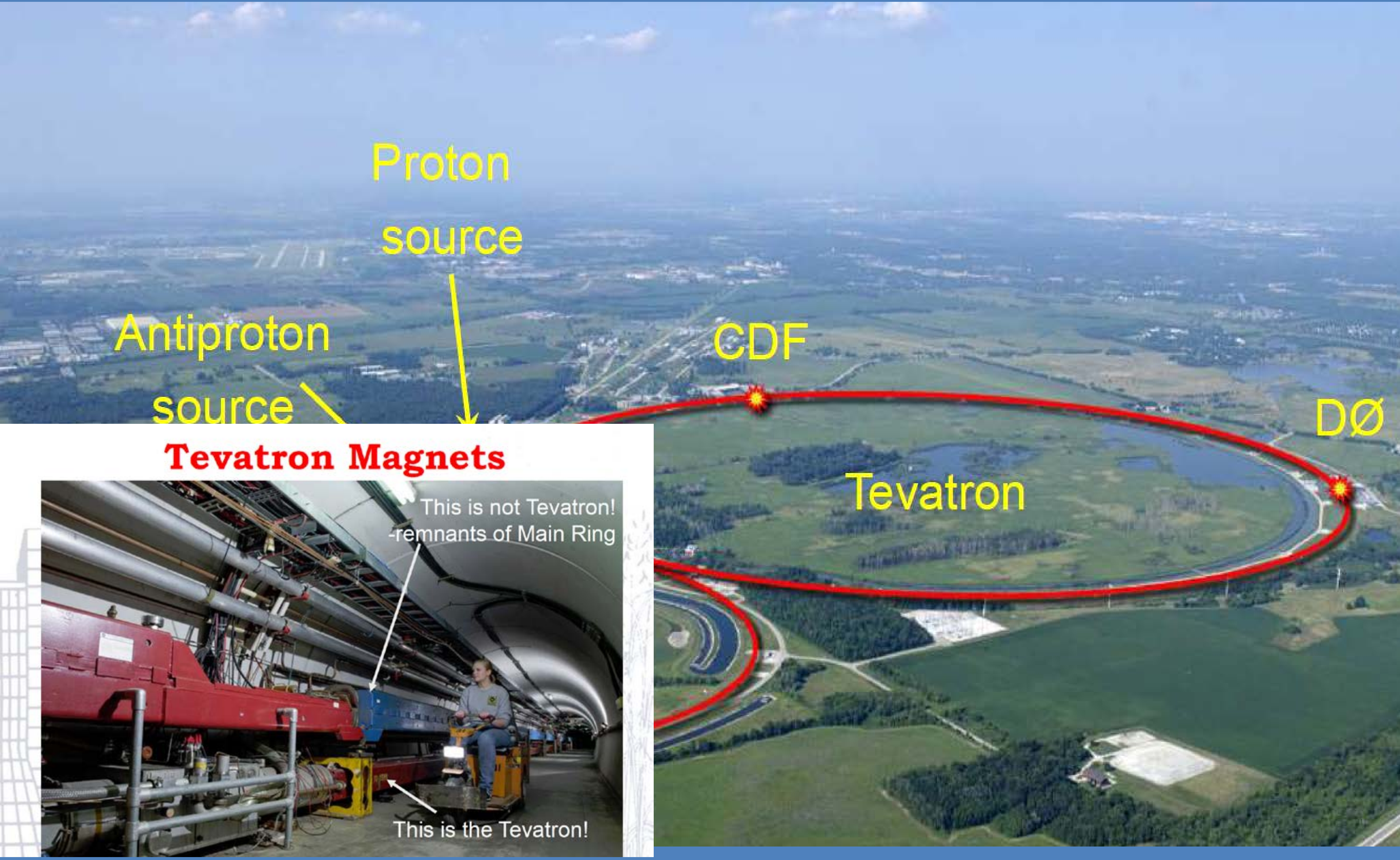
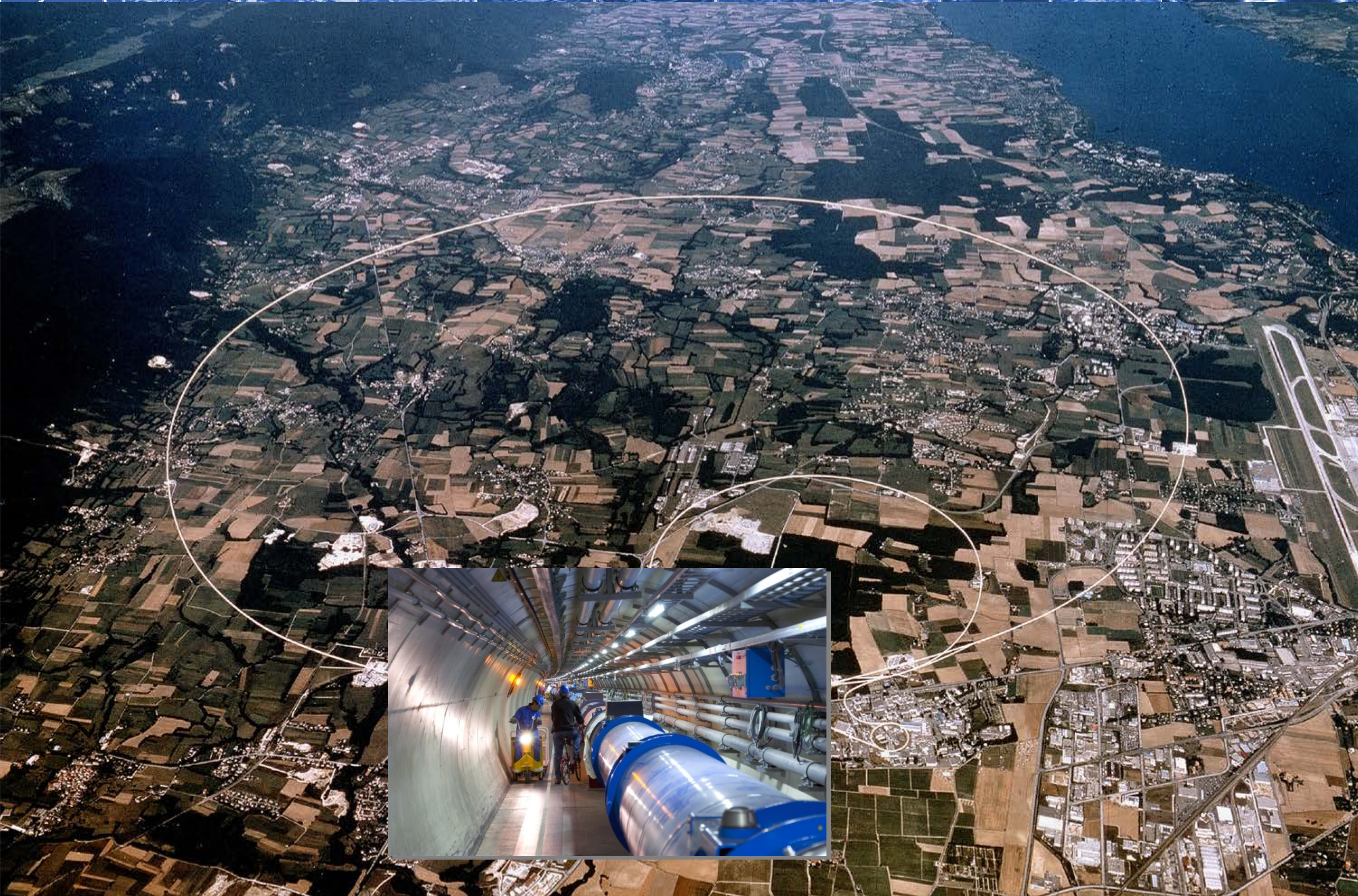
Energy Frontier Baton



from . . . Tevatron



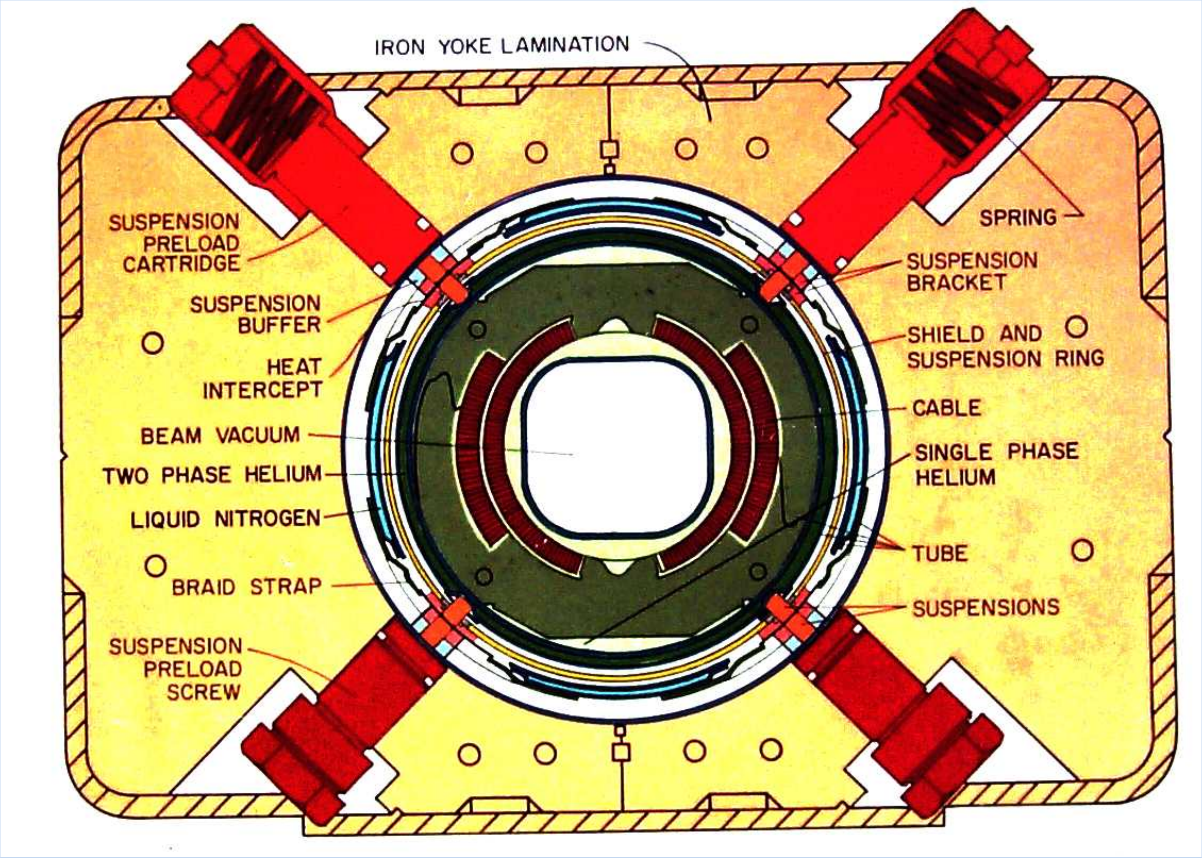
to . . . LHC



FNAL → CERN (I)

- Tevatron SC magnet technology

4.5T SC Magnets



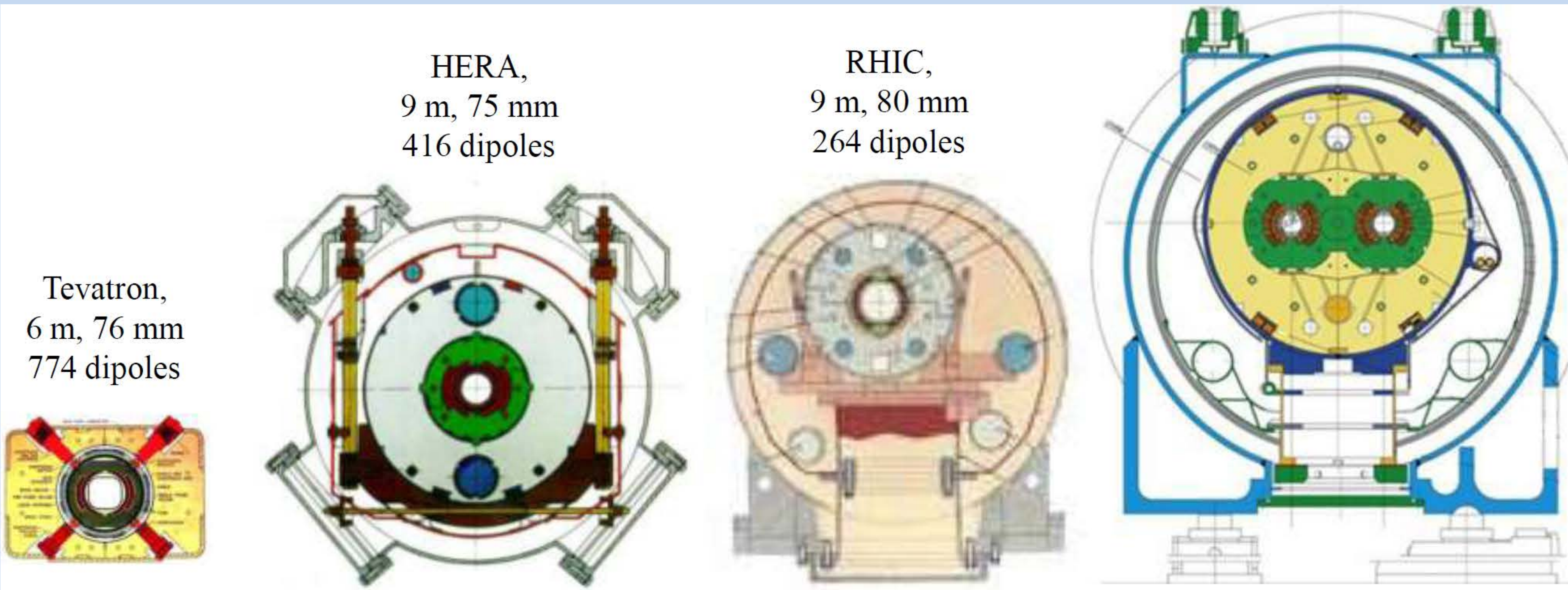
SC Magnets

Tevatron paved the way for HERA, RHIC and LHC

8.3T

LHC,
15 m, 56 mm
1276 dipoles

4.5T **5.3T** **3.5T**



warm iron
small He-plant

cold iron
Al collar

simple &
cheap

2K He
two bores

FNAL → CERN (I)

- Tevatron SC magnet technology
- Stochastic cooling

  (FNAL learnt and greatly advanced the method)
- LHC magnets for the interaction region

  (important US contribution)

- Technical help for LHC

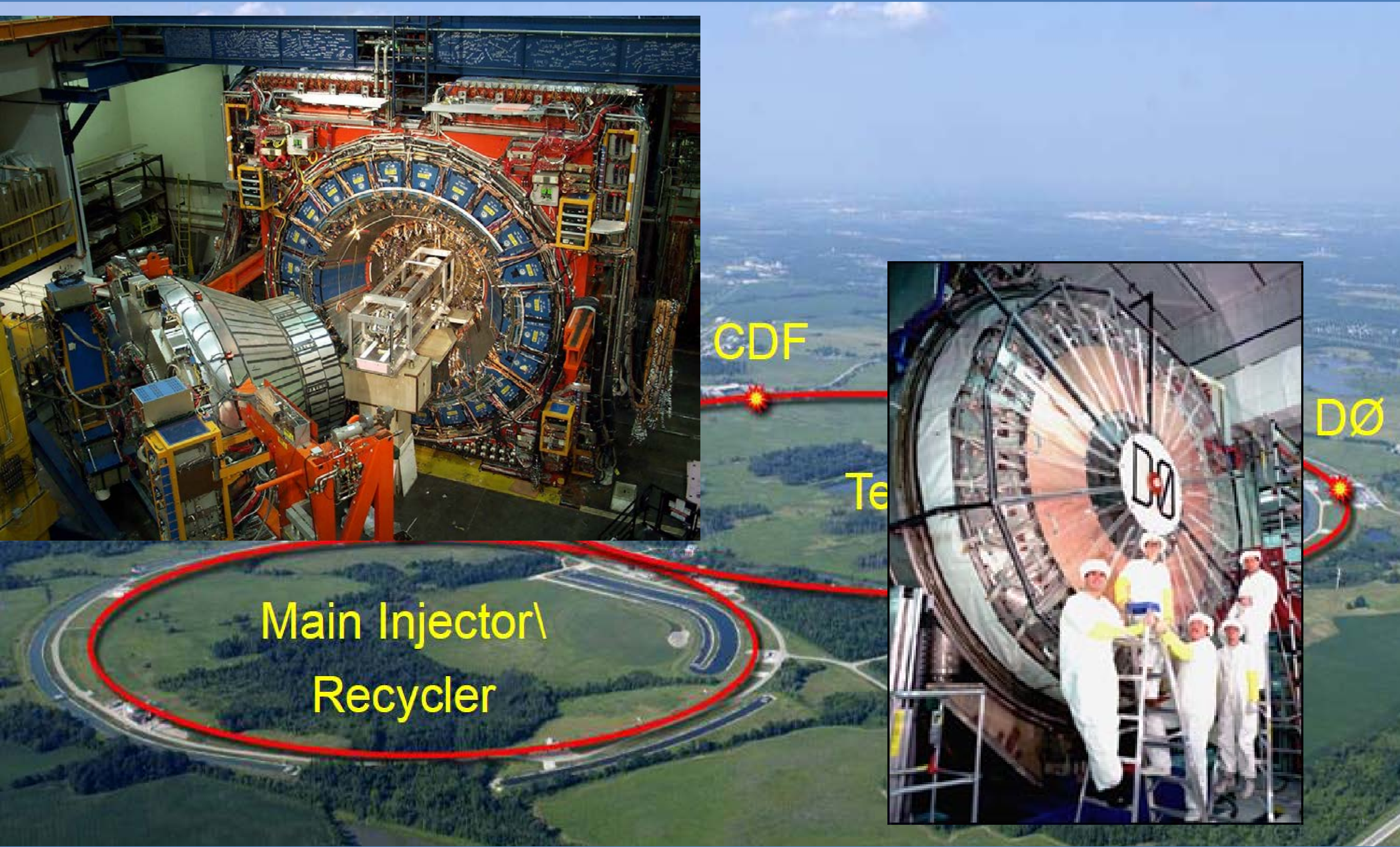
  - during commissioning
  - during recovery in 2008/2009

FNAL → CERN (II)

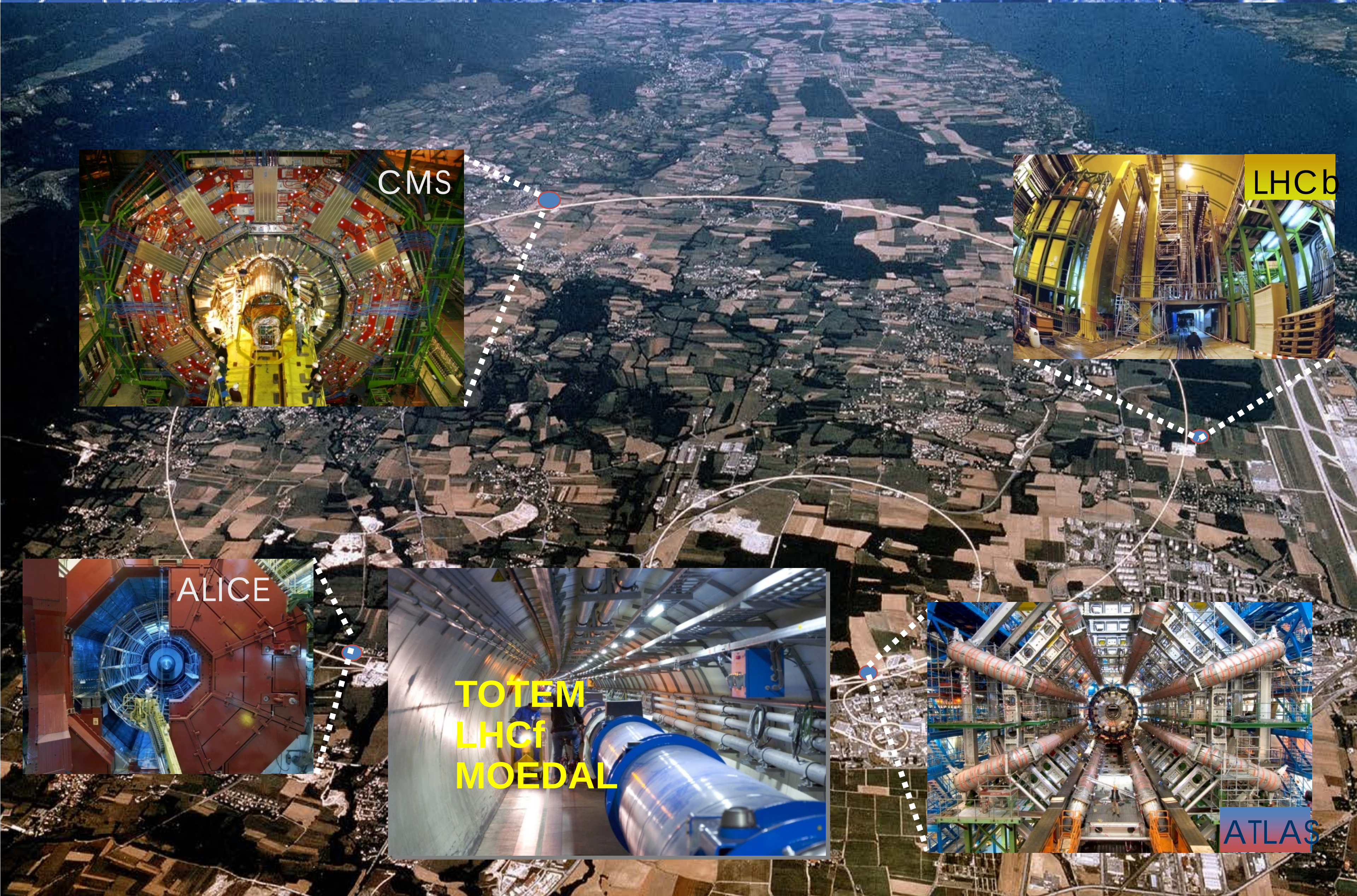
- Advances in Beam Physics/Technology:
  - TeV experts' participation in commissioning/beam studies (LARP teams)
  - Strong involvement in the upgrades

    (Nb_3Sn magnets, Energy Deposition, optics, etc)
  - Beam-beam effects in hadron beam (SPS experience → Tevatron + studies + modeling tools → LHC)
  - Collimation ideas going to realization : hollow electron beams, bent crystals

from . . . Tevatron Experiments



to . . . LHC Experiments



General Remark

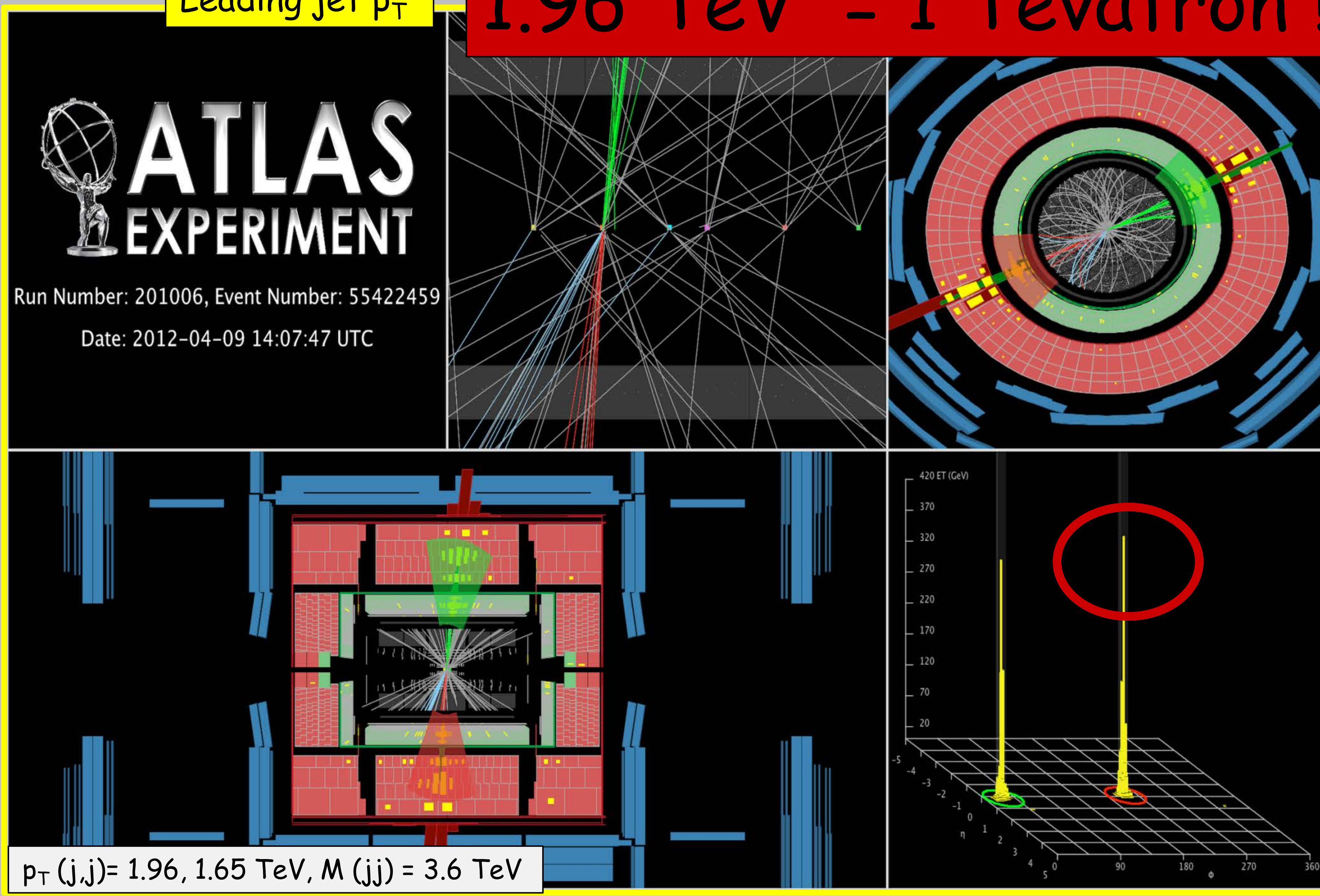
The Tevatron experiments faced a very similar hadronic environment although at lower energies

(But keep in mind that the early CDF and D0 years were also heavily influenced by the CERN-SPS experiments, UA1 and UA2)

Di-jet event recorded by ATLAS on 9 April 2012 at $\sqrt{s}$=8 TeV

Leading jet p_T

1.96 TeV = 1 Tevatron !!



p_T (j,j)= 1.96, 1.65 TeV, M (jj) = 3.6 TeV

Hardware and Analysis Techniques

- Run 1 CDF demonstrated that very good tracking can make up for deficiencies in calorimetry and allow many new physics topics to be breached
  - Especially as a result of silicon detectors
  - B tagging was widely developed and used at the Tevatron
    → precision B-physics at hadron colliders
  - Many top physics techniques and analysis techniques in general
- Run 2 CDF and Dzero detectors were very relevant to the LHC because they were a step up in complexity and of course operated in a similar environment
  - Many things were learned from Run 2
    - Both in terms of what to do and what not to do
  - **Silicon tracking and vertexing was taken to a new level at the Tevatron**

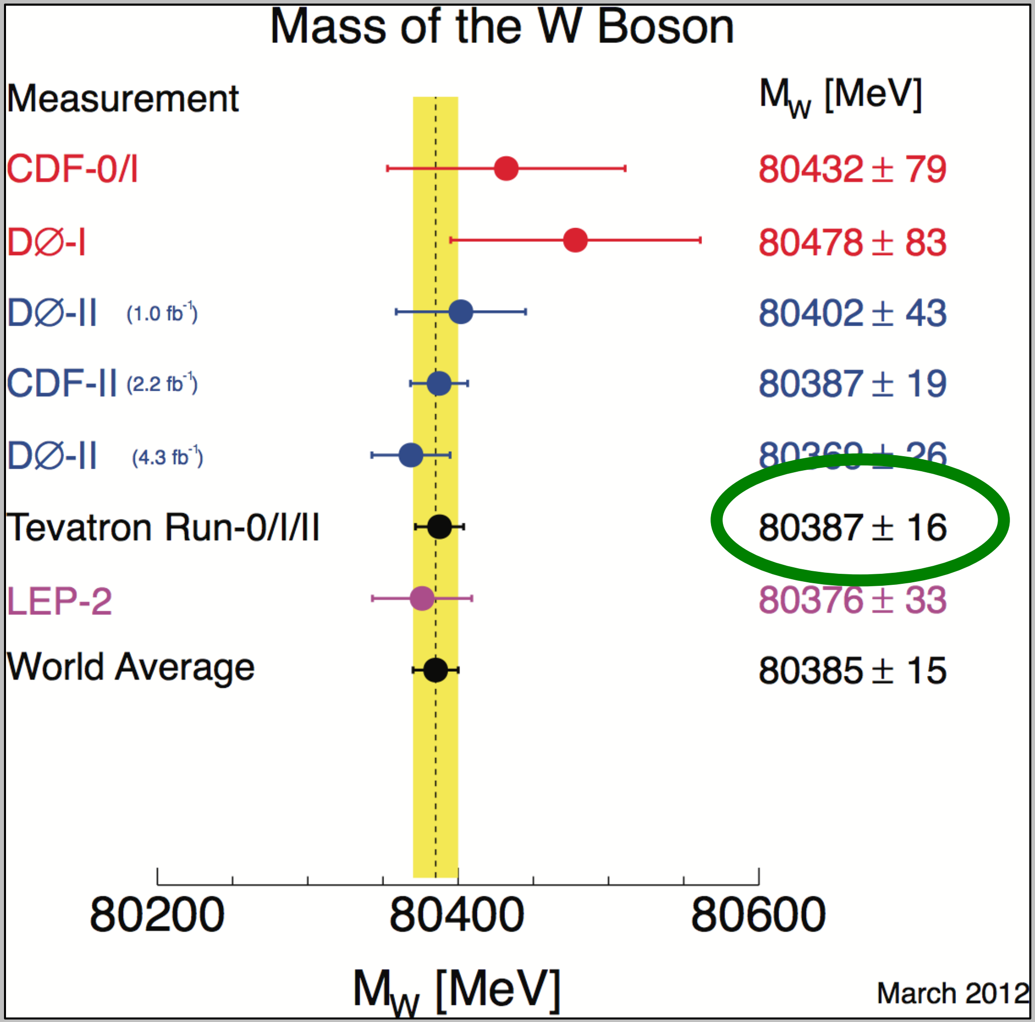
Trigger and Analysis Techniques

- The entire triggering concept in hadron collider environment comes from the Tevatron (and earlier machines)
  - Tevatron has pioneered SVT but also out-of-time triggers (for slow-moving or long-lived particles)
- The importance of the MVA techniques.
  - Tevatron was the first to capitalize on the new qualitative break-through offered by modern computing: an ability to train MVA methods on large samples of data and MC and use it instead of the matrix element approach (also pioneered by the Tevatron), which often only is possible at leading order.
  - These techniques were used to find single-top production at the Tevatron; they are likely to play crucial role in the Higgs discovery at the LHC.
- The importance of combination of multiple channels
  - For the Higgs search, the Tevatron demonstrated that adding a large number of relatively insensitive channels does help the overall sensitivity.

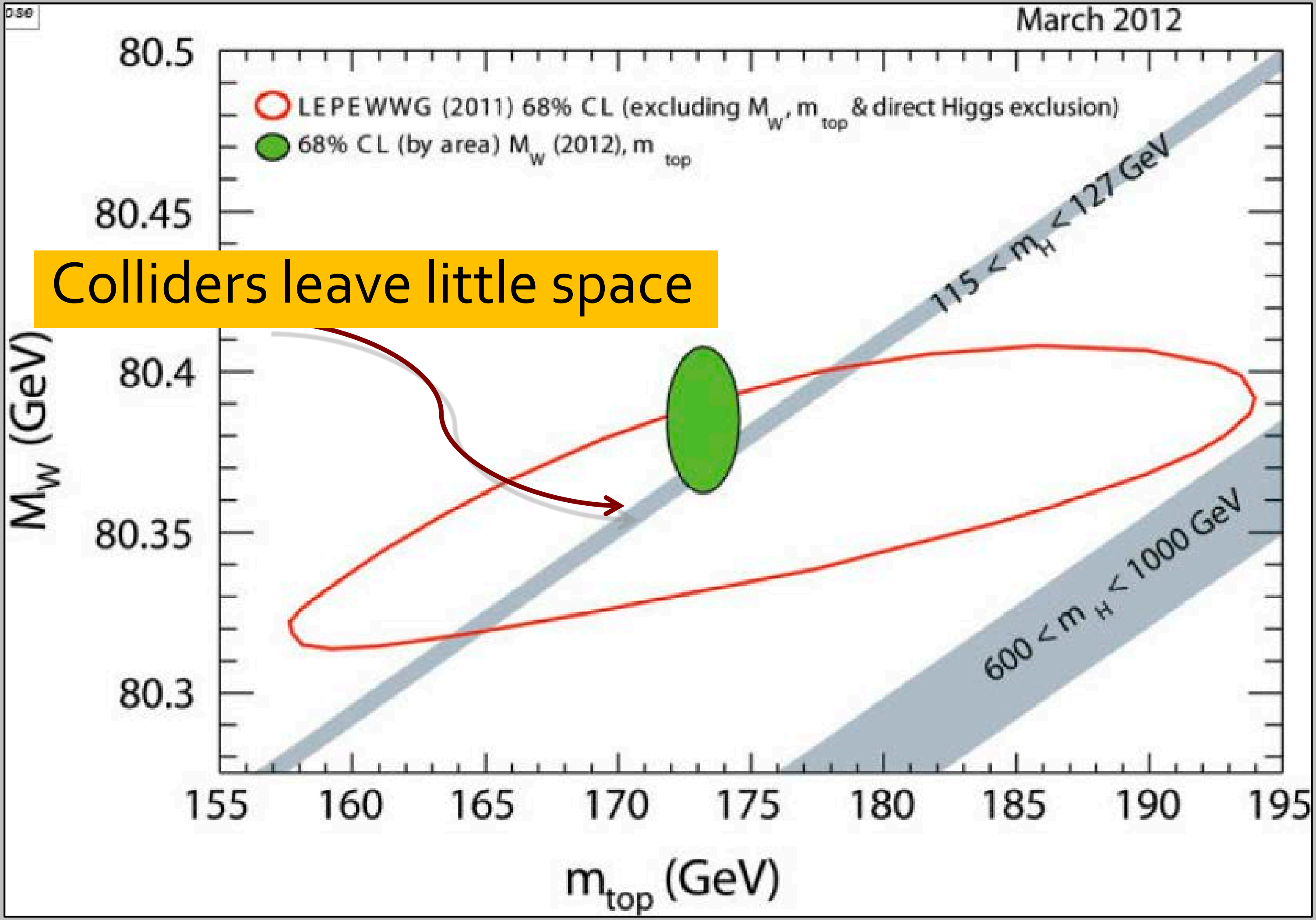
Physics Analyses

- Methods innovated at Tevatron, carried over to LHC
  - Ingenious methods of overcoming constraints

    Example – Jet energy scale (JES) uncertainty dominated top mass uncertainty-> use hadronic W inside top events themselves to calibrate JES. Simultaneous fit to JES and Top mass allows high precision
- Tevatron showed that one can do extremely high precision measurement
  - E.g. recent W mass σ_M~16 MeV !



It will be hard, even with the LHC statistics, to compete with the superb precision (~16 MeV !) obtained in the W mass measurement.



M_W dominates the internal consistency tests of the Standard Model → the Tevatron measurement will contribute in a very significant way to the full picture still for a long time, i.e. until the LHC will improve on the M_W precision.

Tevatron's main legacy to the LHC

- The demonstration that a huge wealth of (superb) precision measurements can be made at hadron colliders
- Advanced analysis techniques brought to full maturity. They allow tiny signals to be extracted from (often complex mixtures of) huge backgrounds, even for very small S/B (e.g. single top, potentially Higgs …)
- Huge gain in sensitivity compared with expectation can be achieved with data, painstaking experimental work, and a lot of ingenuity

BUT most importantly . . .

The transfer of a huge amount of knowledge and experience through members of FNAL working on the accelerator

and

physicists from Tevatron experiments joining ATLAS and CMS

Competitive Collaboration

Collaborative Competition

Co-opetition

Today

Exciting Times

- ***Intensity frontier***

e.g. large neutrino mixing angle Θ_{13}

- ***Energy frontier***

e.g. Higgs around the corner ?

Tomorrow

Road beyond the Standard Model

We are looking forward to

a long lastin tinuation

of the g partnership

between FNAL and CERN

We need you