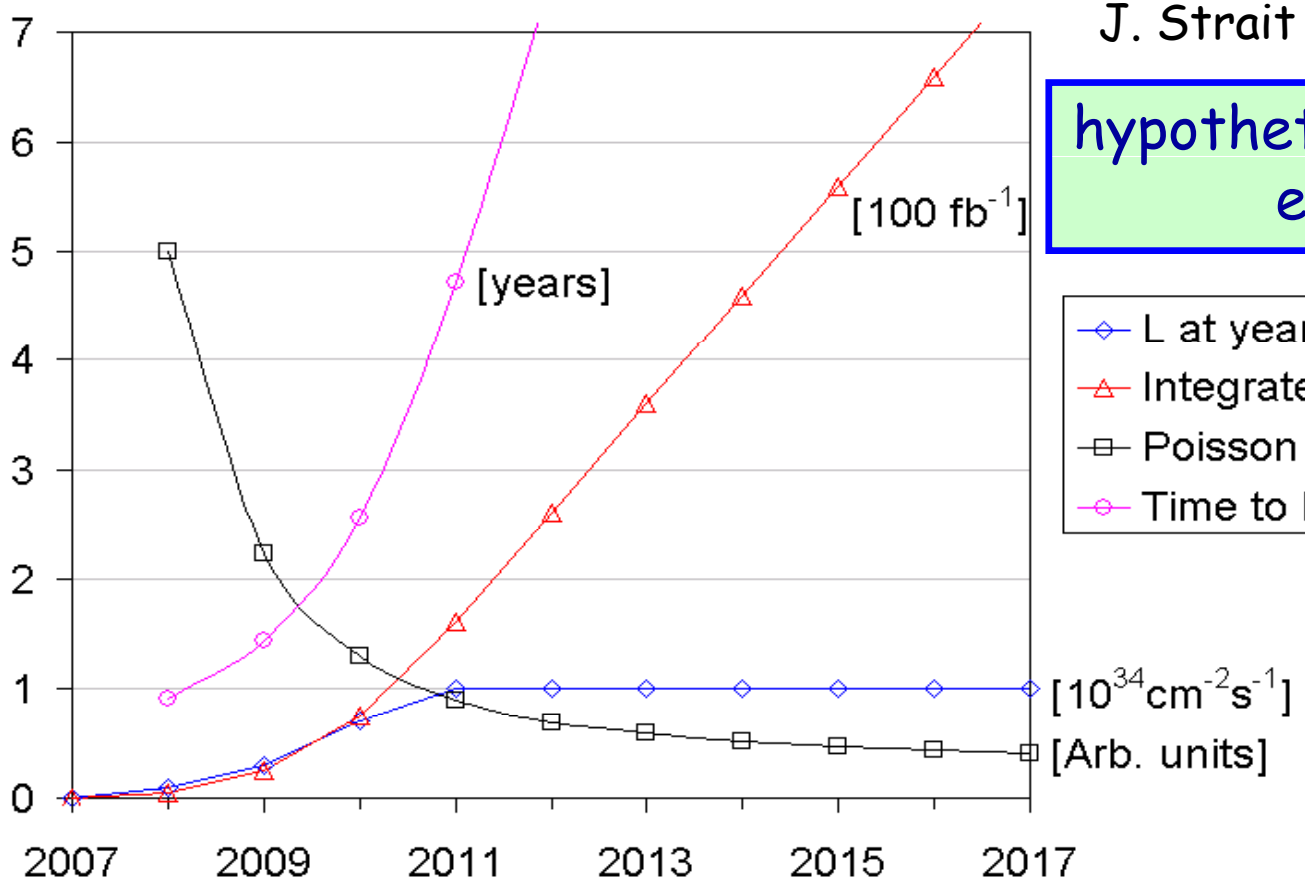
LHC-CC Validity Requirements & Tests

- Some general observations for the deployment of CRAB Cavities in the LHC
- Remarks on using the LHC as a test bed for R&D equipment
- Validation requirements and test goals for CRAB Cavity tests in the LHC
- Summary

Two Strong Reasons for LHC Upgrade

J. Strait 2003



hypothetical luminosity evolution

1) After a few years, statistical error hardly decreases.
2) Radiation damage limit of IR quadrupoles (~700 fb^{-1}) reached by ~2016

$\Rightarrow$

Time for an upgrade!

@W. Scandale and F. Zimmermann at BEAM'07

LHC IR Upgrade Options

Phase 1: consolidation of 'ultimate' performance with $L > 10^{34} cm^{-2} sec^{-1}$

-large aperture NbTi triplet magnets using existing spare dipole cables with the goal of introducing additional margins for the LHC operation

-no modifications of the experiment interface and cryogenic infrastructure

-opening the option for operation with $\beta^* = 0.25m$ and the LHC 'ultimate' beam parameters yielding a performance reach of $L = 2\text{-}3 \times 10^{34}\ cm^{-2}\ sec^{-1}$

Phase I milestones:

-First quadrupole prototype by 2009

-Installation during 2012 / 2013 shutdown

-Ready for operation with $\beta^* = 0.25m$ during 2013 run

LHC IR Upgrade Options

Phase II:

-aims at operation beyond ultimate luminosity (the goal is integrated L!!!)

-implies operation in extremely radiation hard environment (35 MGy/year[@])

(less than 1 year lifetime for magnets with nominal triplet layout!)

➔ new magnet technology and /or special protection / absorber elements

Phase II milestones:

-Full scale (ca. 4m) prototype by end of 2009 within USLARP funding

-Installation during 2015 / 2016 shutdown

-Ready for operation with $\beta^* = 0.25$m and tenfold increase in luminosity and radiation levels (requires upgrades of other components like the collimation system)

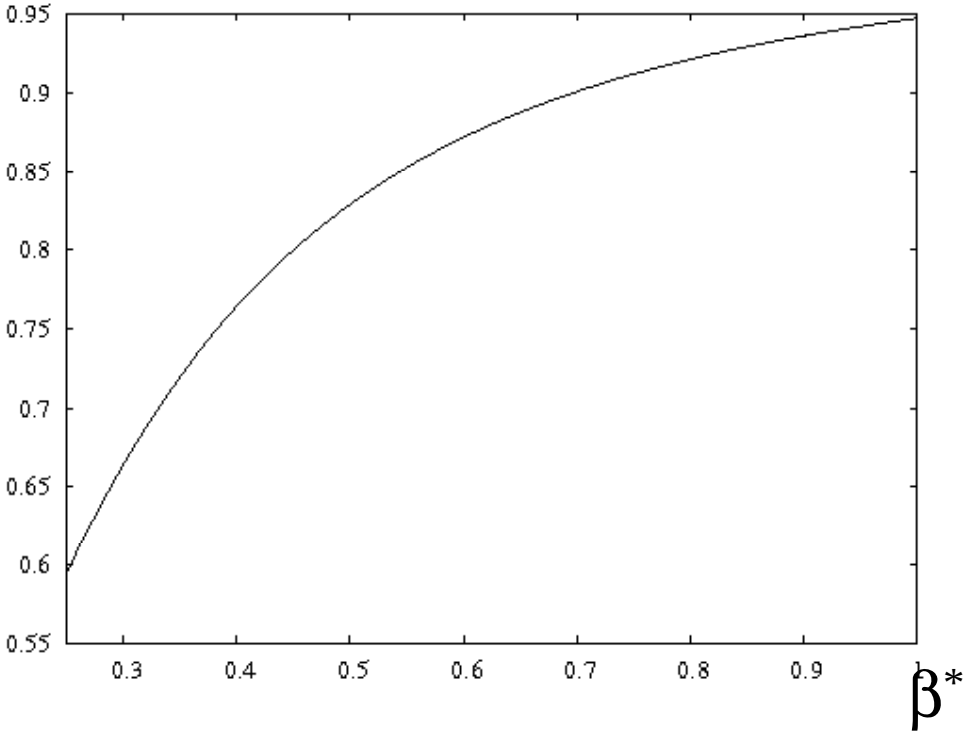
[@]N. Mokhov et al LPR 633 for ($L = 10\ 10^{34}$ cm^{-2} sec^{-1})

Some general observations for the deployment of CRAB Cavities in the LHC

- CRAB cavities are the pre-requisite for an efficient luminosity production with $\beta^* < 50$cm

$$F = \frac{1}{\sqrt{1+\phi^2}}; \quad \phi \equiv \frac{\theta_c \sigma_z}{2\sigma_x}$$

ϕ = Piwinski angle



Some general observations for the deployment of CRAB Cavities in the LHC

- CRAB cavities are interesting for the Phase I and Phase II upgrades;

  Phase I upgrade is planned for installation in 2012/2013 shutdown

  Phase II upgrade is planned for installation by 2016

  ➔ It would be desirable to have CRAB cavities installed in the LHC by 2013

  ➔ requires proof of feasibility with sufficient lead time for final design optimization, production and installation (3 years? ➔ demonstration of feasibility by 2010 !?)

Some general observations for the deployment of CRAB Cavities in the LHC

- Two options exist for the Phase II upgrade:

  -One requiring CRAB cavities (early separation scheme) and

  -One requiring higher than ultimate beam currents (large Piwinsky angle scheme) (does not require CRAB cavities)

  -Both options are challenging and require further studies and R&D

  ➔ The sooner we know if CRAB cavities are feasible, the sooner we can select a preferred Phase II upgrade path and focus the required studies accordingly

Remarks on using the LHC as a test bed for R&D equipment

- The CRAB Cavity tests and the required installation work must not compromise the normal LHC operation:

  ➔ The LHC should only be used as a test bed for R&D work if no alternative options exist for these tests (e.g. tests are not possible in the Tevatron or RHIC).

  ➔ As many tests as possible should be done prior to the CRAB Cavity installation in the LHC tunnel (➔ need for a dedicated test stand ➔ infrastructure and manpower).

Remarks on using the LHC as a test bed for R&D equipment

- The CRAB Cavity tests and the required installation work must not compromise the normal LHC operation:

➔ Installation of the Crab Cavities must fall into the shadow of a scheduled LHC shutdown (timing).

➔ Time required for the installation of Crab Cavities in the LHC tunnel?

➔ Time required for the hardware commissioning of the Crab Cavities in the LHC tunnel?

Remarks on using the LHC as a test bed for R&D equipment

- CRAB Cavity installation during planned LHC shutdown:

➔ Regular annual LHC shutdowns (ca. 3 month) are probably too short (➔ possibility of a phased installation in the tunnel?)

➔ what installation work can already be done ahead of the tests?

➔ Installation during extended shutdown periods:

-Phase I IR upgrade during the 2012/2013

(this leaves only 4 years for the design, prototyping and construction of an LHC Crab Cavity!)

Remarks on using the LHC as a test bed for R&D equipment

- The installation and tests in the LHC must not compromise the approved LHC operation:

  ➔ The CRAB Cavity test installation must be compatible with the existing infrastructure (e.g. cryo power and space requirements for klystrons and wave guides) (➔ impact of eventual infrastructure upgrades on the LHC operation?).

  ➔ The installed CRAB Cavities must Not limit other upgrade options for the LHC (e.g. one should not sacrifice the 200MHz capture cavities for the CRAB Cavity installation).

Remarks on using the LHC as a test bed for R&D equipment

- The installation and tests in the LHC must not compromise the approved LHC operation:

➔ The installed Crab Cavities must be transparent to the normal LHC operation (no impedance effects on the LHC beam during normal operation ➔ how can we turn the cavities 'off'?)

➔ RF shielding as part of the cavity design?

Validation requirements and test goals for CRAB Cavity tests in the LHC

- Test program with CRAB Cavities in the LHC:

  ➔ Compatibility of the CRAB Cavity tests in the LHC with the LHC collimation and machine protection system (the current proposal foresees only the installation of one CRAB cavity which implies distributed bunch oscillations around the LHC machine)

  ➔ Measurement of cleaning inefficiencies and loss patterns

  ➔ Does this operation mode provide useful results for the desired operation mode of local CRAB cavities?

Validation requirements and test goals for CRAB Cavity tests in the LHC

- Test program with Crab Cavities in the LHC:

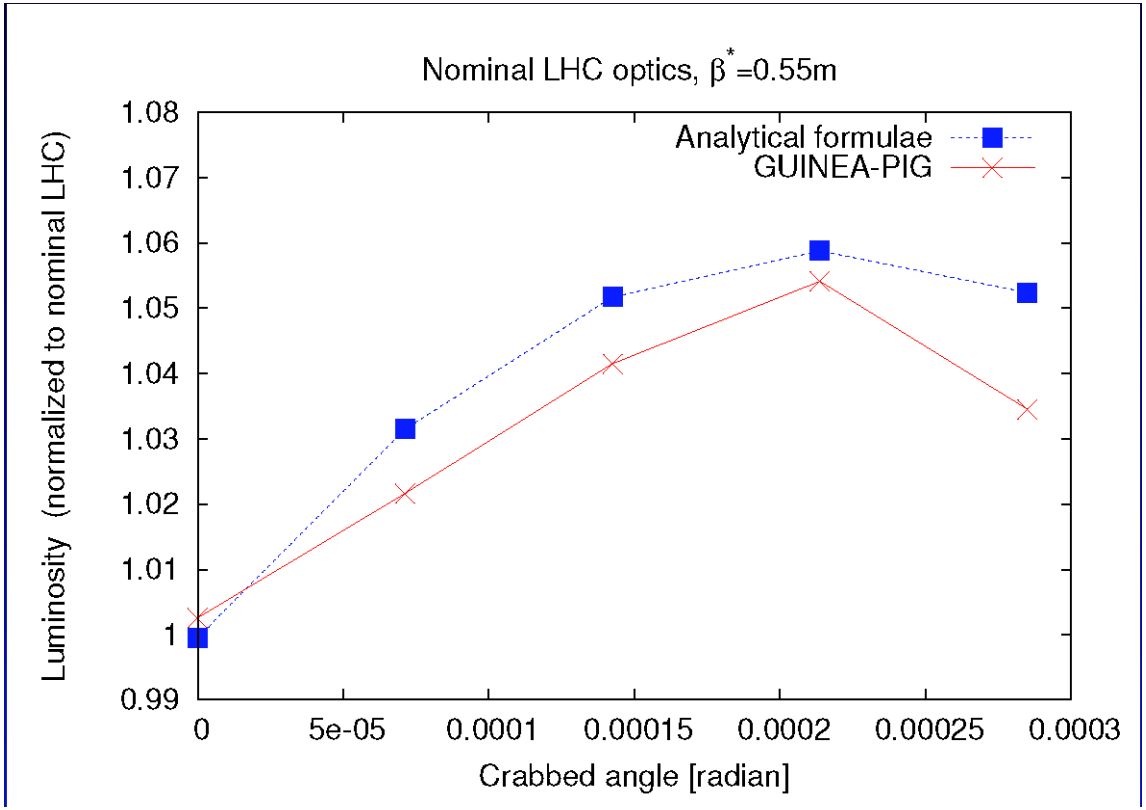
  ➔ Test program must be able to provide clear evidence of feasibility and benefit of CRAB Cavity operation in the LHC (tests must demonstrate: significant luminosity improvement (> 10%) without emittance growth; while maintaining the losses and background levels of normal operation)

  ➔ Is this possible with only one installed CRAB cavity?

Validation requirements and test goals for CRAB Cavity tests in the LHC

- Tests with $\beta^* = 0.55$m provide at best 5% luminosity increase[@]:

Measured effect during tests is smaller than 6%!

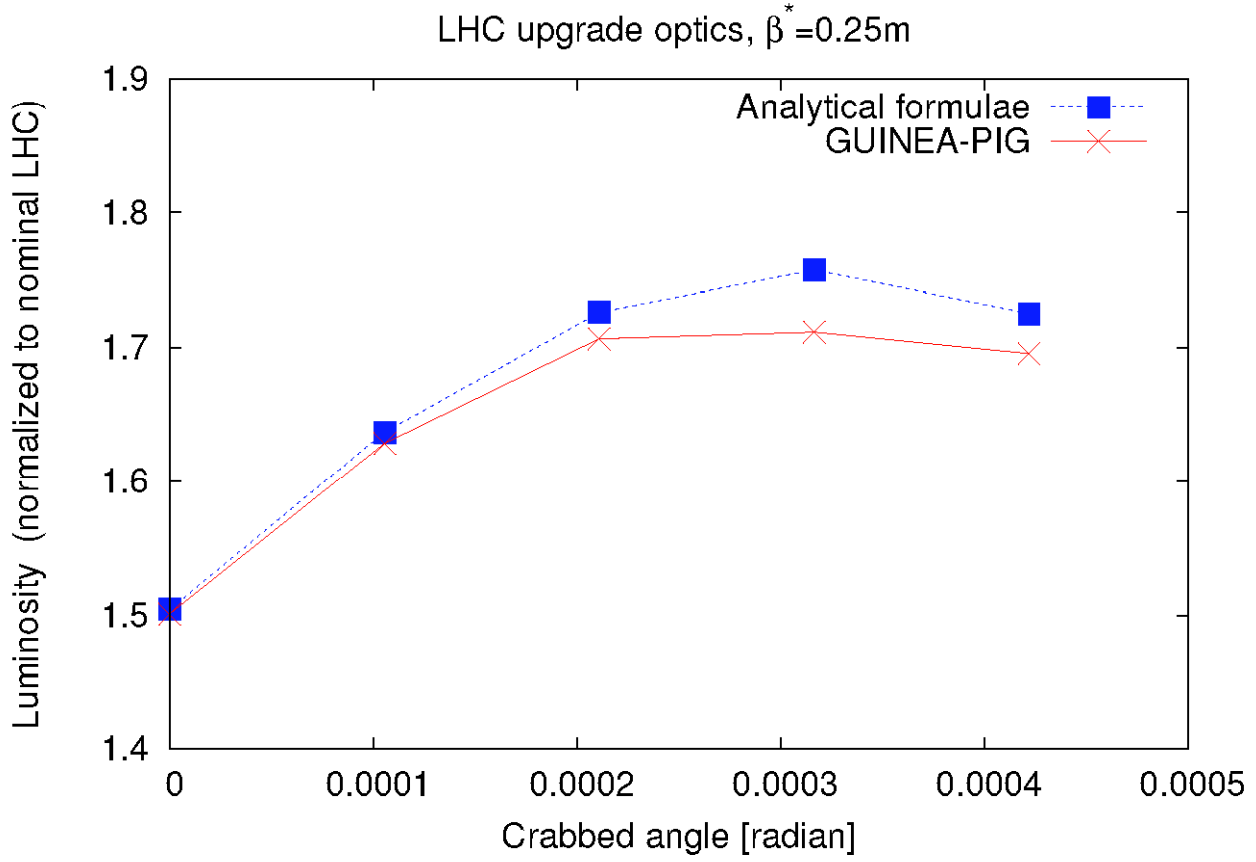


[@]Yi-Peng Sun et al at this workshop

Validation requirements and test goals for CRAB Cavity tests in the LHC

Tests with $\beta^* = 0.25$m provide up to 16% luminosity increase@:

Measured effect during tests should be larger than 10%!



@Yi-Peng Sun et al at this workshop

Summary

- The Phase I LHC upgrade would significantly benefit from CRAB cavity installations! ➔ feasibility demonstration by 2010 would be desirable!!!
- Choice for Phase II IR upgrade option depends on feasibility of CRAB cavity technology:
  - ➔ requires feasibility demonstration by the time of Phase I
- Using the LHC as a test bed for CRAB cavity studies implies:
  - ➔ transparent installation for normal LHC program
  - ➔ impact on cavity design and installation schedule
  - ➔ can only be justified if tests can provide clear conclusions