US LHC Accelerator Research Program

brookhaven - fermilab - berkeley

Beam Commissioning and Fundamental Accelerator Physics

Beam Commissioning

- Why? How? When? What is a "system"?

Fundamental Accelerator Physics

- Beam-Beam interaction
- Electron cloud & other vacuum effects
- Remote operations & maintenance
- LHC upgrade optics
- Interaction Region compensation
- Energy deposition & Beam loss scenarios

Beam Commissioning
Why?

Why should LARP Accelerator and Instrumentation Physicists be involved in LHC Beam Commissioning?

- to speed up the commissioning of this difficult machine by applying unique (and non-unique) US expertise

- to take the rare opportunity for US physicists to "learn from the school of hard knocks"

- to benefit US hadron machines, present and future

Beam Commissioning
How?

CERN is receptive: the consensus with Bailey, Collier, and Myers is to support 1 scientist per commissioning shift

- ideally: 12 FTEs
- guideline budget: 9.5 FTEs

Staff these shifts with a combination of visits:

- long (up to a year)
- relatively brief (as short as a month)

"Breadth and depth": the very best semi-junior physicists, as well as more senior experienced physicists.

Beam Commissioning
When?

Still must work out in detail how this will be done:

- integration with the CERN teams must begin well before first beam (injection test)
- compare with detector groups planning for remote groups to have system responsibilities

Beam Commissioning:
What is a "system"?

LARP Beam Commissioners must have specific responsibilities:

- "System Commissioners" (integrators) in RHIC parlance
- "Mr. X" in LEP operations parlance

Initial instruments are natural examples of a "system"

- a LARP Beam Commissioner may be an Instrumentation Physicist or an Accelerator Physicist
- but he/she pulls shifts, as a peer, in the Control Room
- instrument or not, the goal is "end-to-end" responsibility

Where are the boundaries of responsibility? Low/high level controls? Need more discussions with CERN ...

Fundamental accelerator R&D
Topics

Beam-Beam Interaction

- RHIC: strong-strong, Tevatron: Electron Lens, LBL: sims

Electron cloud and other vacuum effects

- RHIC & the Tevatron as cryogenic test beds. Synch light.

Remote operations & maintenance

- work with REAP, GRID, and MVL efforts

LHC upgrade optics

- synergy with magnet program

Interaction Region compensation

- before & after upgrade

Energy deposition and beam loss scenarios

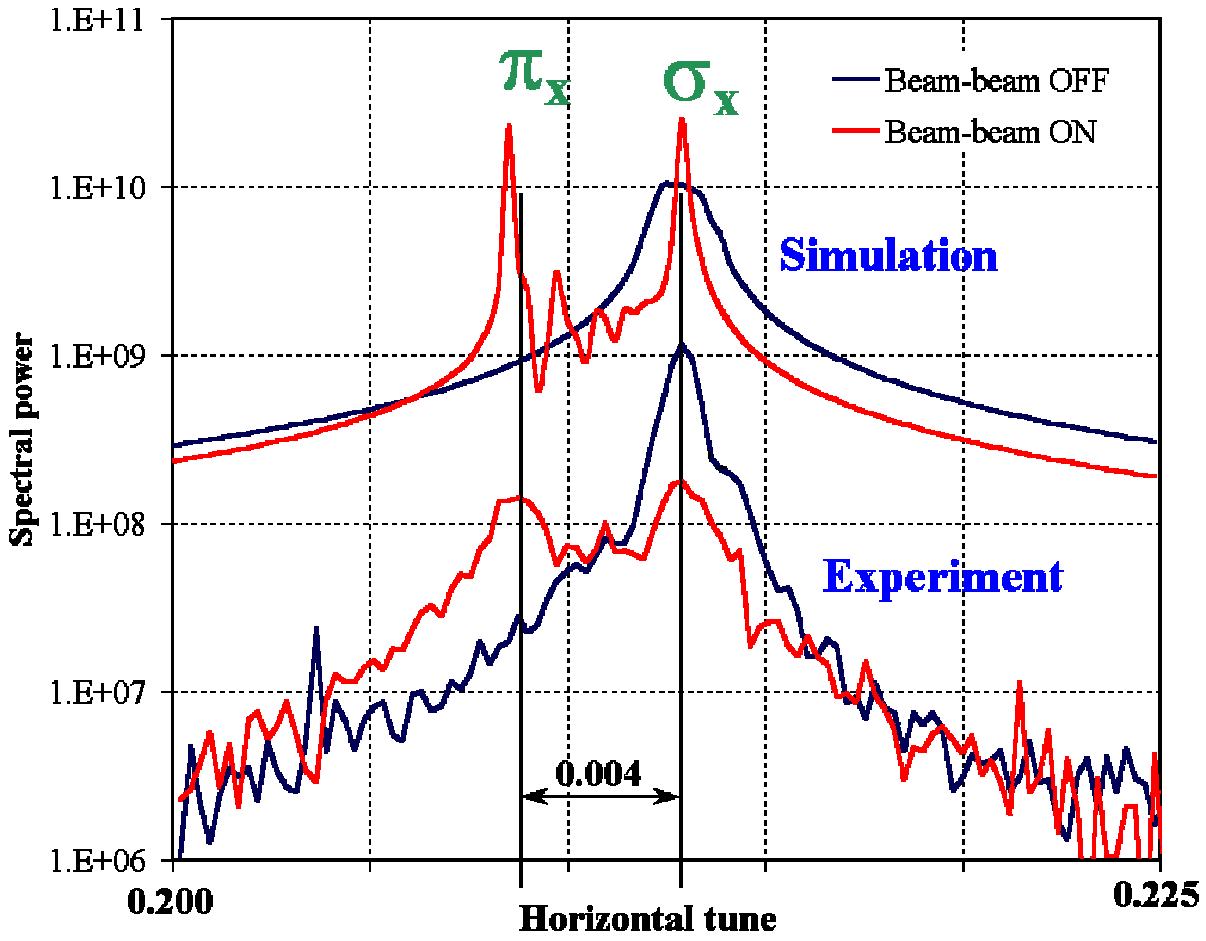
- before & after upgrade

Beam-Beam Interaction

Strong-Strong experiment & simulation (RHIC)

Data: Fischer et al (BNL). Simulation: M. Vogt et al., DESY

4096 turn spectra



RHIC is first hadron collider to see strong-strong modes!

Experiment:

- single p bunch/ring
- ξ **= 0.003**

-Observation:

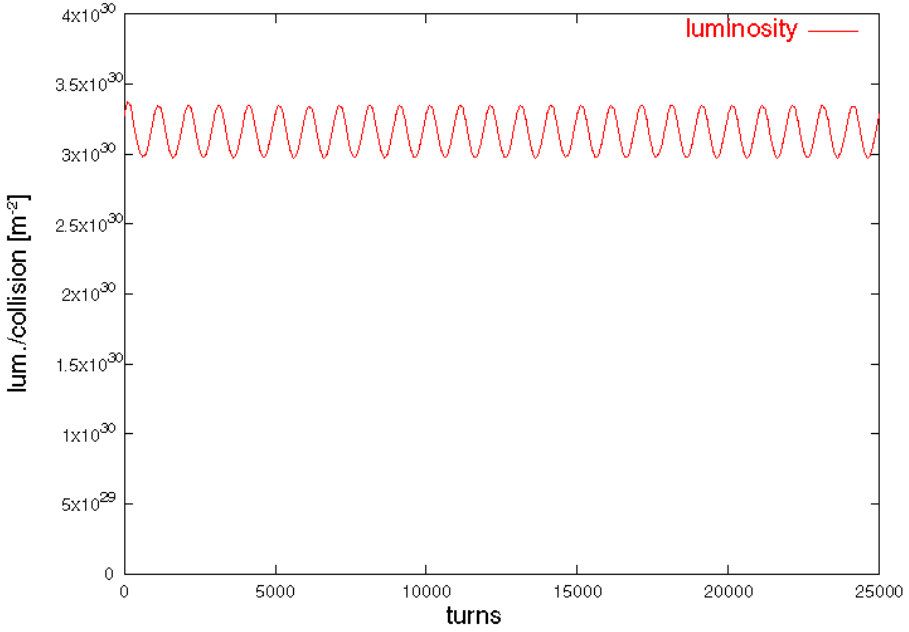
- π_x-mode shift: 0.004
- expectation:

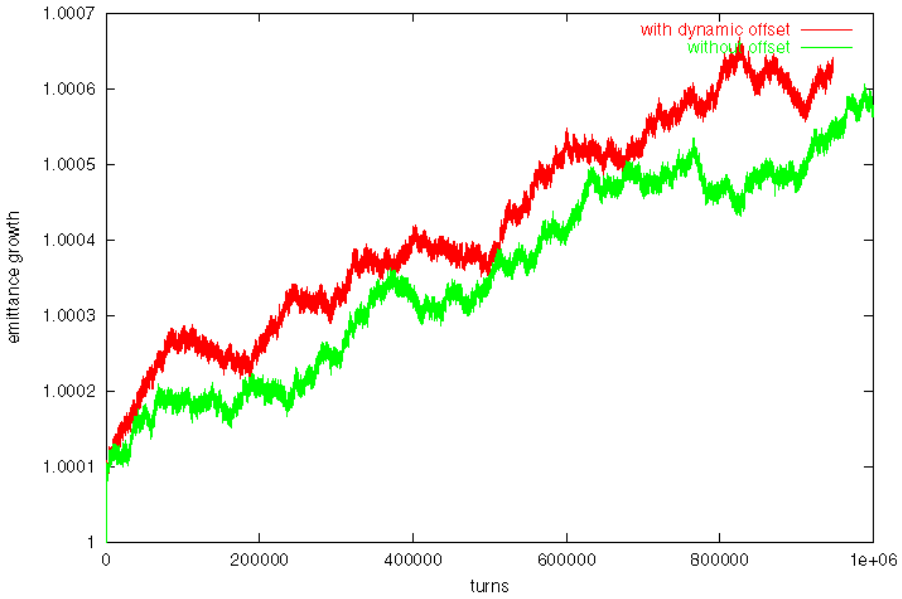
  $1.21 \cdot \xi = 0.0036$

[Yokoya, Meller, Siemann]

Beam-Beam
Simulated influence of wobbling

Simulation: J.Qiang, LBNL





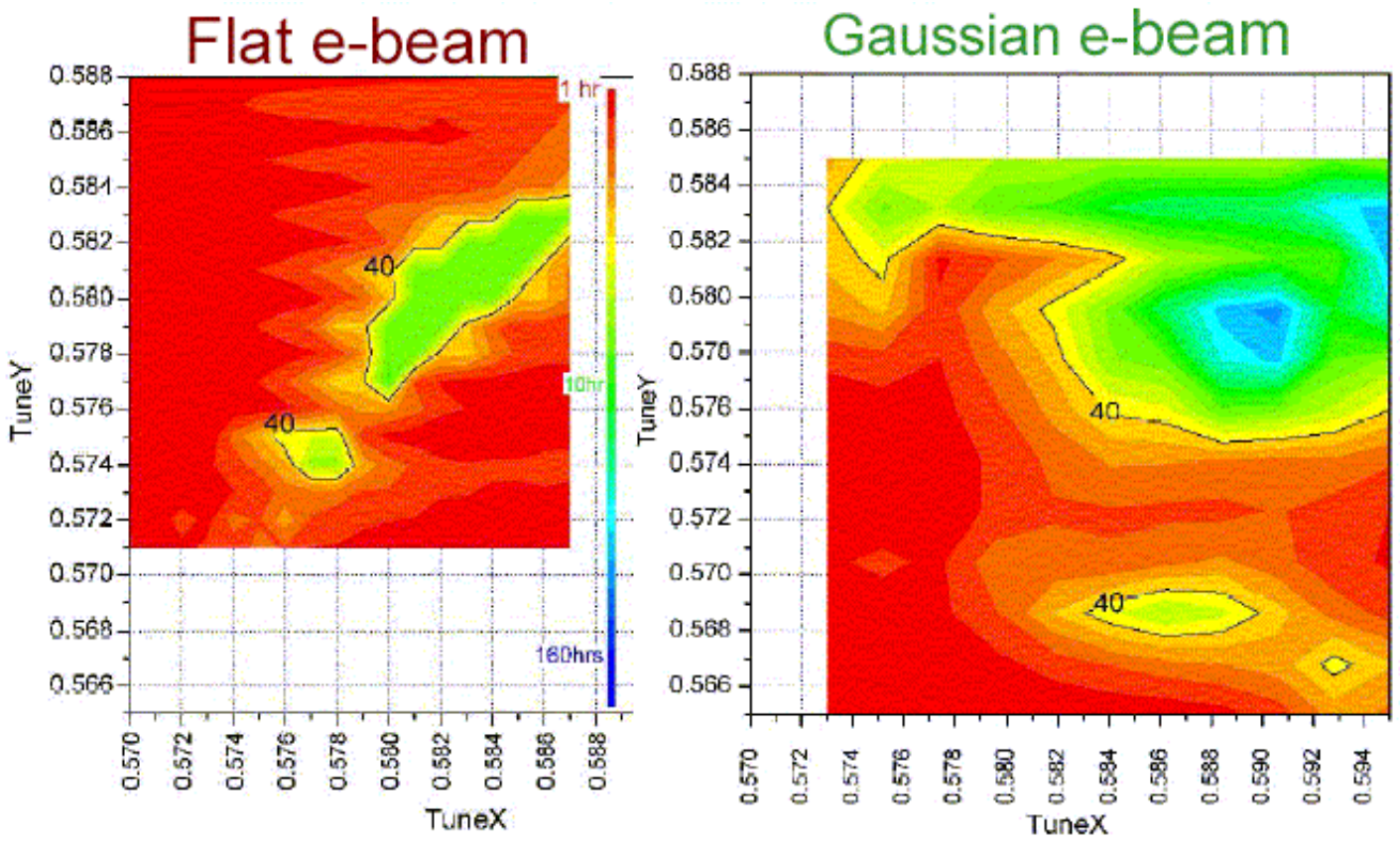
Luminosity per collision versus time during the circular sweeping process in the luminosity monitoring scheme being developed at LBNL for the LHC

Emittance growth in a strong-strong beam-beam simulation.
Green head-on BB collisions
Red with 0.1 sigma wobbling

Beam-Beam
Lifetime vs tunes with Tevatron Electron Lens

Data: V. Shiltsev, FNAL

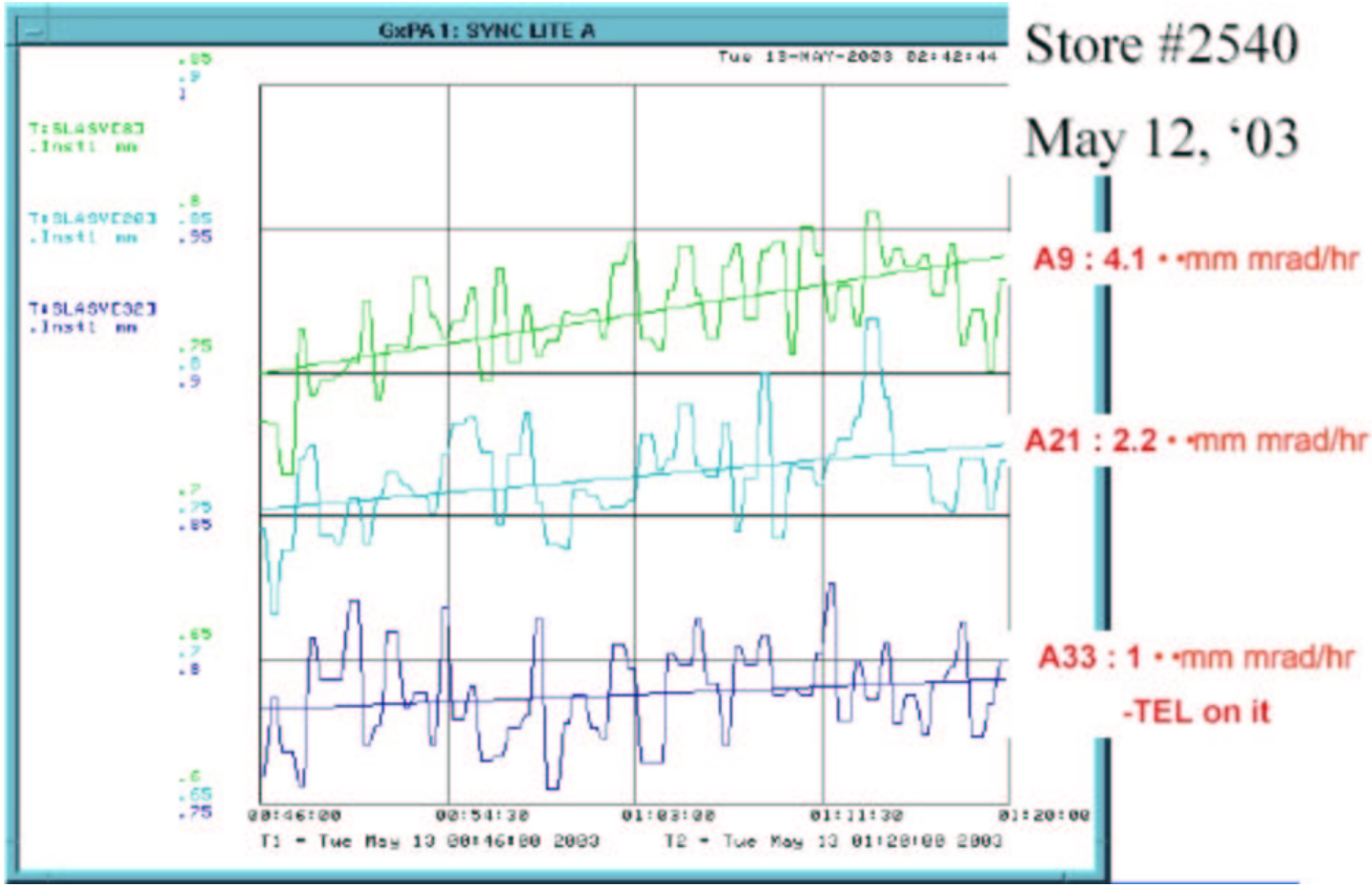
TEL tune shift of 0.004



Status report: new Gaussian profile gun is much more promising ...

Beam-Beam
Anti-proton emittance growth rates

Data: V. Shiltsev, FNAL

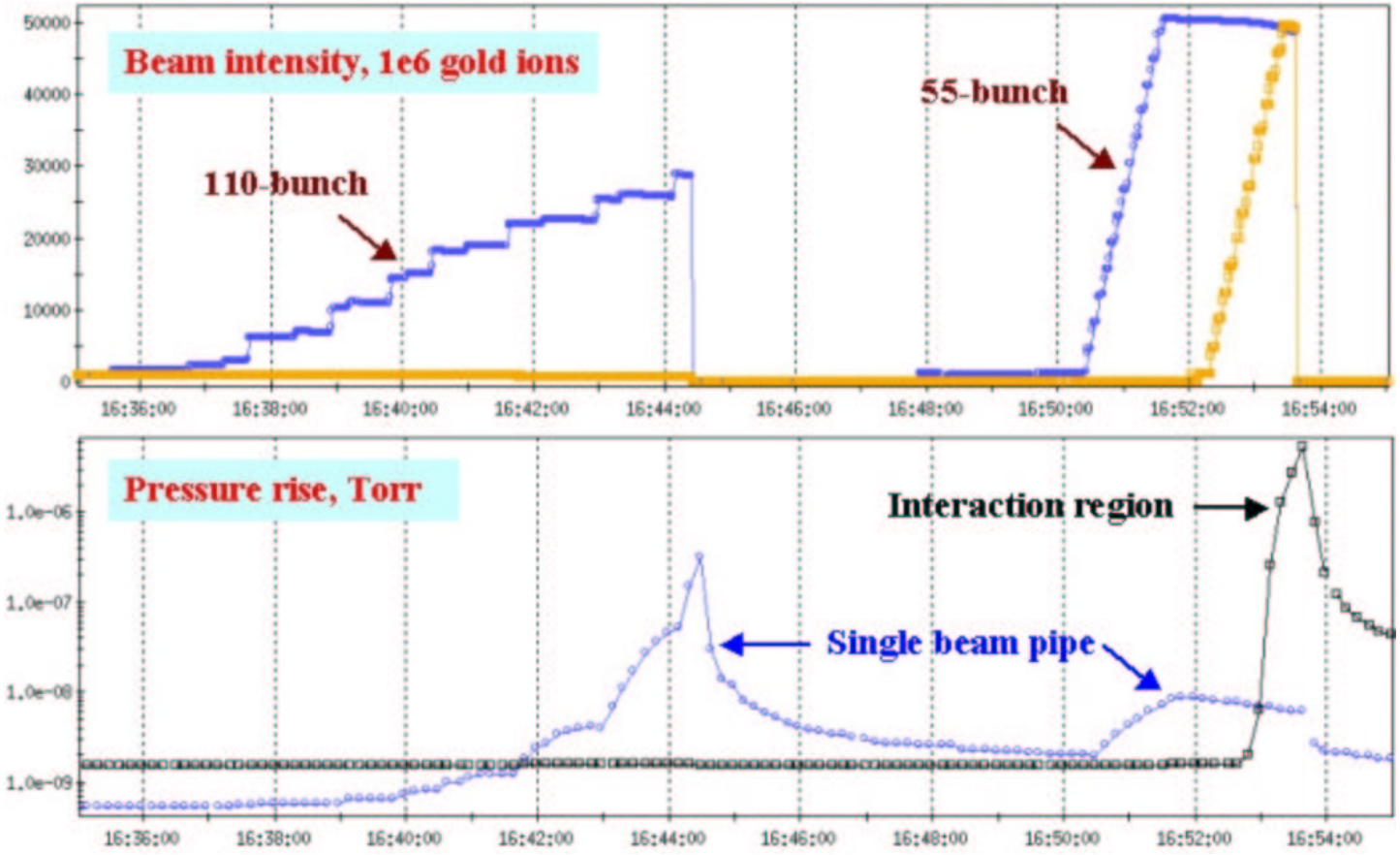


Some evidence of reduced emittance growth rates with TEL on

Electron cloud and other vacuum effects

Data: Zhang, Fischer et al, BNL

RHIC suffers, but not the Tevatron

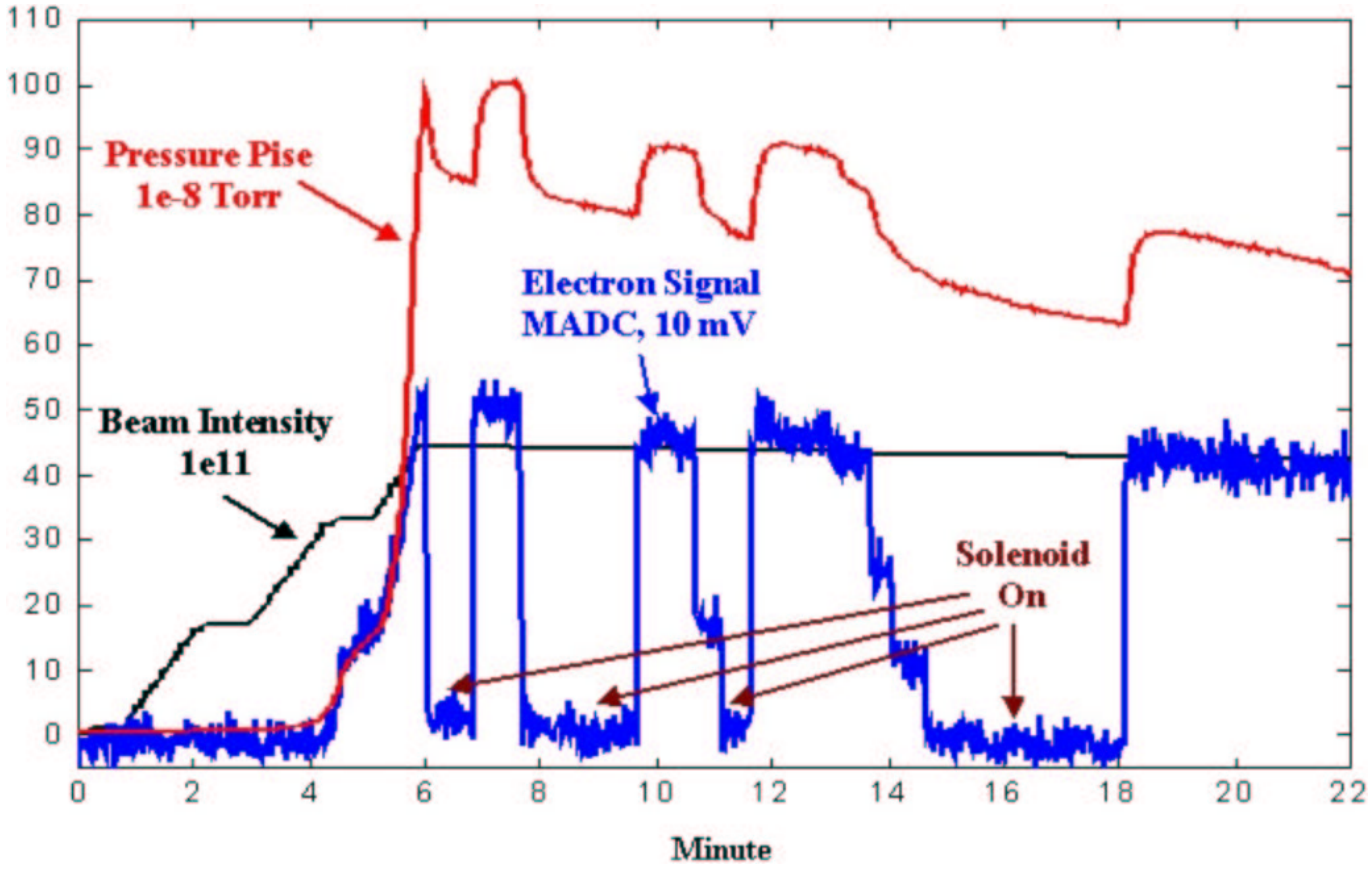


Destructive RHIC pressure rise in warm sections in both rings

Electron cloud and other vacuum effects

RHIC

Sometimes the problem is electron cloud ...



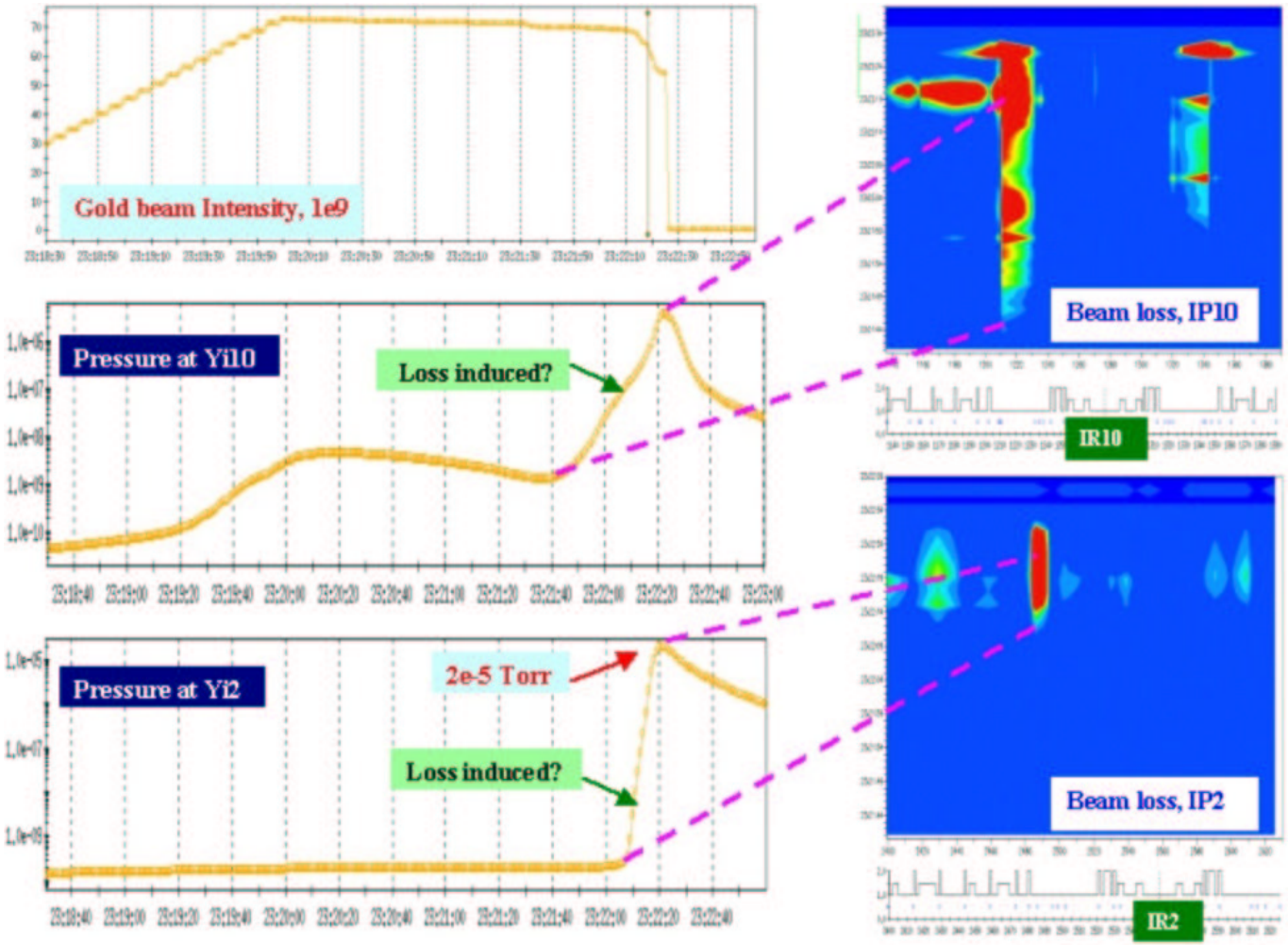
In these data

- pressure rise coincides with signal from electron detectors
- solenoid around electron detector (4 m/34 m) reduces signal

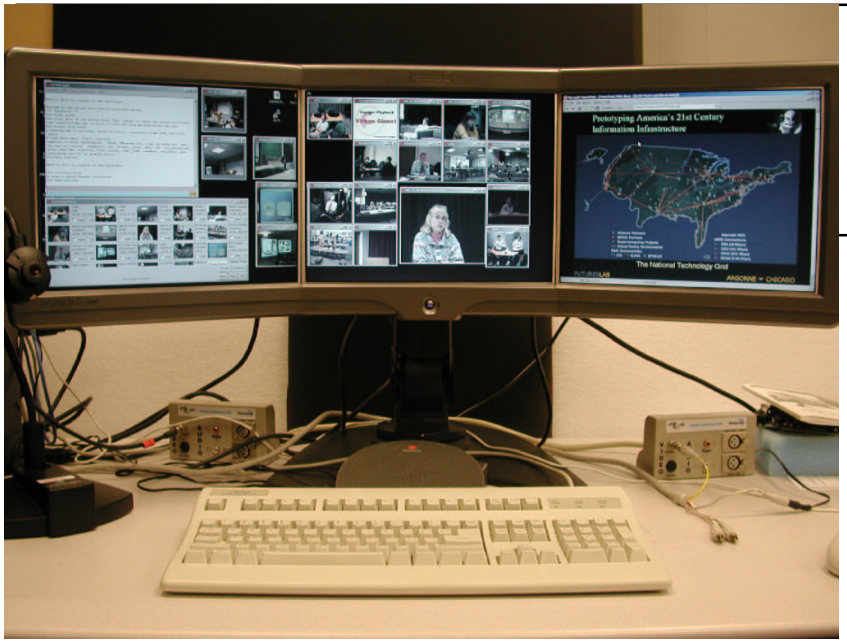
Electron cloud and other vacuum effects

RHIC

Sometimes the problem appears to be related to ION beam losses ...



There is little other world experience at these energies



Remote Operations and Maintenance

The relevance is clear, although the technology is still in rapid motion

- CMS Virtual Control Room
- GRID, MVL

Remote control room scenarios:

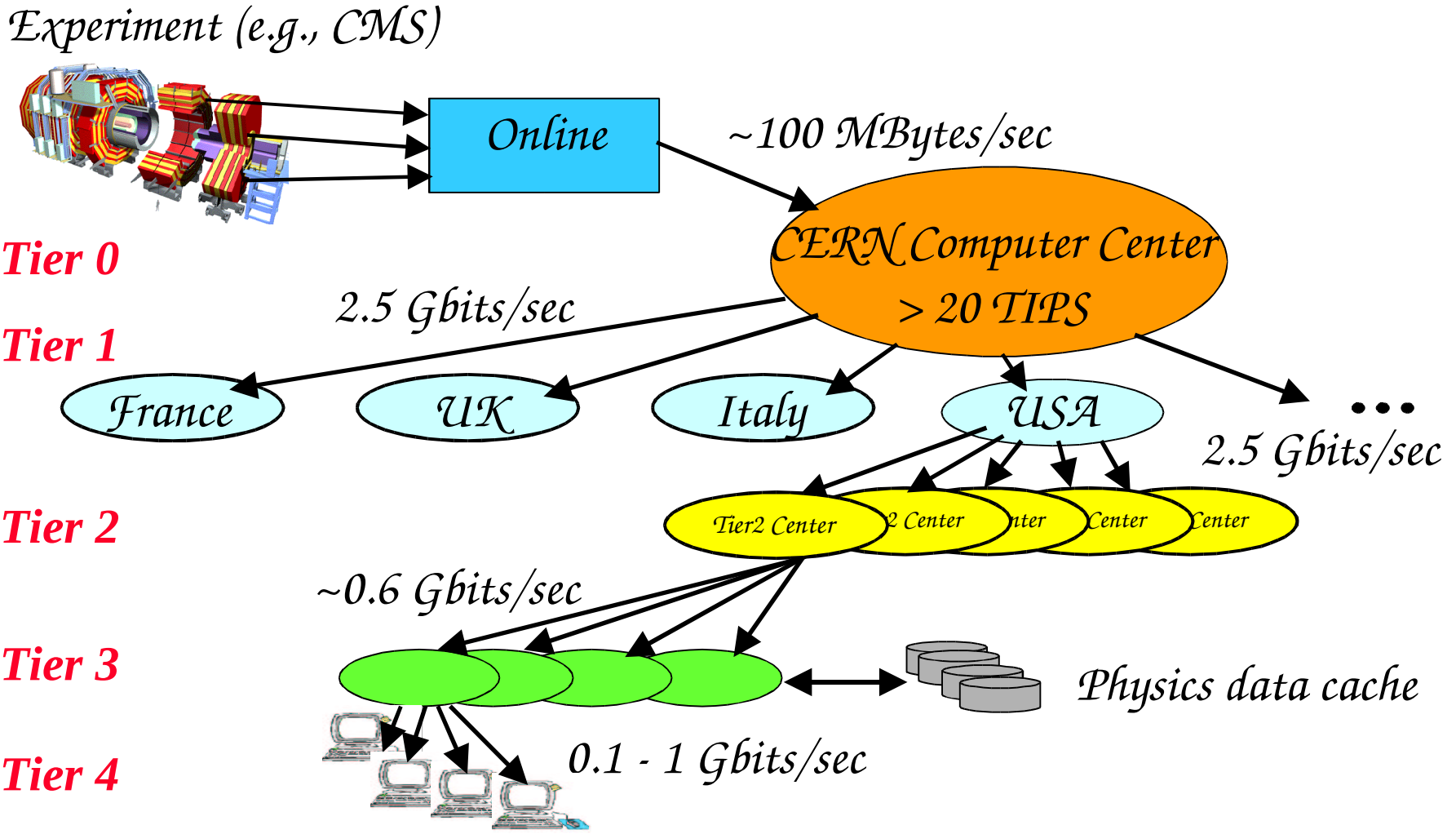
- symmetric synchronous
- symmetric sequential
- asymmetric

For LARP, asymmetric:

"Don't duplicate the entire control room, just enough identical displays, plus presence"

Remote Operations and Maintenance

Global LHC Data GRID



Remote Operations and Maintenance
ESGARD MVL

Our goals are strikingly similar to those of the European ESGARD "Multipurpose Virtual Laboratory" (MVL) proposal:

- create a versatile set up, easy to transport and install
- naturalistic video and audio technology
- accelerator controls, access to stored data, e-logs

MVL institutions:

- DESY, Daresbury, Elletra, GSI, INFN Milan, Saclay, U. Rome, U. Valencia, + non-Europeans expressing informal interest

If successful, ESGARD could have a very interesting prototype implementation in 2 or 3 years?

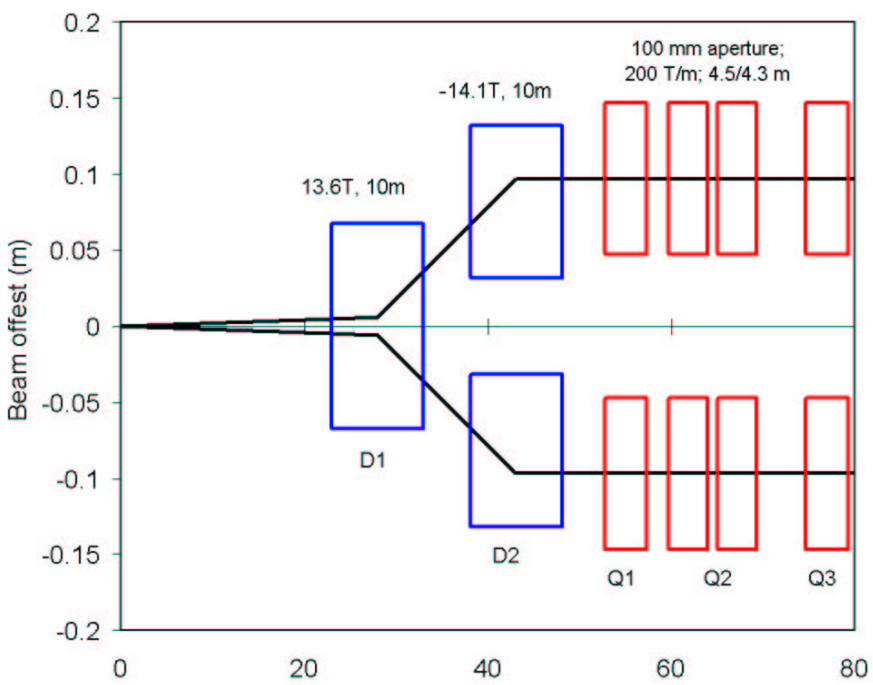
LHC upgrade optics

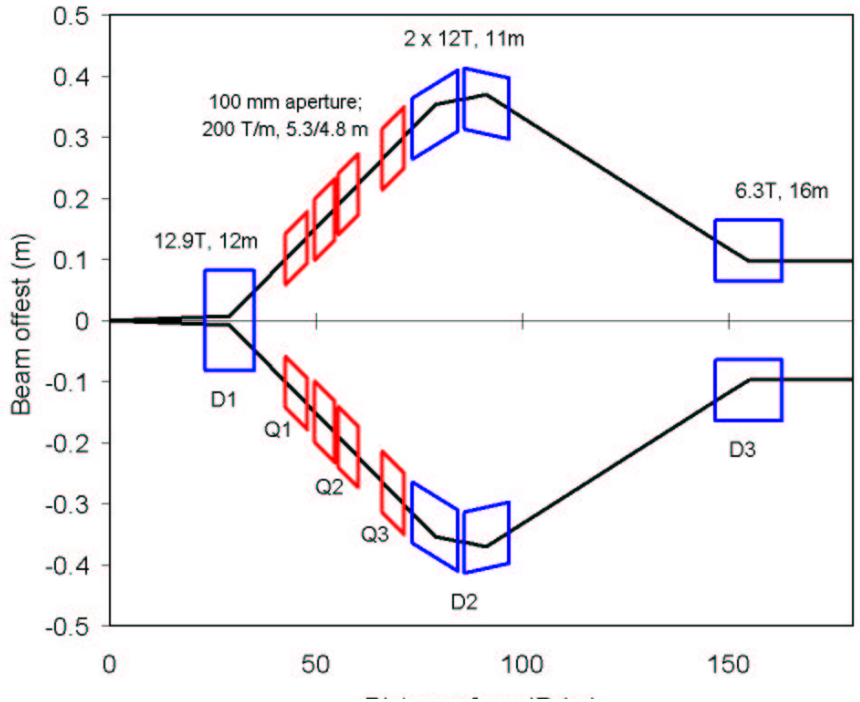
In principle there are many upgrade possibilities on the table ...

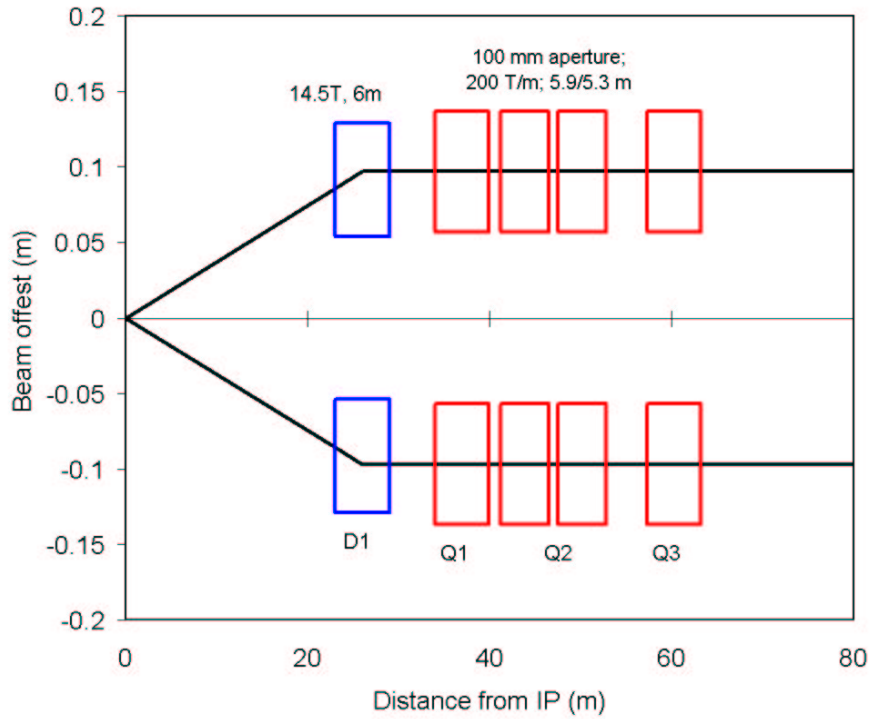
Table 2: Beam parameters for different LHC upgrade

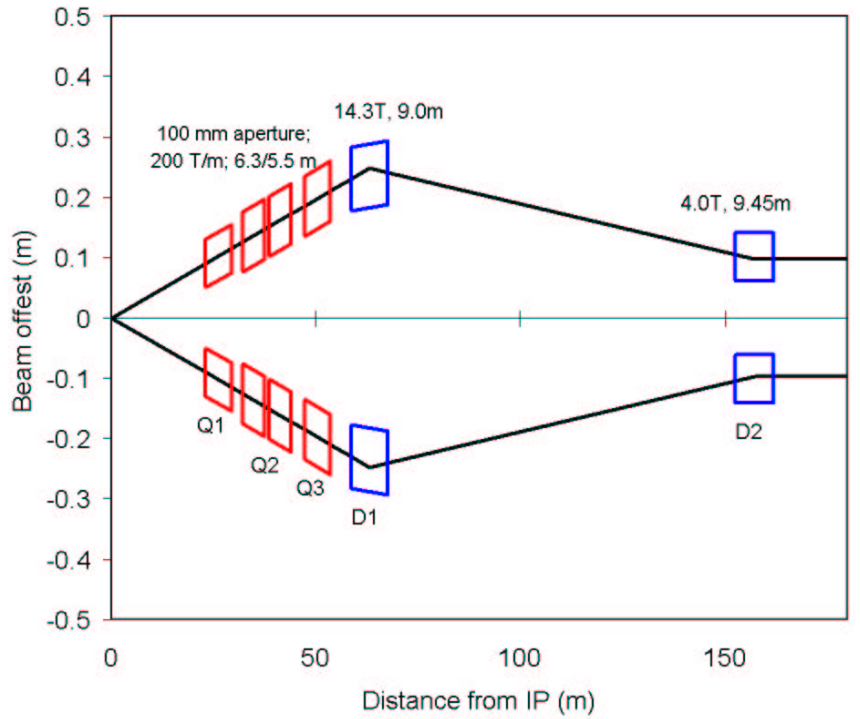
Scenario Ref.	Remarks	E [TeV]	Ib [mA]	nb [-]	σ_z [mm]	Luminosity [cm-2.s-1]
A	Nominal	7	0.20	2808	77	1.00E+34
A'	Ultimate	7	0.30	2808	77	2.31E+34
A"	Modest upgrade	7	0.30	2808	38.5	4.63E+34
Bbb	With bunched beam	7	0.30	5616	38.5	9.25E+34
Bsb	With super-bunch	7	1029	1	75000	9.40E+34
B'	Strong bunches	7	0.48	2808	77	8.70E+34
Cbb	With bunched beam	14	0.14	2808	54.4	1.00E+34
Csb	With super-bunch	14	75.6	1	8250	1.00E+34
Dbb	With bunched beam	14	0.23	5616	54.4	1.00E+35
Dsb	With super-bunch	14	720	1	75000	1.00E+35

... but in practice only IR upgrades are "this side of the horizon"


100 mm aperture;
200 T/m; 4.5/4.3 m
-14.1T, 10m
13.6T, 10m
D1
D2
Q1
Q2
Q3
Beam offest (m)


2 x 12T, 11m
100 mm aperture;
200 T/m, 5.3/4.8 m
6.3T, 16m
12.9T, 12m
D1
Q1
Q2
Q3
D2
D3
Beam offest (m)

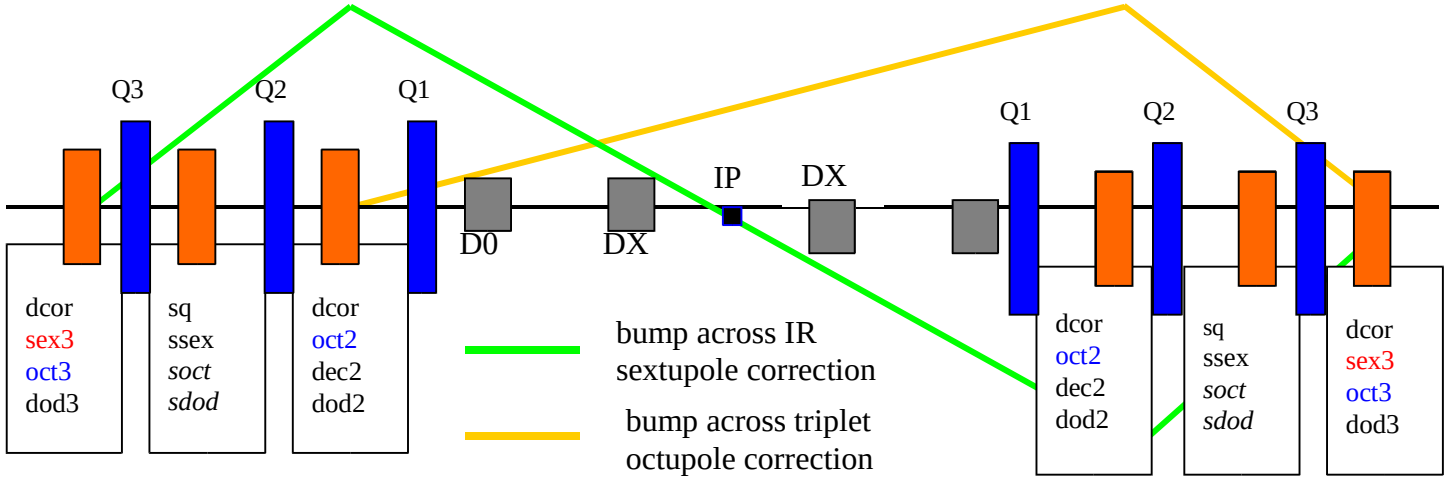

100 mm aperture;
200 T/m; 5.9/5.3 m
14.5T, 6m
D1
Q1
Q2
Q3
Beam offest (m)
Distance from IP (m)


14.3T, 9.0m
100 mm aperture;
200 T/m; 6.3/5.5 m
4.0T, 9.45m
Q1
Q2
Q3
D1
D2
Beam offest (m)
Distance from IP (m)

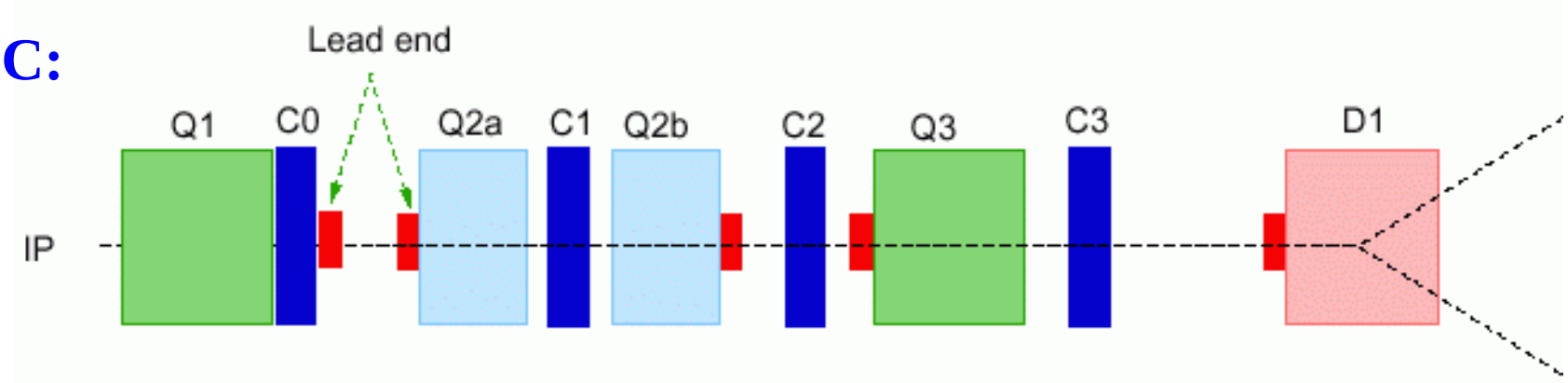
ggs

Interaction Region compensation
RHIC -> LHC -> Upgrade

RHIC:



LHC:

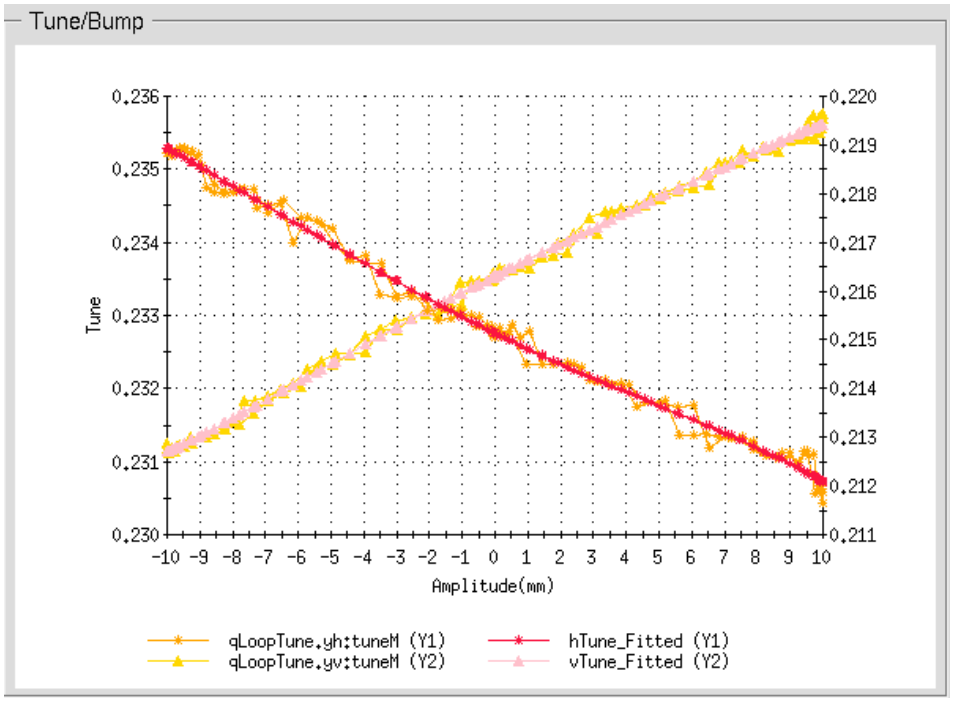


Interaction Region compensation

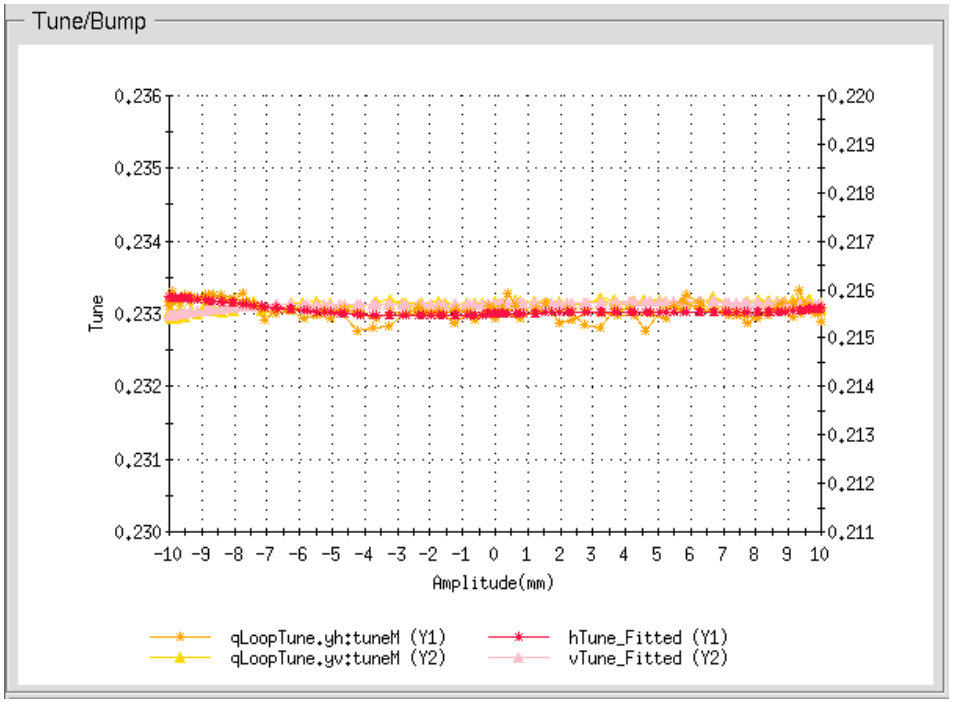
RHIC - tune versus bump amplitude

Data: Pilat et al, BNL

Before IR8 sextupole correction



and after



Relies on automated PLL tune measurements with 1e-5 resolution

Energy deposition & beam loss scenarios

The large stored energy (350 MJ) in the LHC beam will provide many operational problems

- analysis of energy deposition effects is ongoing
- strong technical expertise at Fermilab
- IR magnet heat load problem gets worse in an upgrade

Gradual beam loss from intended buckets into abort gap

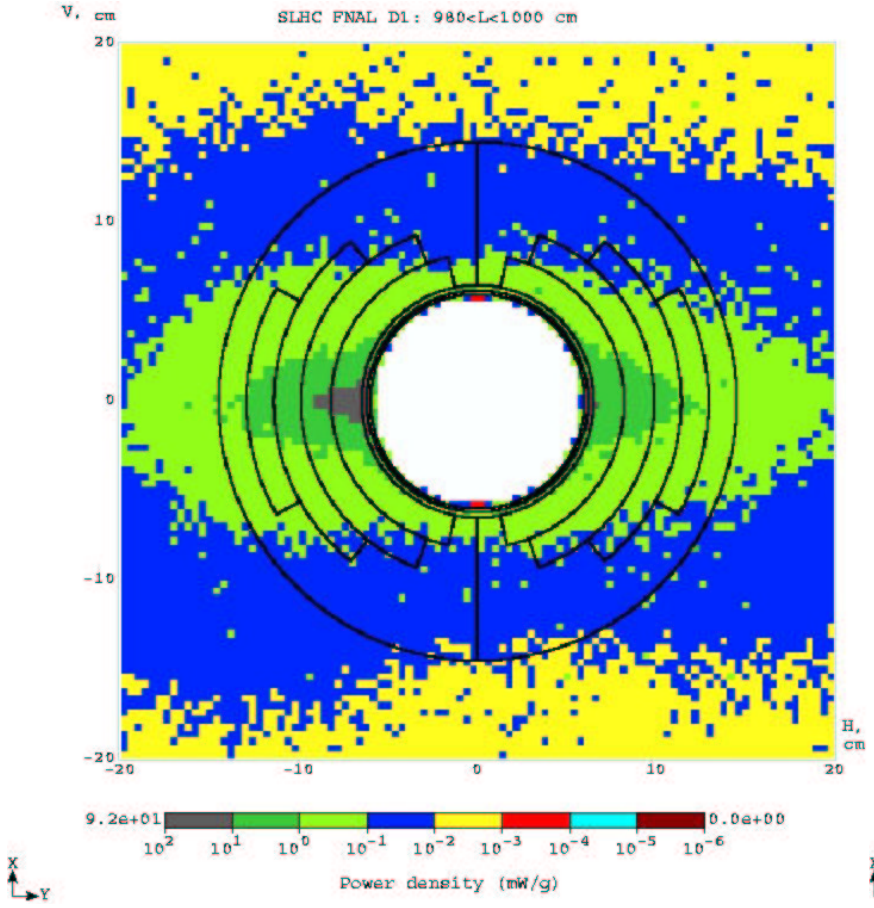
- can cause quenching during beam dump/abort
- is not well understood (cf Tevatron)
- is amenable to study with Longitudinal Density Monitors

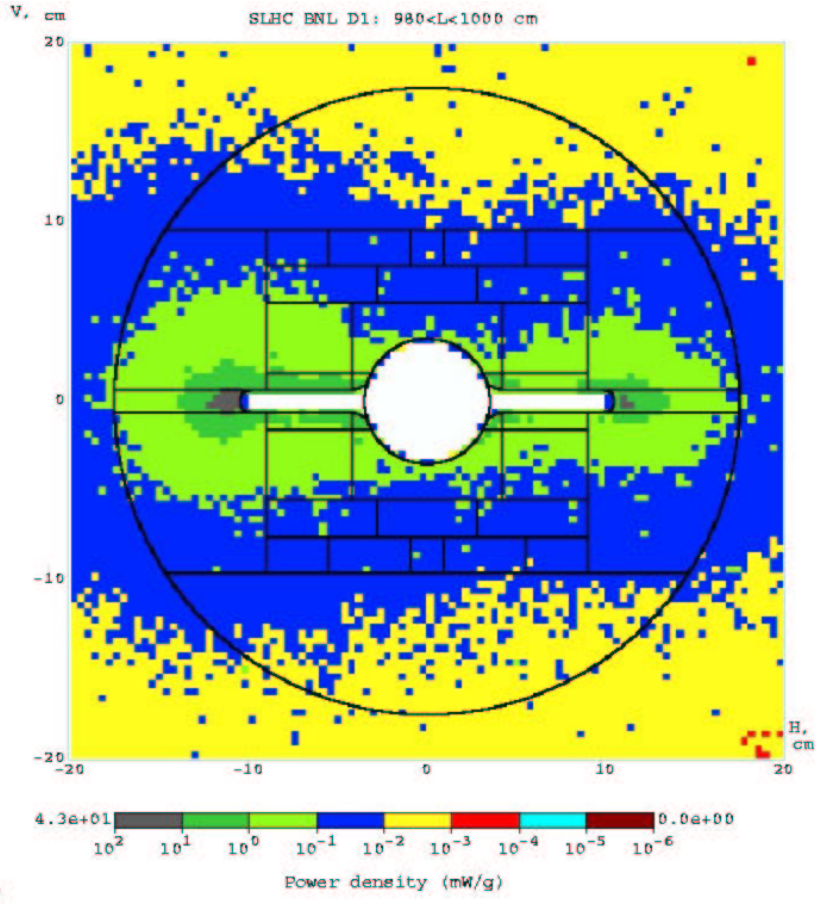
Energy deposition

D1 in a "dipoles first" upgrade scenario

MARS data: Mokhov et al, FNAL

Will the first beam splitting dipole survive? 3.5 kW per magnet?





Summary

LARP Beam Commissioning

- deliver more luminosity, sooner, to US Experimentalists
- "learn from the school of hard knocks" for present & future
- ideal control room presence 12 FTEs, guideline allows 9.5 FTEs
- integration with CERN teams must begin early

Beam Commissioners will have system responsibilities

- eg "end-to-end" integration of initial 3 instruments
- control room shifts by Accelerator & Instrumentation Physicists
- where are the boundaries, etc? More discussion w CERN needed

Fundamental Accelerator Physics (many details)

- level of effort activity, using/developing unique US capabilities
- smooth flow from LHC nominal to LHC upgrade topics
- natural synergy with Instrumentation activities