Phase II Scenarios

R. Calaga, Sept 18, 2009

- LHC Upgrade & Crab Scenarios (3)
  - Assumption: Phase I Success Needed ?
- Luminosity Leveling
- Future Prospects & Challenges

Ack: CC Collaboration

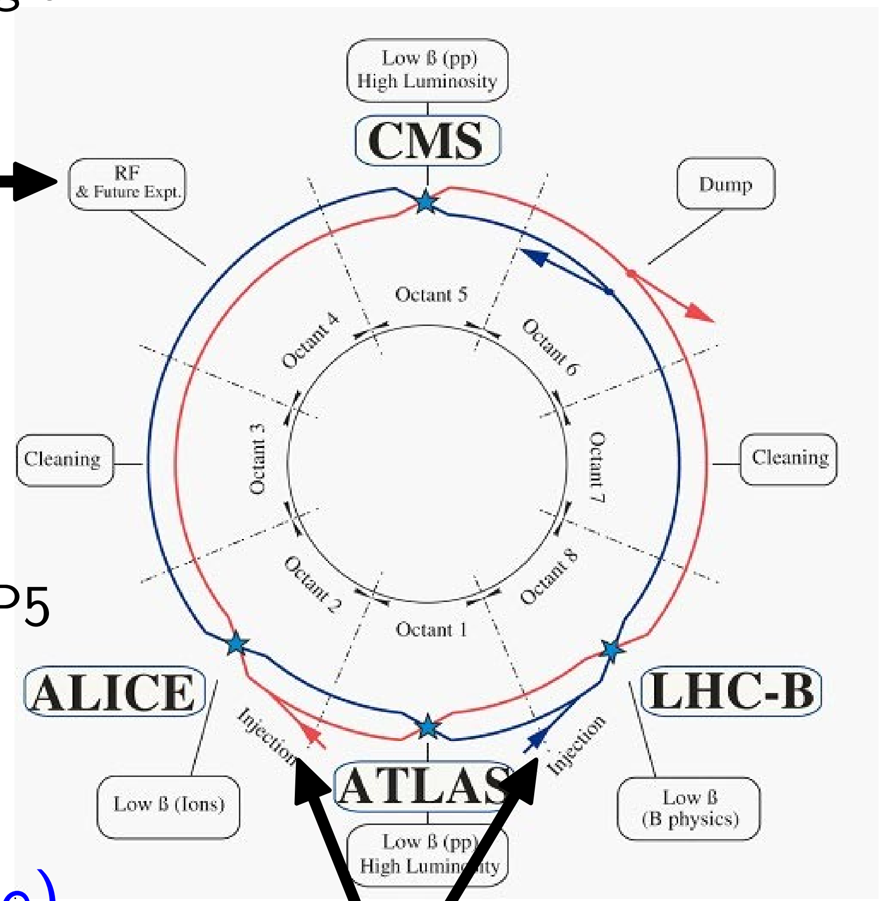
Phase II Scenarios

Upgrade scenarios aim at x10 increase in Luminosity:

- D0 in detector ($N_b = 1.7 \times 10^{11}$, $\beta \sim 10$ cm, crab cavities to $\mathrm{eff}\{\Phi_{piw}\} = 0$)
- LPA scheme ($N_b = 5 \times 10^{11}$, $\Phi_{piw} \sim 2$, $\sigma_z = 12$ cm, $\mathrm{eff}\{\Phi_{piw}\} = 0$, leveling)
- Full crab crossing (outside detectors, natural leveling knob)
- Low emittance ($N_b = 1.7 \times 10^{11}$, $\varepsilon \sim 1\mu$m, benefit from leveling with crabs)

Potential Crab Scenarios

- Global
  - Installation in the capture cavity region
  - Extend/Use the IR4 Dog-Leg
  - Lock Ph. Adv IP1→IP5
- Global II – where ?
  - IR4 + Dog-Leg elsewhere in ring
  - Adv: flexibility in phase adv IP1→IP5
- Local (Phase II current baseline)
  - Dog-legs (if needed) in IR1/IR5 Region
  - Adv: rest of the ring “untouched”

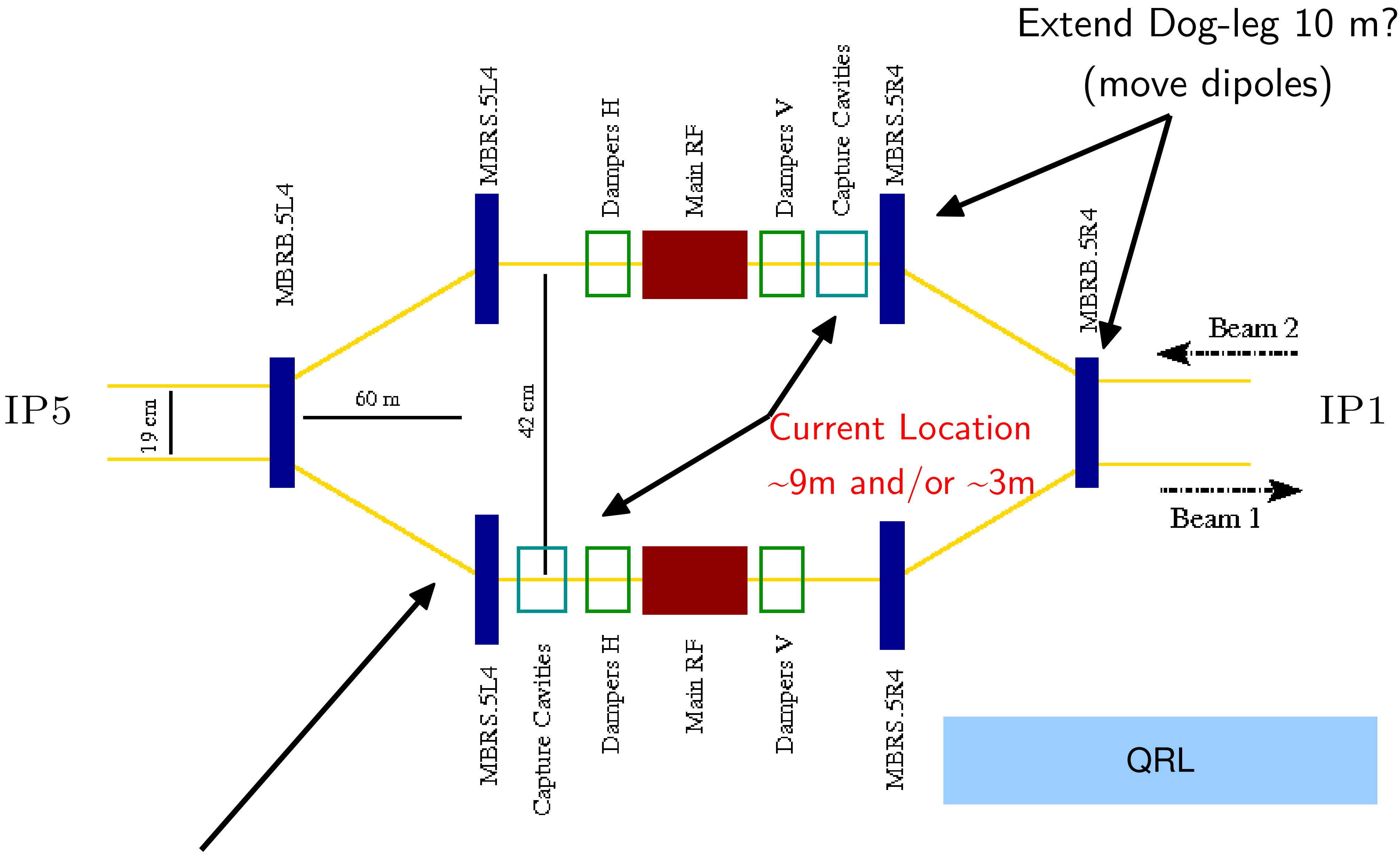


Global Vs. Local

Global	Local
IR4 section has potential options	Beam-to-beam spacing difficult
RF infrastructure/cryogenics	Need IR dog-legs, $$$$
Integration easier, fewer cavities	4 cavities/IP, control (phase...)?
	Impedance, Failures/trips (x2 or x4)
Beam dynamics more complex	Collimation worries are more relaxed
Voltage maybe large for small β^*	Crab voltage is modest (IR Optics)
Ph.Adv IP1→IP5 no flexibility	Rest of ring is undisturbed

Perhaps many others...

Global Extension, IR4



Other potential location (~37cm separation, synchrotron radiation ?)

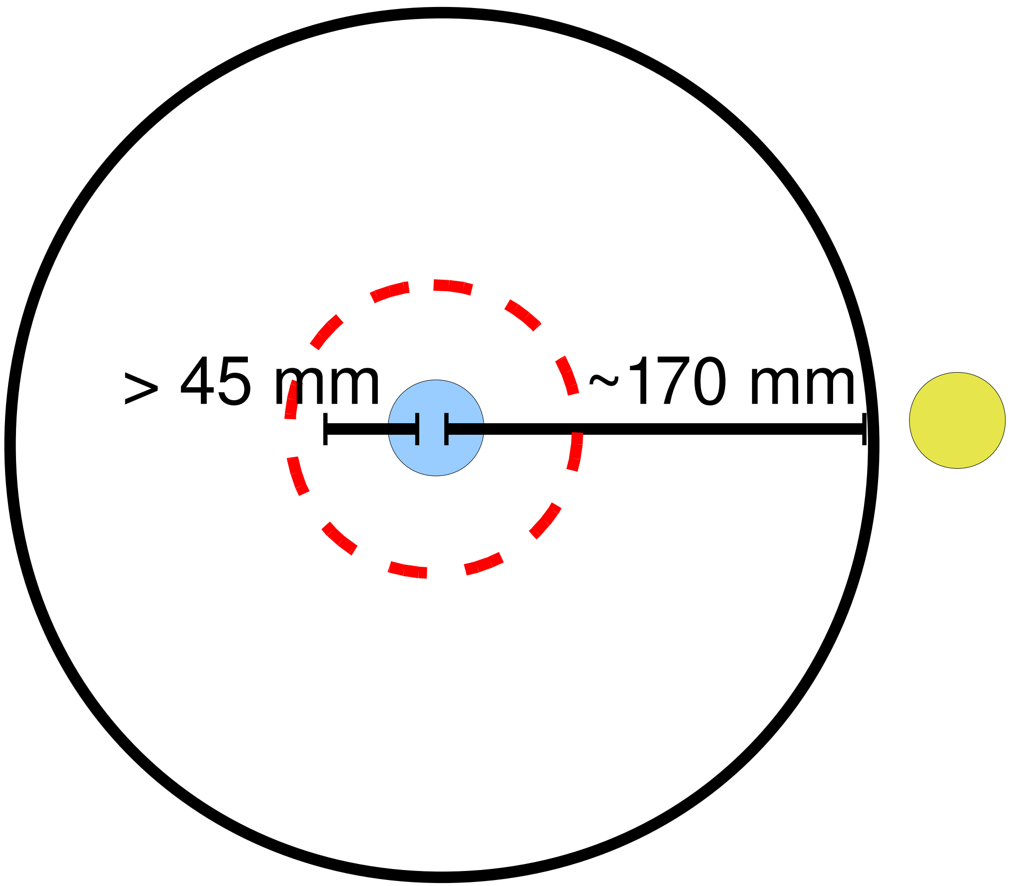
Less problematic for Beam 1 due to QRL, compact cavities better

Elsewhere in LHC

Optimistic maximum cavity size: 170 mm (beam pipe radius)

Smaller aperture NEVER desired (SRF Cavity !!!)

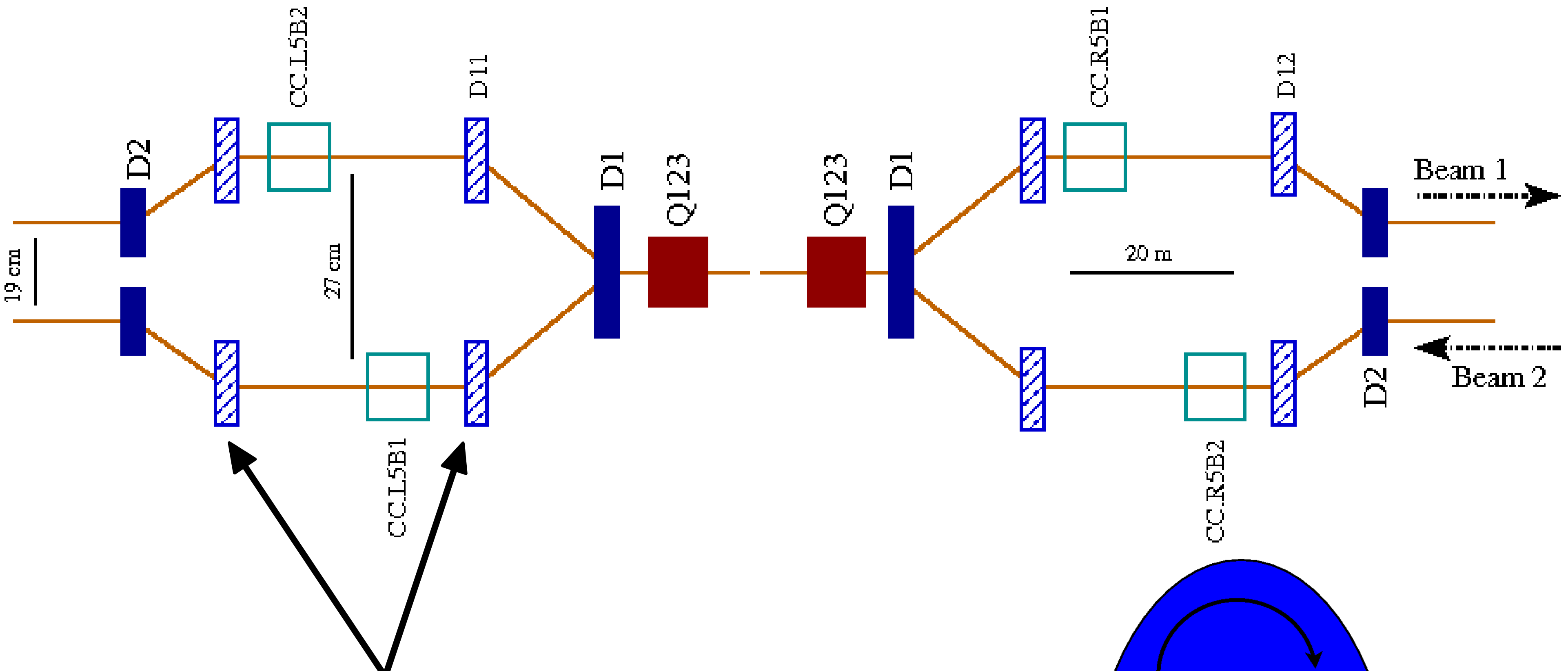
Voltage cost $$$ (smaller βcc & β*)



- Elliptical (VV): 180 mm or less
- Kota Cavity: 150 mm ($V_\perp$??)
- Jean's toaster cav: < 150 mm
- Zenghai's ½ Wave: 120-150 mm

* 800 MHz – BP inside Helium!

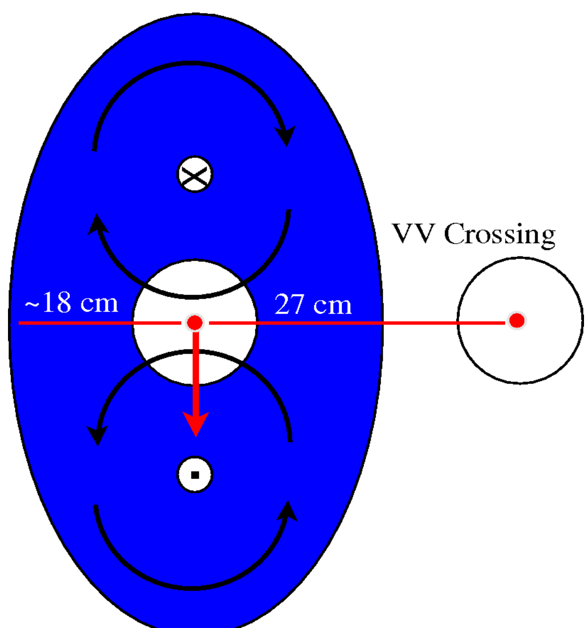
Local Scheme, IR1/5



Two extra dipoles for dog-leg (if needed)

Maximum separation “within” reach of conventional technology (VV X-ing)

Compact cavities <u>ideal</u> for local scheme



Nominal Separation: 19cm

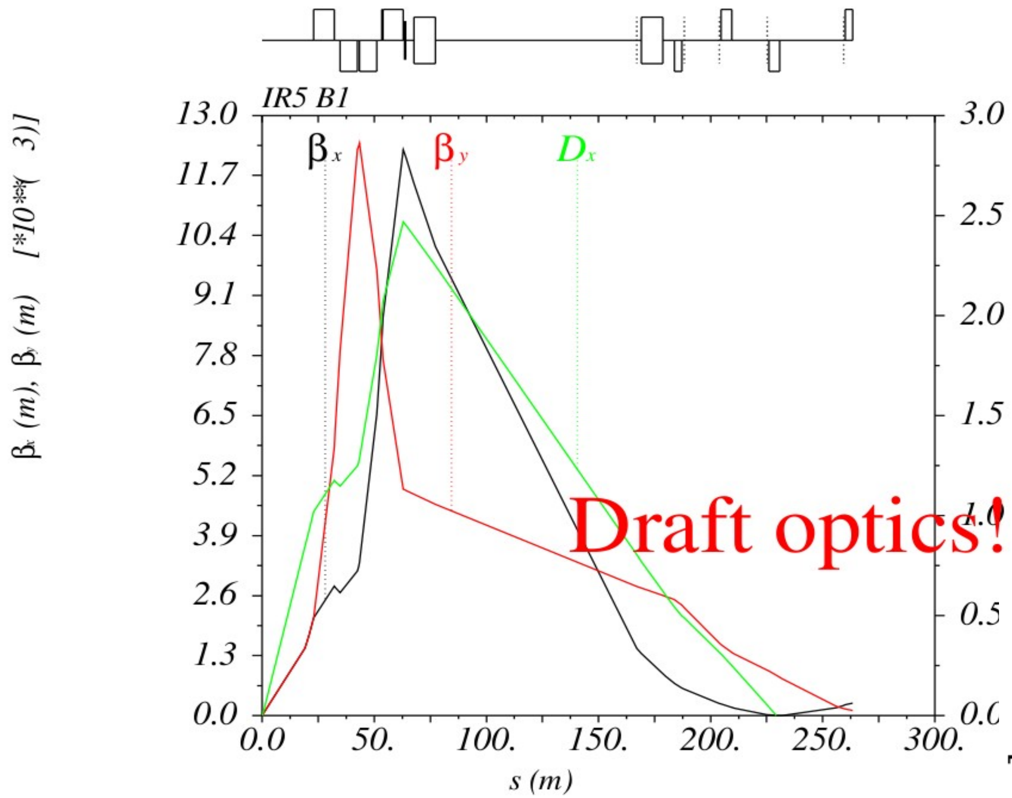
Aperture, Local Scheme

Magnet	Aper-H [mm]	Aper-V [mm]	Tesla	L [m]
D_1	134	110	7	10
D_{11}	106	70	7	10
CC	120-140 (84 required)			20
D_{12}	78	60	4	10
D_2	69	53	3.85	10

- Large aperture cavities for sufficient margin (orbit, optics, etc..)
- Instrumentation & active feedback (orbit & phase control)
- RF infrastructure and cryogenics (see R. Ostjic's talk)

Courtesy R. Tomas

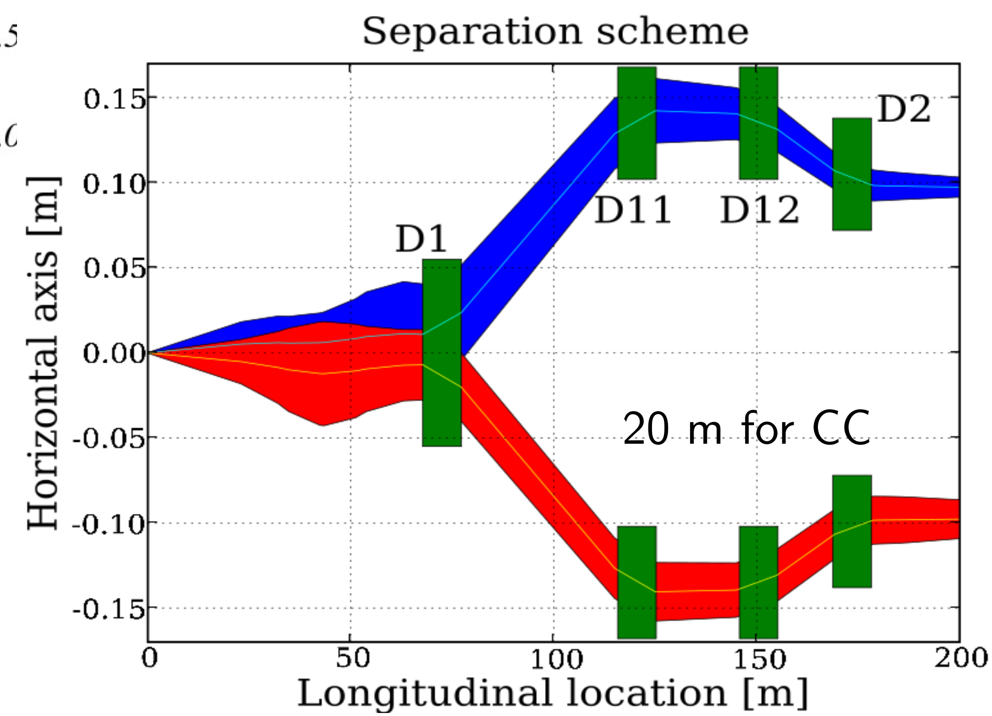
Local Layout & Optics



$\beta_{cc} \sim 5$ km

Voltage $<$ 5 MV (1-2 Cav)

Cryomodule $<$ 10 m



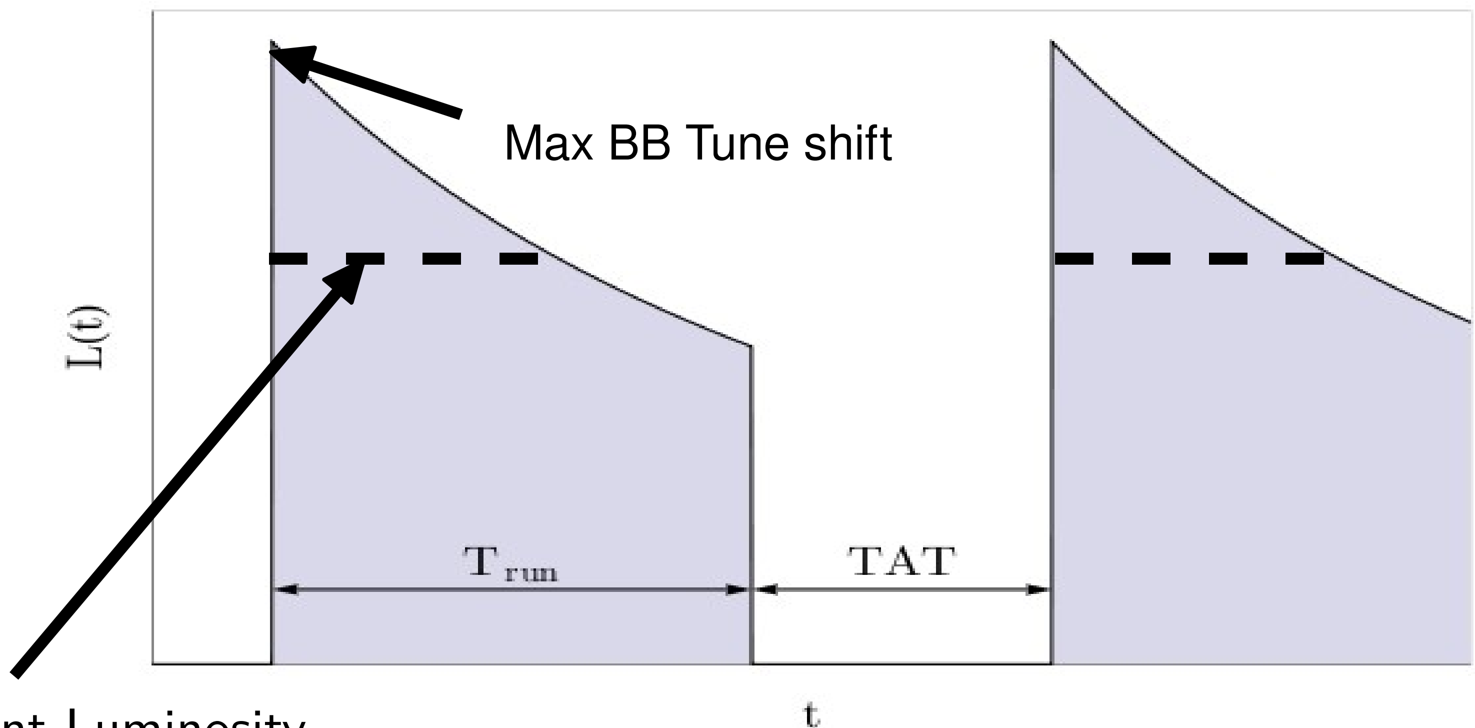
Crossing Scheme: VV (or HV)

Crossing Angle ≥ 0.5 mrad

DA ~ Similar to w/o crabs (Y. Sun)

Courtesy R. Tomas

Lumi Leveling, Crossing Angle



Constant Luminosity

Less pile up @start

Less peak radiation on

IR magnets/detector

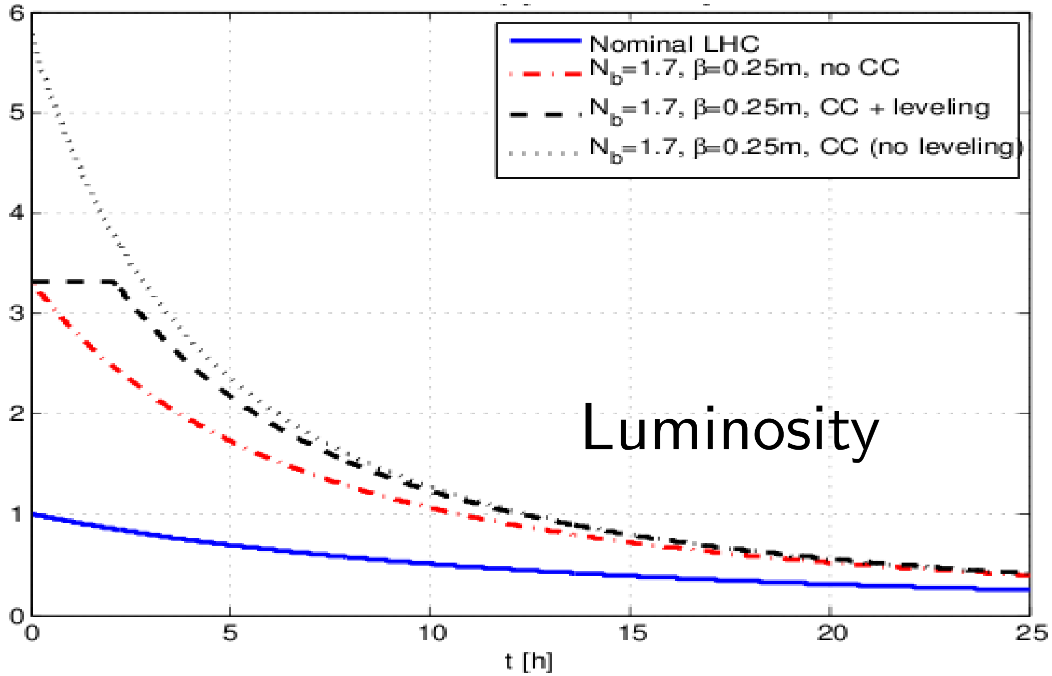
No-Leveling: $L(t) = L_{peak}/(1+t/\tau_{eff})^2$

$$\tau_{eff} \propto 1/L_{peak}$$

Leveling: $L = L_0 \; (\tau_{eff} \propto 1/L_{peak})$

Graphic courtesy G. Sterbini

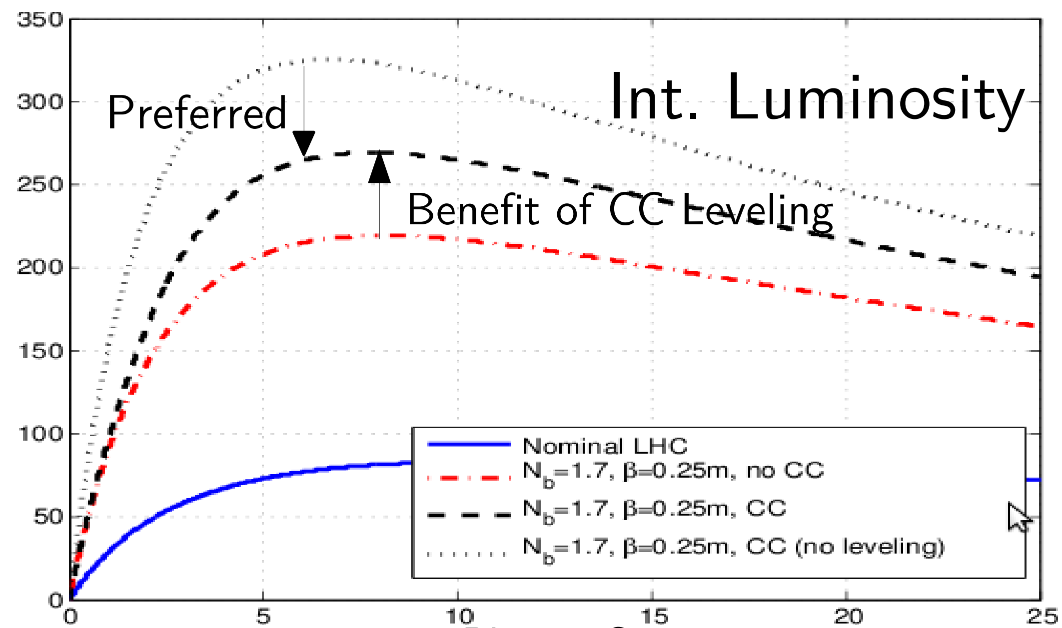
Lumi Leveling



(Assuming only proton burn-off, IBS, rest gas scattering)

Optimum run time $\propto \tau_{lev}$

Assume $T_{tat} = 5$ h



Need to study the effects of modulation of (beam-beam parameter, synchro-betatron resonances, bunch overlap)

Courtesy G. Sterbini

Beam Dynamics

A detailed "phase 2" lattice with crabs needed (X-angle, X-scheme)

DA calculations to follow as lattice, x-scheme evolves

Collimation effects (perhaps non-issue)

Impedance of 8-cavities and damping requirements !!

If global scheme remains:

Fixed phase advance between IP1-5 depending on x-scheme

Prospect of Novel Structures

Brilliant ideas $\rightarrow$ reality maybe on the horizon

But: when you add all couplers, they also look beastly

R&D outcome:

    Develop a "true" deflecting cavity (for ex: Delayen's idea)

New SRF proof of principle, $\sim$5yrs (within reach for phase 2)

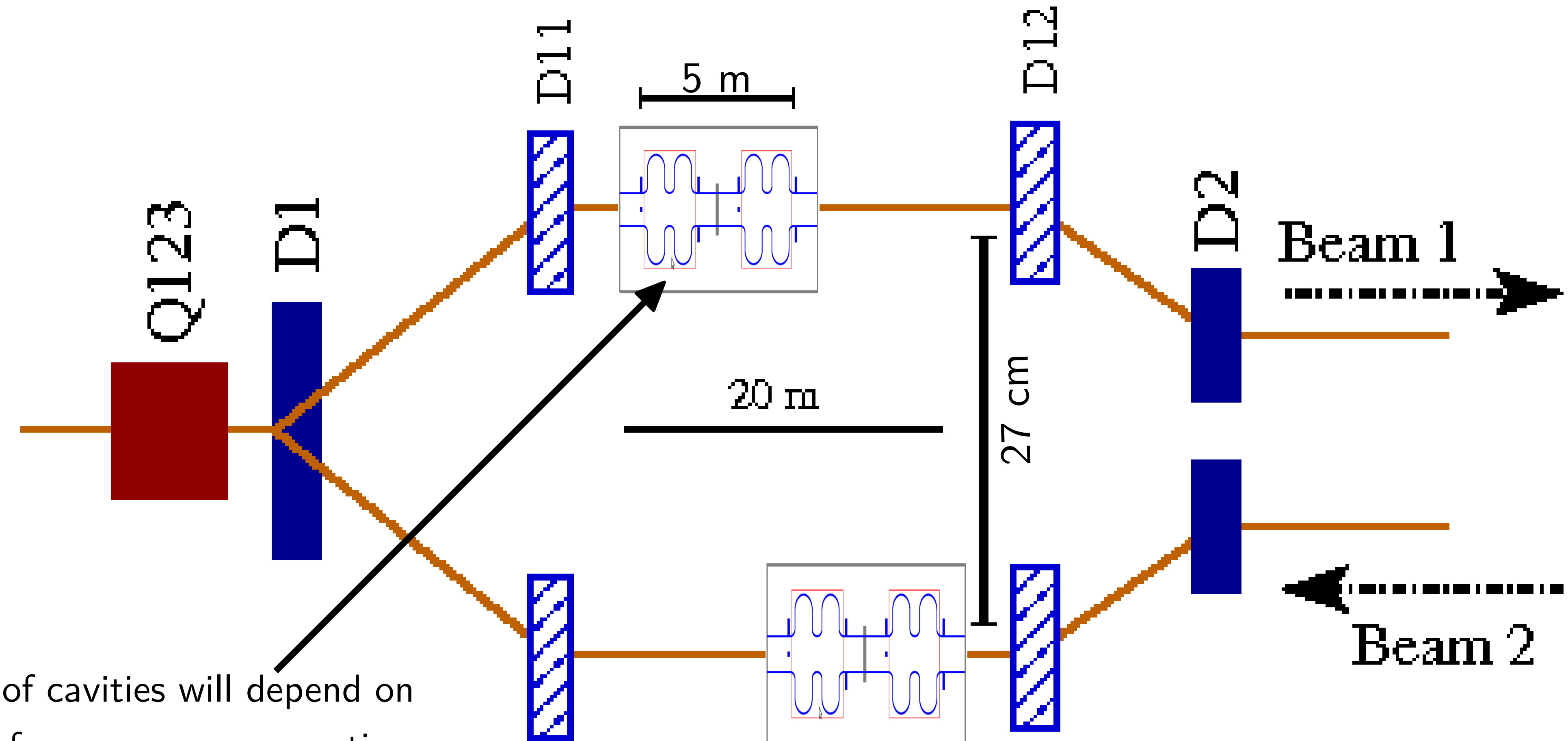
Beam testing (light sources, test facilities)

How Much Hardware, Local

Two cryomodules per/side of IP (total 8 cryomodules for 2 IPs)

Four dipoles per/side of IP (if dog-leg needed - $$)

Power supplies, cryogenics etc.. (see R. Ostojic's Talk)



# of cavities will depend on performance, energy, optics

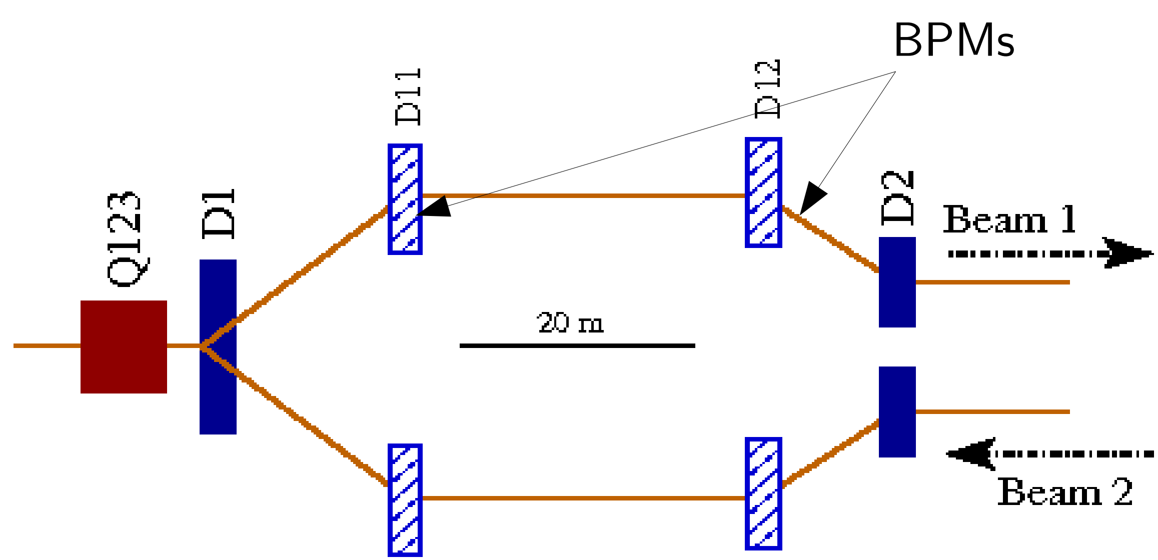
Some Other Considerations, Local

Commissioning & control of 8 cavities

- Damp/detune/ramp 8 cavities (min), needs study
- Longitudinal modes: $\{Rsh < 200\ k\Omega,\ Im(Z/n) < 0.15\ \Omega\}$
- Transverse stability, $\min(Q_{ext} \sim 10^{3\text{-}4})$, spec $\sim 10^2$

Fast orbit feedback (10 Hz sufficient ?)

- 4-bump near the crab cavity region
- Minimize beam loading and instabilites

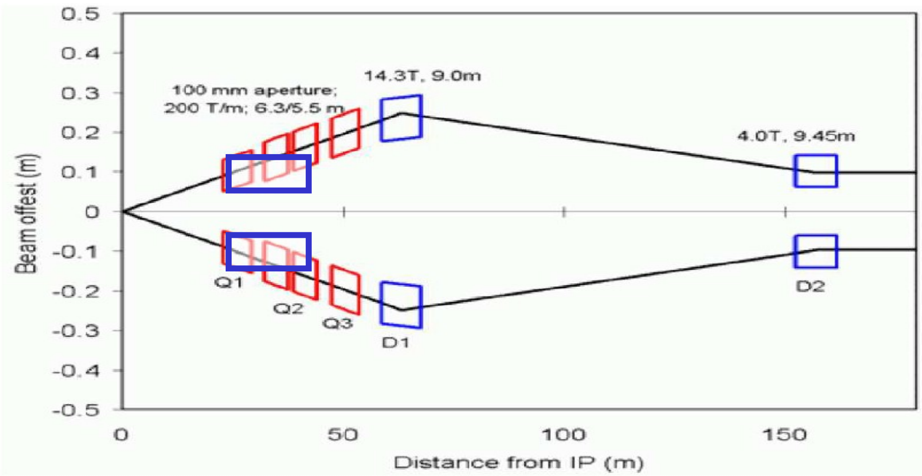


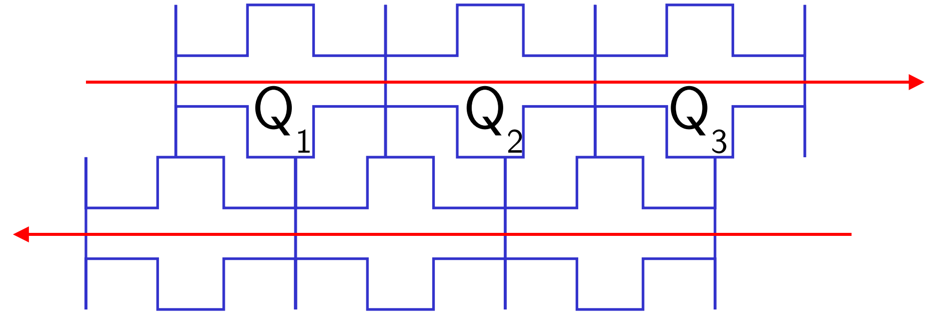
Conclusions

- Strategy to crab crossing phase II upgrade is taking shape
- Upgrade maybe <u>incremental</u>
- Prototype tests vital before BIG investment in time & money
    - Need clear recommendation to proceed *
- Operations to benefit greatly from KEK-B experience
- Compact structures vital for future: ? yrs for construction & commissioning
- Initiate a coordinated study group lead by CERN

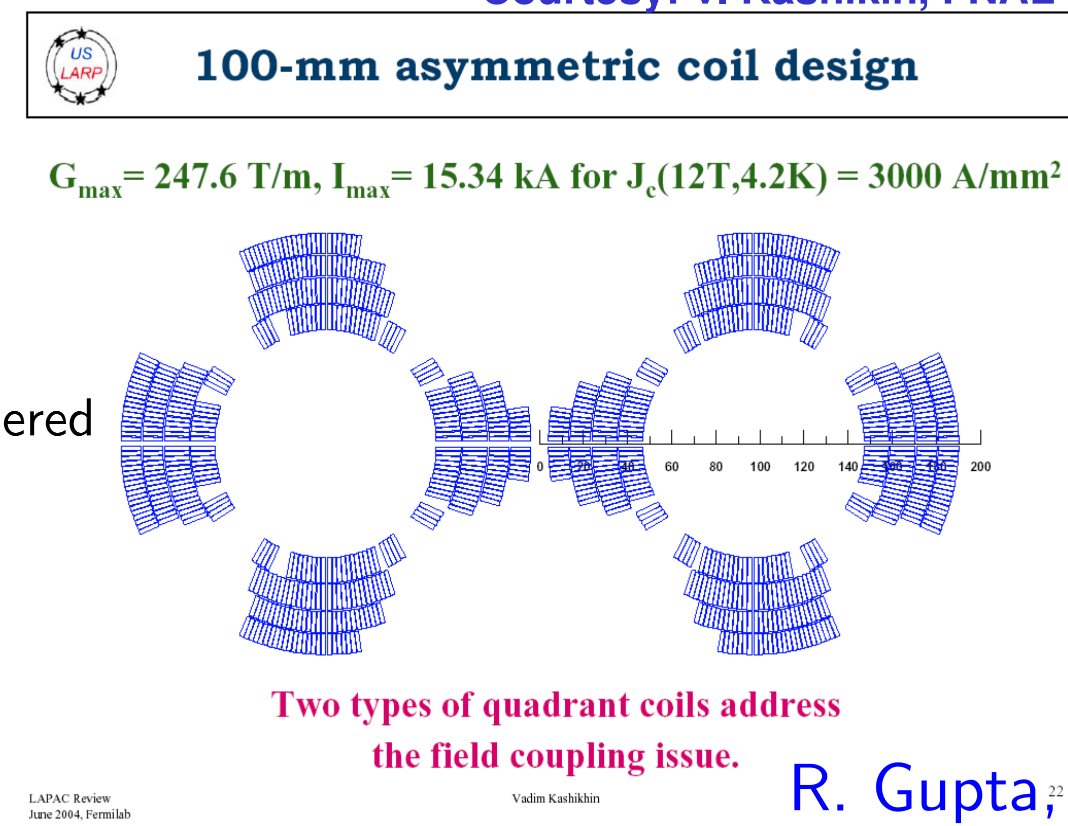
* Possibility to test KEK-B Crab Cavity in SPS ? F. Zimmermann

The Ultimate Upgrade





Courtesy: V. Kashikin, FNAL



Proposed in 2006 but could be considered

if crab crossing is proved success

Minimum X-Angle (3-4 mrad ?)

+

(Flat beams)

R. Gupta, BNL

Conceptual Design Report

LHC-CC09:

Workshop report & AB-recommendations for Phase I & II strategy

LHC-CC10:

"Conceptual design report"

LHC Crab Scheme Overview

Crab Optics

Collimation & Machine Protection

Cavity-Coupler Design

Cryomodule Design

Infrastructure, Cryogenics & Instrumentation

Cryomodule Fabrication & Installation

RF & Beam Commissioning

Phase I Measurement Procedures & Instrumentation

Phase II Scenarios and Implementation

Down Selection Discussion

Cavity:

- Exact cavity dimensions and 3D file format made available
- Symmetrical or asymmetrical shape
- Available beam pipe aperture ($\sim$ 14 cm)
- Peak surface fields normalized to 2.5 MV kick from 2-cell cavity
- Relevant RF parameters (R/Q's, Lorentz force detuning, errors studies)

Coupler:

- Exact (and final) design of the couplers (LOM, SOM, HOM) & damping numbers
- Fixed orientations (no long horizontally oriented couplers possible)
- Dimensions of various couplers (Length, radius) and interfaces (flanges etc...)
- Static heat losses of all coupler and required cooling circuit
- Weld points of each coupler, feasibility & difficulty of different weld paths
- Tolerance studies on fabrication/alignment errors on damping and cavity fields
- Mechanical and thermal analysis of each coupler assembly and impact on damping and cavity
- RF window sizes and locations, handling (fragile), bellows

Multipacting:

- Local field map quality (RF-codes)
- Initial seeds, SEY coeffecients & cavity coverage area
- Impact of individual couplers and MP bands (soft/hard)

Down Selection Discussion

Cavity treatment:

- Cavity design/ports and complexity of cleaning
- General configuration of BCP/EP and HP water rinsing (horizontal/vertical)
- Support structure of specific design

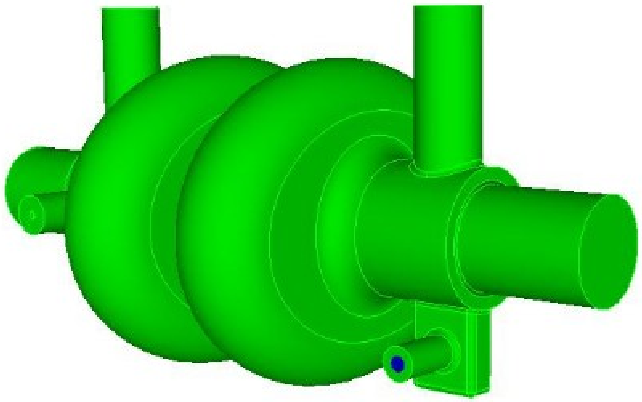
Helium Vessel (remember counter-rotating beam is $<$ 42 cm away):

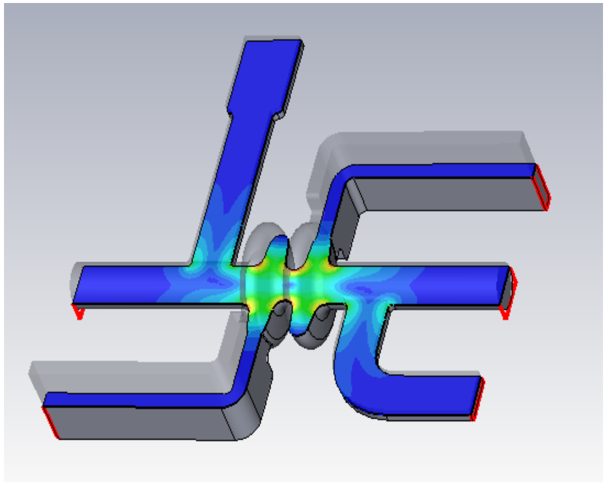
- Geometrical dimensions of the He-vessel
- Detailed weld points of He-vessel and difficulty of welds (impact of couplers)
- He vessel thickness, bellows and detailed mechanical stability study
- Tuning mechanism & impact on the cavity tuning (freq. tuning $\sim$ 10's of kHz)
- He-flow noise and pressure regulation and suppression ($\sim$ 10 Hz/mbar)

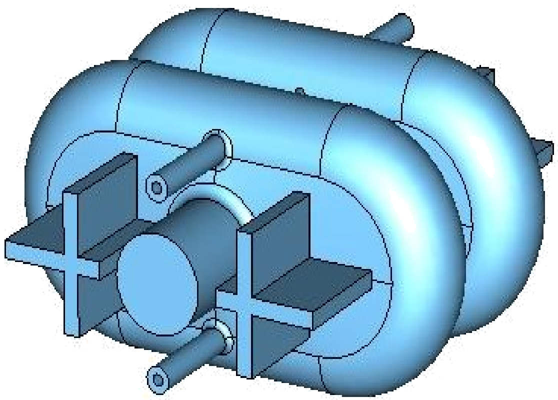
Misc:

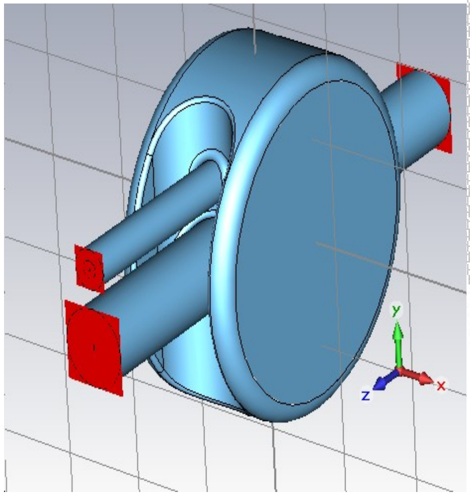
- Assembly guidelines for cavity-coupler and alignment (fixed points, survey)
- All required instrumentation (pressure-temperature gauges, connectors etc..)
- Transporation of the cavity-coupler-cryomodule (Longitudinally $<$ 5 m & Transversely $<$ 0.9m)

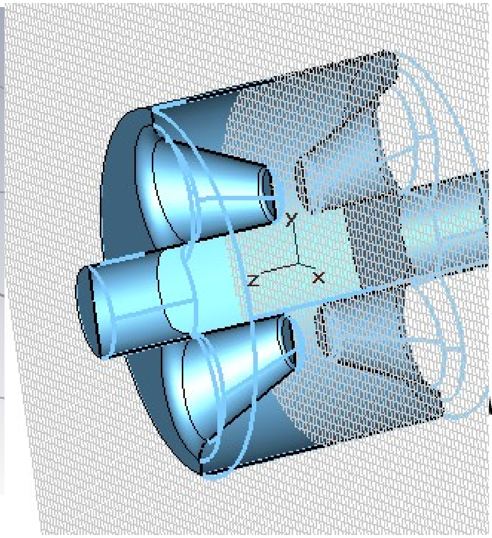
Down Selection Discussion

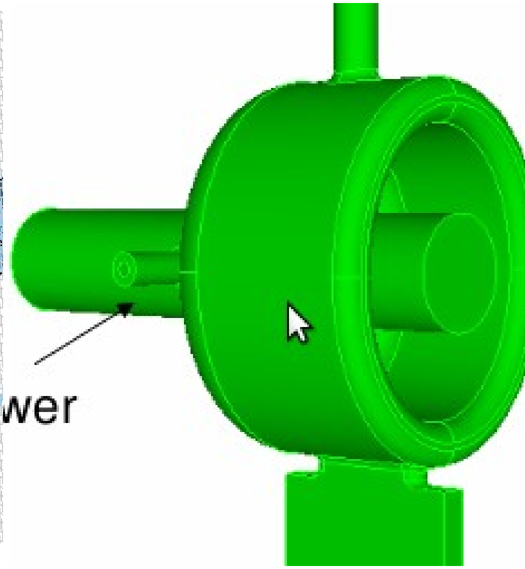


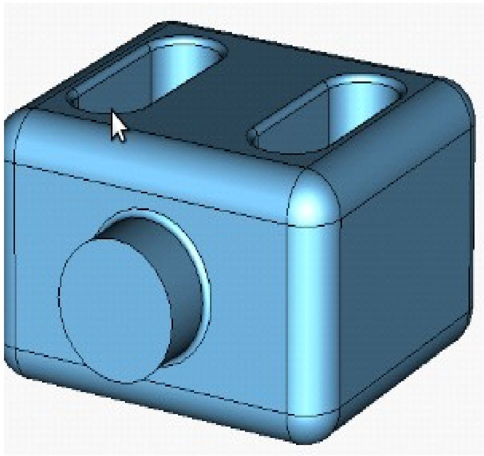












Prototype tests (“ Main Goals”)

Feasibility of crab cavities in the hadron a machine

Cavity-coupler R&D

- Gradient reach, impedance. damping, tuning, ramping, reliability

Cryomodule & LHC environment

Cavity control, machine protection, interlocks

Safe beam operation (low intensity) & reliability

- Beam tests, measurements (orbits, emittances, optics, noise)
- Collimation, impedance (intensity increase), beam-beam effects

Setup for luminosity gain tests (2-cavities preferred):

- unsqueezed optics, tune modifications, reduced emittance