Dipoles in the Road Map

Steve Peggs

Upgrade timescales

IR & Beam-Beam

Energy deposition

External comments

Dipole D1A specs

Summary

LARP magnet program

LARP

DOE Guidance

"It is our firm intention that the LARP activities serve to explore the limits of the technologies described herein. While the end products of LARP will be applied to the LHC, LARP is not intended to be an engineering and construction service organization to that facility."

"LARP is not intended to replace existing base program support at the various laboratories in superconducting magnet development and other ongoing areas."

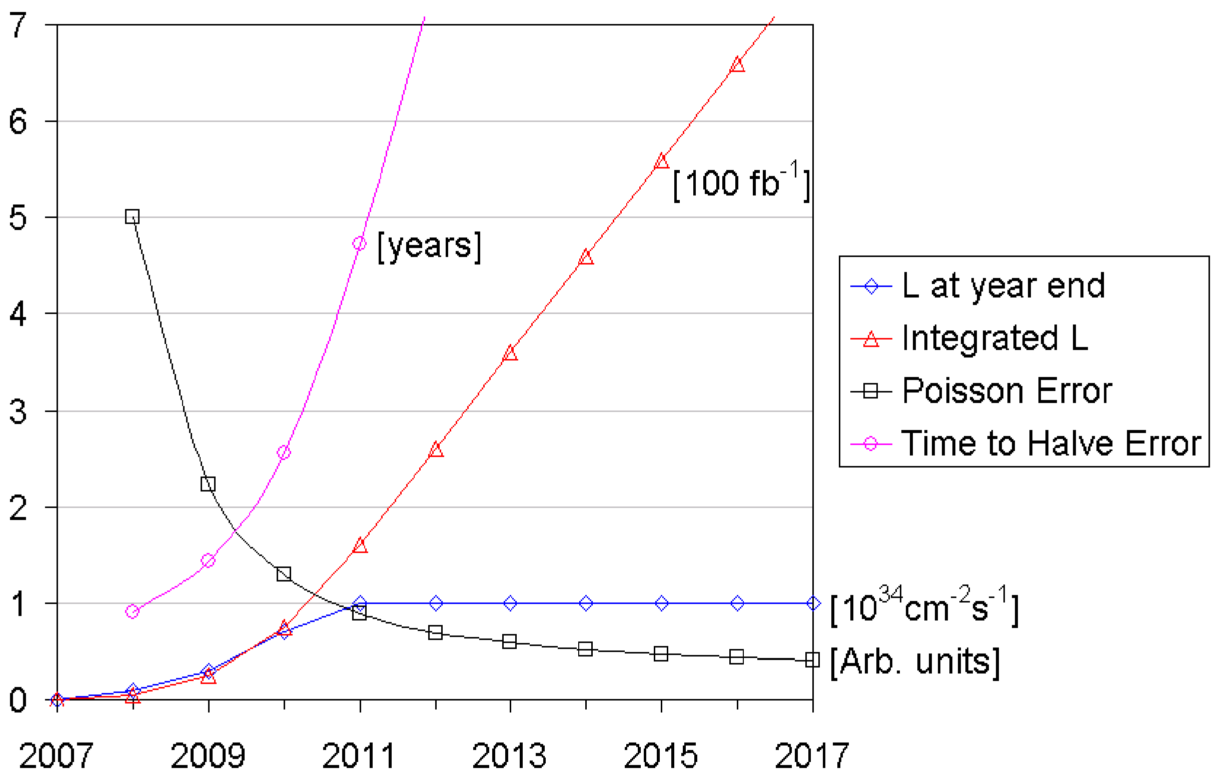
LARP Proposal

"have fully developed and proven accelerator-ready magnet designs, ready for production, by about 2012, as required to support the LHC physics program."

Upgrade timescale

Expect the upgrade to occur in about 2012

- suggested by the “time to halve” curve
- permits ~2 years of beam experience before design commitment



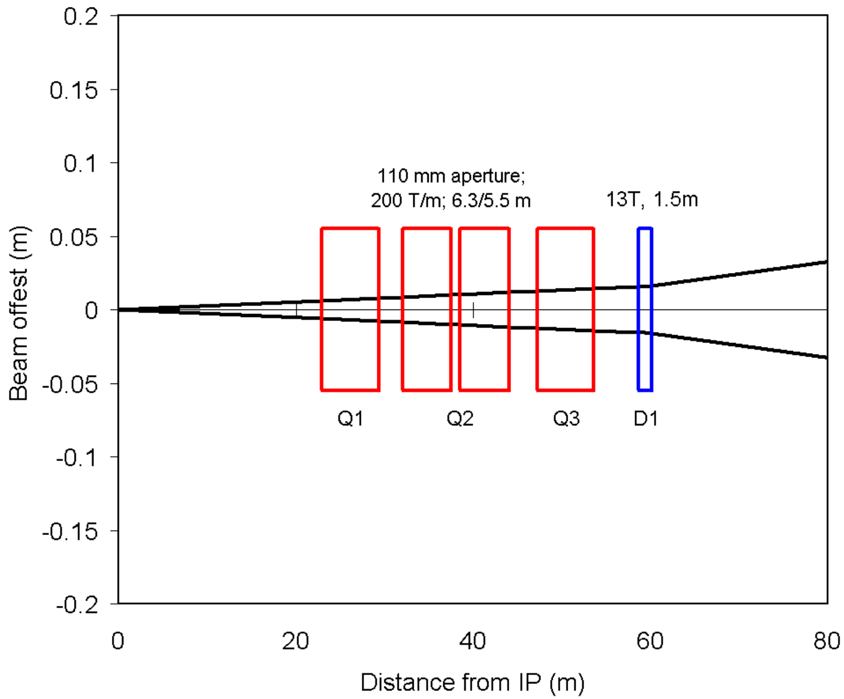
⇒ Must consider several ways to achieve it.

⇒ Must start R&D now.

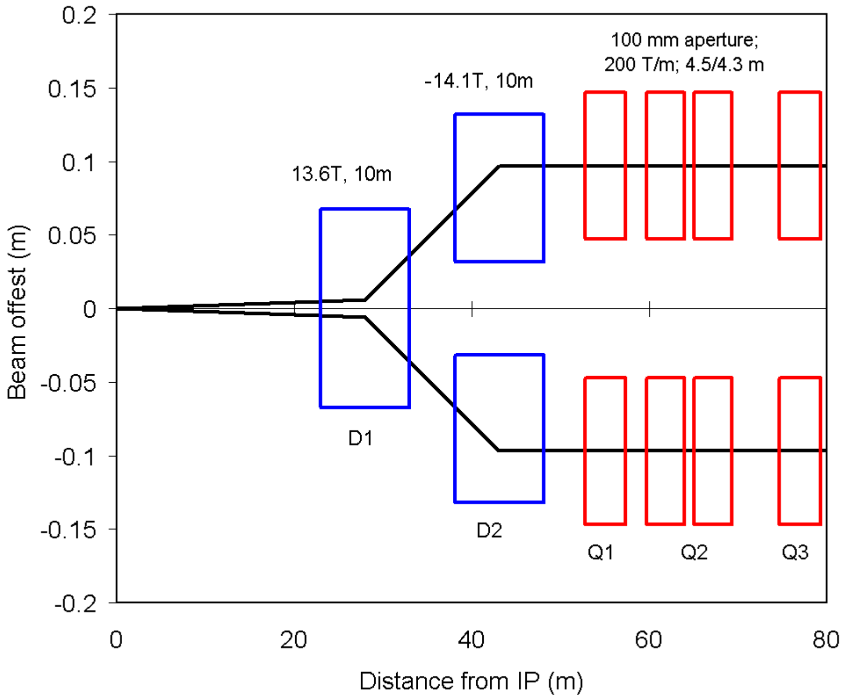
⇒ Must choose R&D directions judiciously.

“Straightforward” IR layouts

Quads 1st



Dipoles 1st



Eg baseline IR with larger bore quads
- the most likely contender

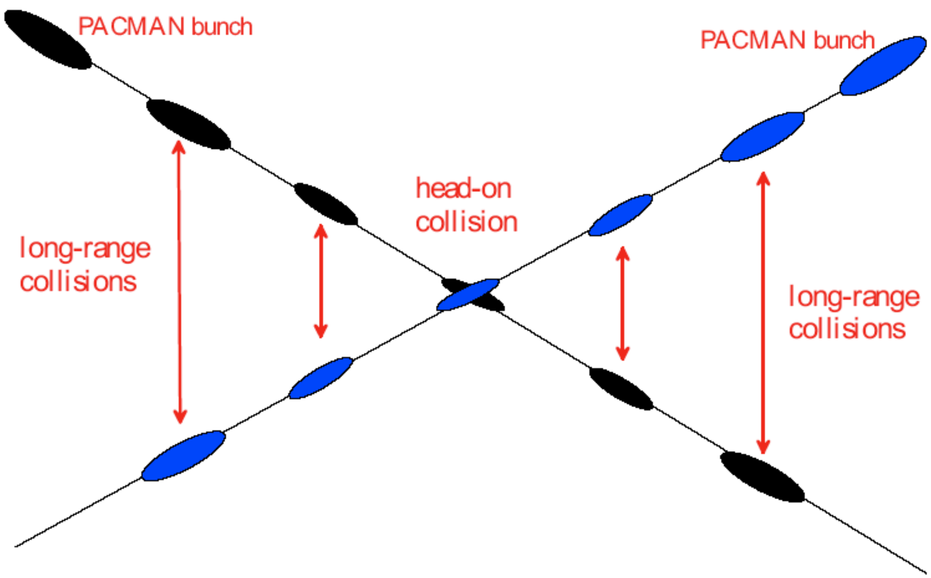
Fewer long-range collisions
- larger β_{max}
- in some favour at CERN

Long range beam-beam collisions

Many *strong* long range collisions per IP, before separation begins

~ 32 with "quad first" (25 ns bunch spacing)

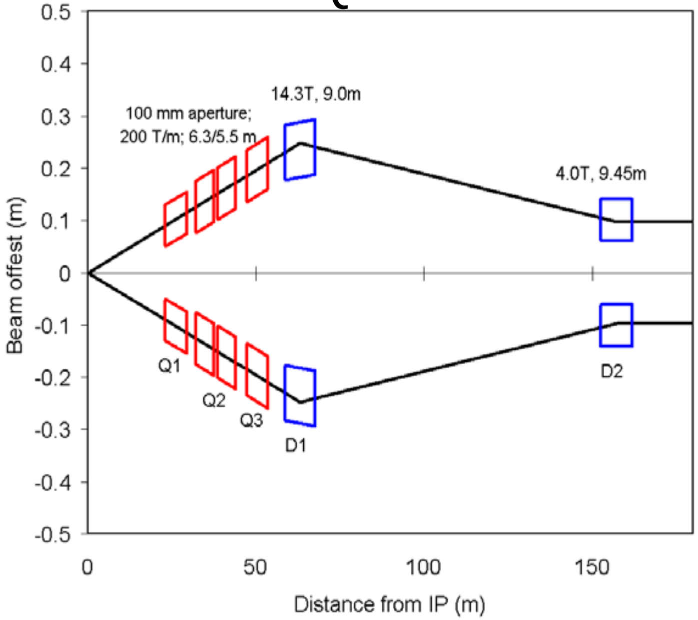
~ 13 with "dipole first"



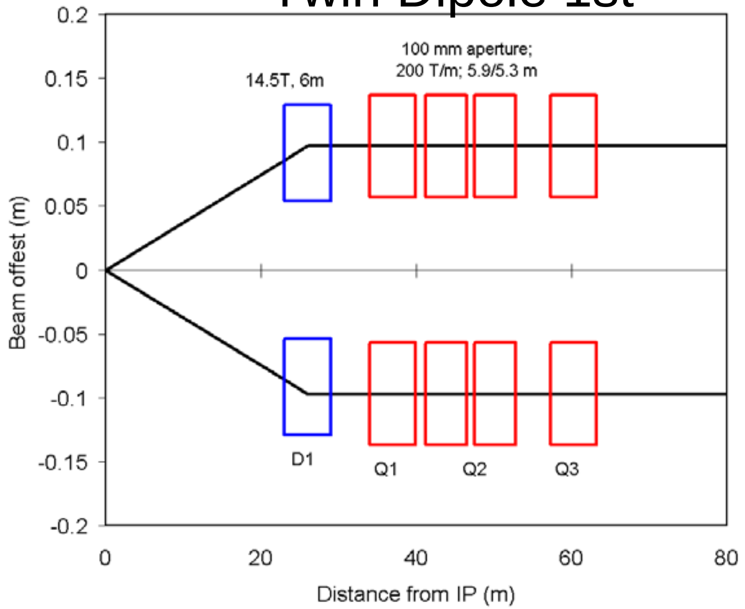
If necessary, a large crossing angle (~ 10 mrad instead of ~ 0.3 mrad) would reduce the long range tune shift by a factor of ~ 1,000

“Large crossing angle” layouts

Twin Quads 1st



Twin Dipole 1st



Typical crossing angle 10 mrad

~ 23 cm separation at first magnet

- requires crab cavities (cf KEKB)

Crab cavity parameters

variable	symbol	**KEKB**	**LHC**
beam energy	E_b	8 GeV	7 TeV
rf frequency	f_{crab}	508 MHz	1.3 GHz
crossing angle	Θ_c	11 mrad	8 mrad
IP β	β^*	0.33 m	0.25 m
cavity β	β_{cav}	100 m	2 km
kick voltage	V_{crab}	1.44 MV	46 MV
phase tolerance	$\Delta\phi$		0.06 mrad

Interest: much in Japan, some in US, some at CERN

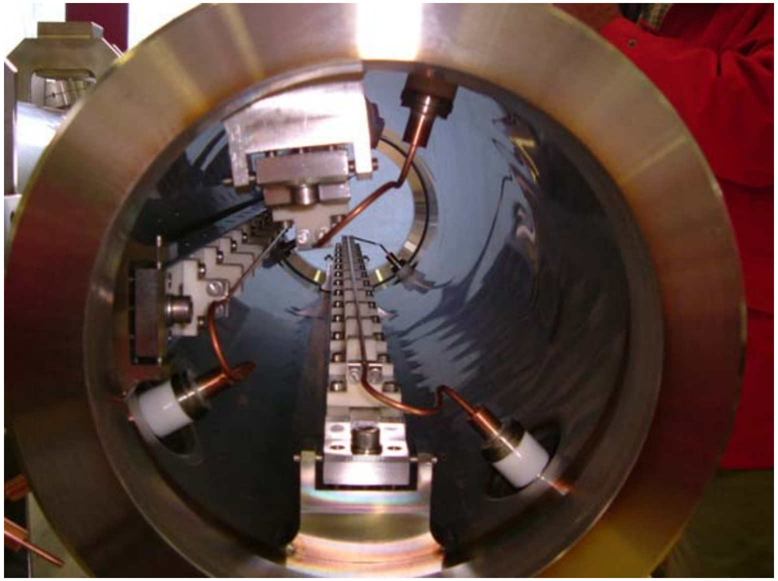
Active beam-beam compensation?

Electron Lens (FNAL)

Corrects head-on or long range

- performance unproven ..

Wires (SPS)



Long range only

- simple concept
- interest at CERN & BNL
- partial solution ..

Beam-beam program

Electron Lens promising, but conditions difficult to control

Wire compensation of LR collisions at LHC will allow smaller crossing angles and/or higher bunch charges;

- experimental demonstration in the SPS
- pulsed wire desirable for PACMAN bunches
- bi-lateral interest from BNL?

Alternative: large crossing angles with crab cavities

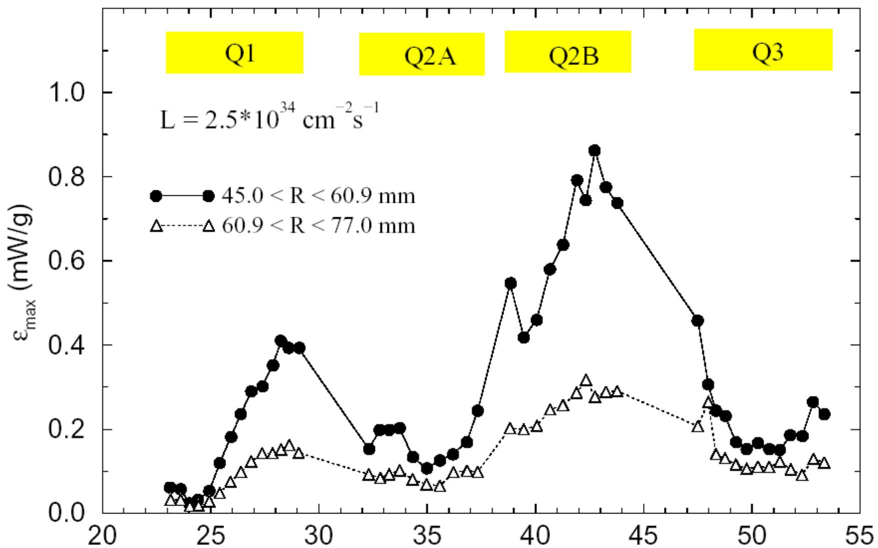
Part of the LARP Task “Interaction Regions & Beam-Beam”

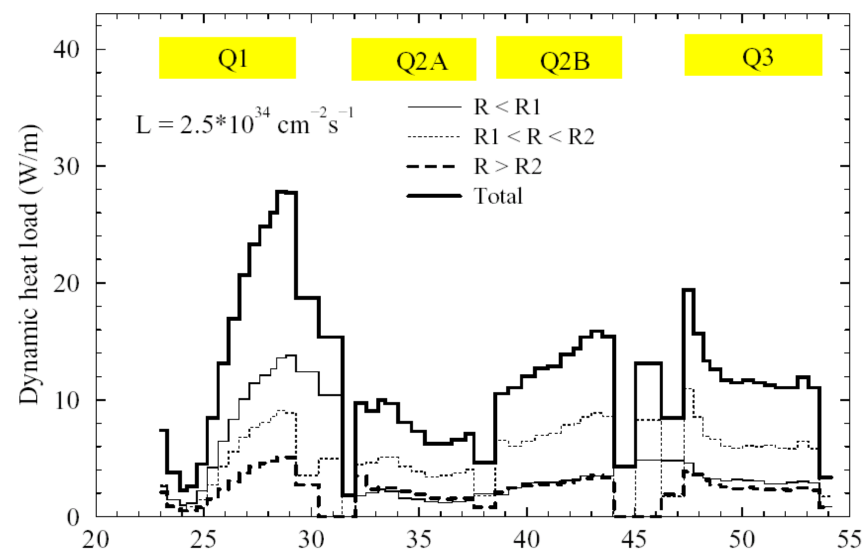
Energy Deposition

LARP

Energy deposition and radiation are *major* issues for new IRs.

- In quad-first IR, E_{dep} increases with L and decreases with quad aperture.
  - ε_{max} > 4 mW/g, $(P/L)_{max}$ > 120 W/m, $P_{triplet}$ >1.6 kW at $\mathcal{L} = 10^{35}$ cm^{-2} s^{-1}.
  - Radiation lifetime for G11CR < 6 months at hottest spots.

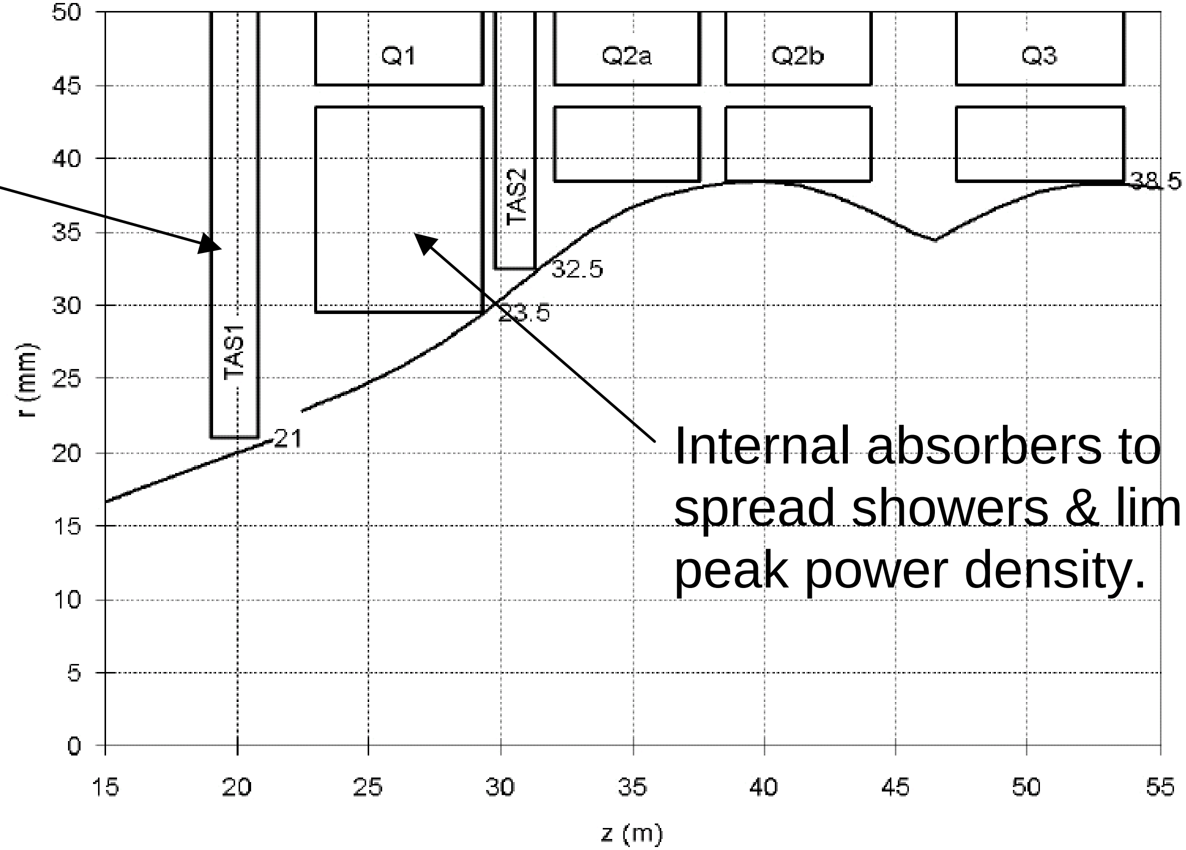




T. Sen, et al., Beam Physics Issues for a Possible 2nd Generation LHC IR, EPAC 2002.

TAS1 & TAS2 with quad first

Front absorber (TAS) to limit flux hitting quads.



Internal absorbers to spread showers & limit peak power density.

Figure 3: The aperture in the inner triplet with 90 mm aperture quadrupoles, $\beta^{*}=0.25$ m, beam separation=9.4σ.

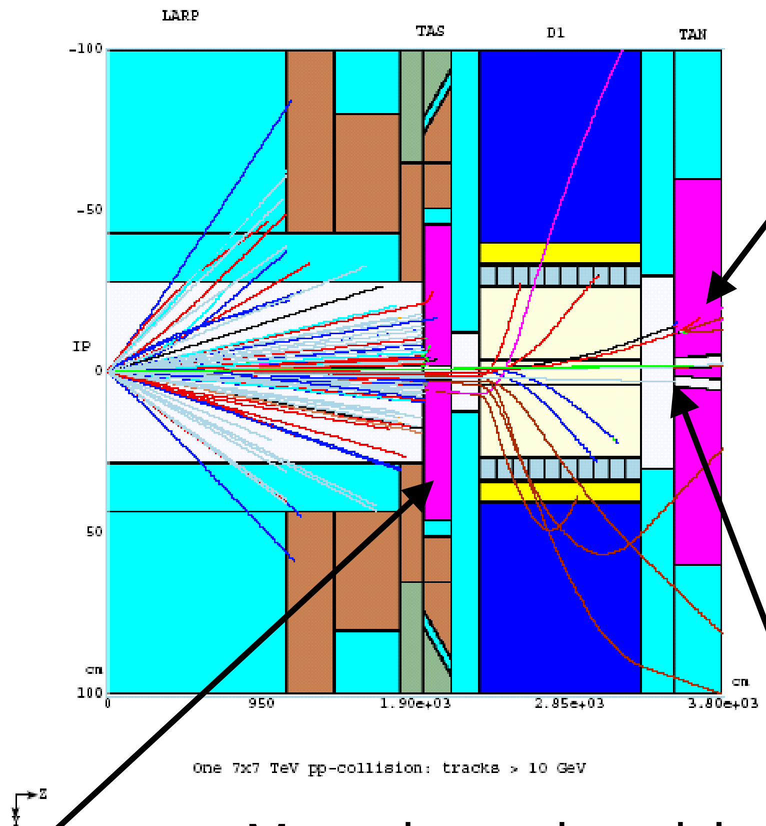
T. Sen, et al., Second Generation High Gradient Quadrupoles for the LHC IRs, PAC 2001.

Energy deposition with dipole first

CERN question:

"Could a magnetic TAS help limit the flux hitting the first dipole?"

DIPOLE-FIRST IR: ONE PP-EVENT



TAN

TAS

Most charged particles entering dipole are swept into the magnet.

Fermilab

N. Mokhov

Ruggiero, Taylor, et al - EPAC 04

"Nb_3Sn technology
- appears to be the only candidate for a substantial improvement"
(current NbTi technology is not sufficiently radiation hard)
- could open upgrade scenarios such as 'dipole-first'"

"Important issues related to long Nb_3Sn magnets need to be addressed by vigorous R&D"

"The effective Nb_3Sn filament diameter (>100 μ) is too large" (Material development required.)

"The choice of the coil aperture is driven more the power density limit than by the beam acceptance"

"An estimate of the radiation parameters of the magnets requires extensive simulations based on detailed knowledge"

LARP External Review - June 2004

LARP

"LAPAC suggests that the main issue is demonstration that (Nb_3Sn) quads can be made in both long and short lengths."

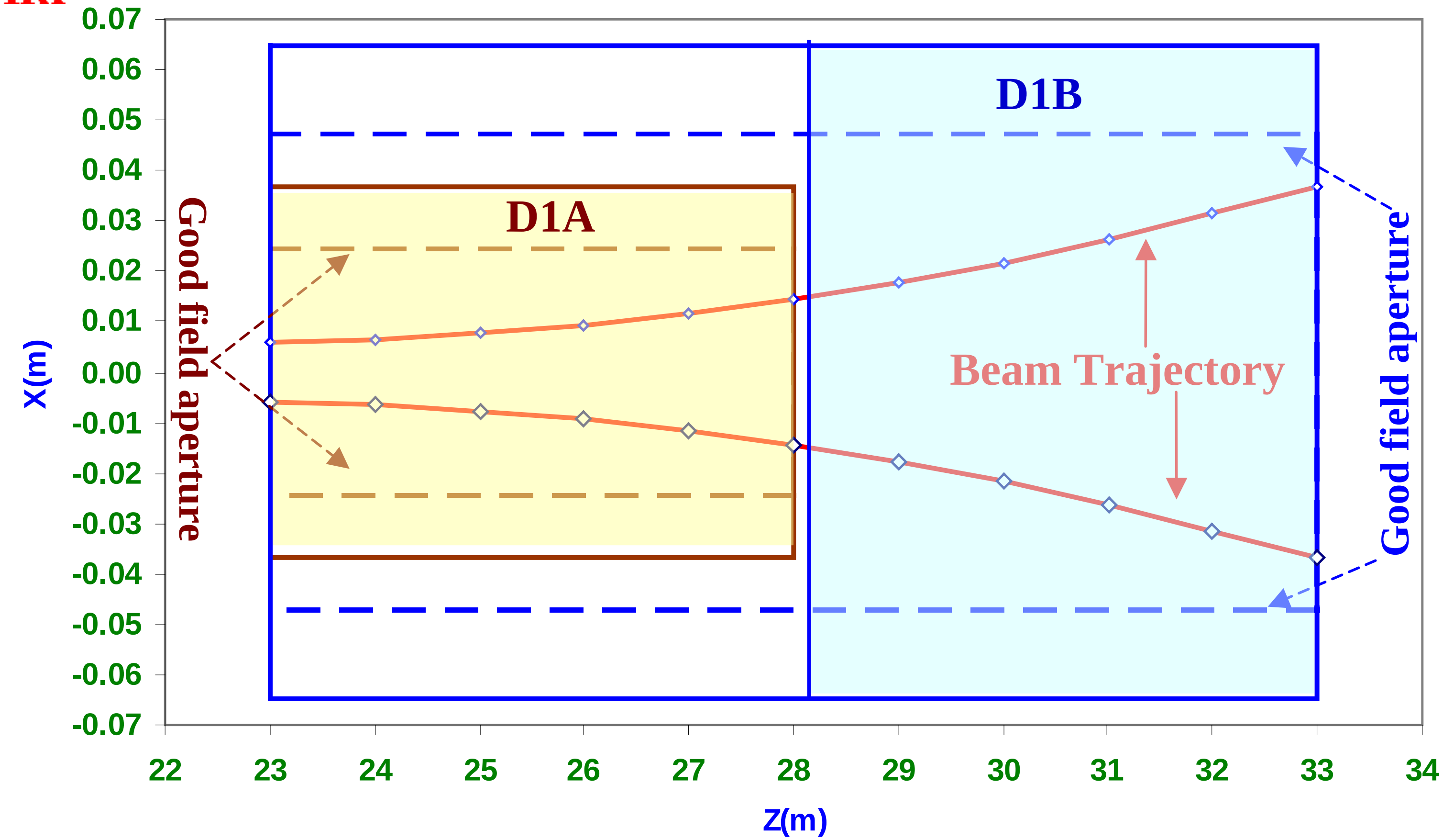
"... demonstration of a working long quadrupole, the first of its kind in the world, will be a key element in the decision to start … the LHC luminosity upgrade."

"(Dipole) work is focused on the 'dipole first' scenario, which must meet the most severe requirements; an open mid-plane design … 15 T, 10 m"

"Since the new IR layout … is not known, … recommend against going further than … to deliver a low cost and simple (dipole) demonstration model …"

LARP doesn't fully agree, but the comments are telling

Address D1A problem first …



"Specs": L = 5 m, B = 15 T, GFA(H,V) = +/-(28,14) mm

"Good field": better than 10^{-3}

Summary

The challenge of increasing LHC luminosity towards 10^{35} cm^{-2} s^{-1} is considerable. Many options need to be pursued, including dipole first and large crossing angles.

IR layout "Road Map" assumptions:

- Install the upgrade 5 or more years after first collisions
- Upgrade design will respond to 1 or 2 years of "real beam"
- Beam-beam will play a crucial role in evaluating the options
- "Quad first" is the most likely scenario
- Evaluate other layouts with CERN (and others?)

Luminosity debris:

- Will magnets quench? Can heat be removed? Survival time?
- How much worse in the "dipole first" scenario?
- End-to-end analysis required