Design Issues of the LHC as Injector

(very) brief overview and status ..

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(many other contributors ..)

Main objective and motivation

High energy injector (HEB) needed for FCC-hh, injection energy $\approx$ 3.3 TeV

- Reuse LHC as existing facility, advantages:
  - Tunnel and infrastructure
  - Experience running at 4 TeV (2012)
  - Ramp and extract two beams, decrease filling time by a factor 2, <u>no polarity reversal</u> needed
- Aim is to minimise the changes

Reuse LHC, main issues

- Extraction systems and beam transfer to FCC-hh required

- Multiple ramps required (3 - 4 ramps to fill collider)

  ➡ cycle time important (and reliability)

 Present ramp rate 10 A/s, dictated by dipoles, some insertion elements limit the ramp speed

- Further assumption: no colliding beam experiment in the baseline

  ➡ low β^* insertions and experiments can be removed, makes it simpler and helps ramp speed

Evaluate main issues

- Possible ramp rate

- Modification to optics (where needed):

    - Replace experimental insertions

    - Modifications for injections

    - Modifications for extractions

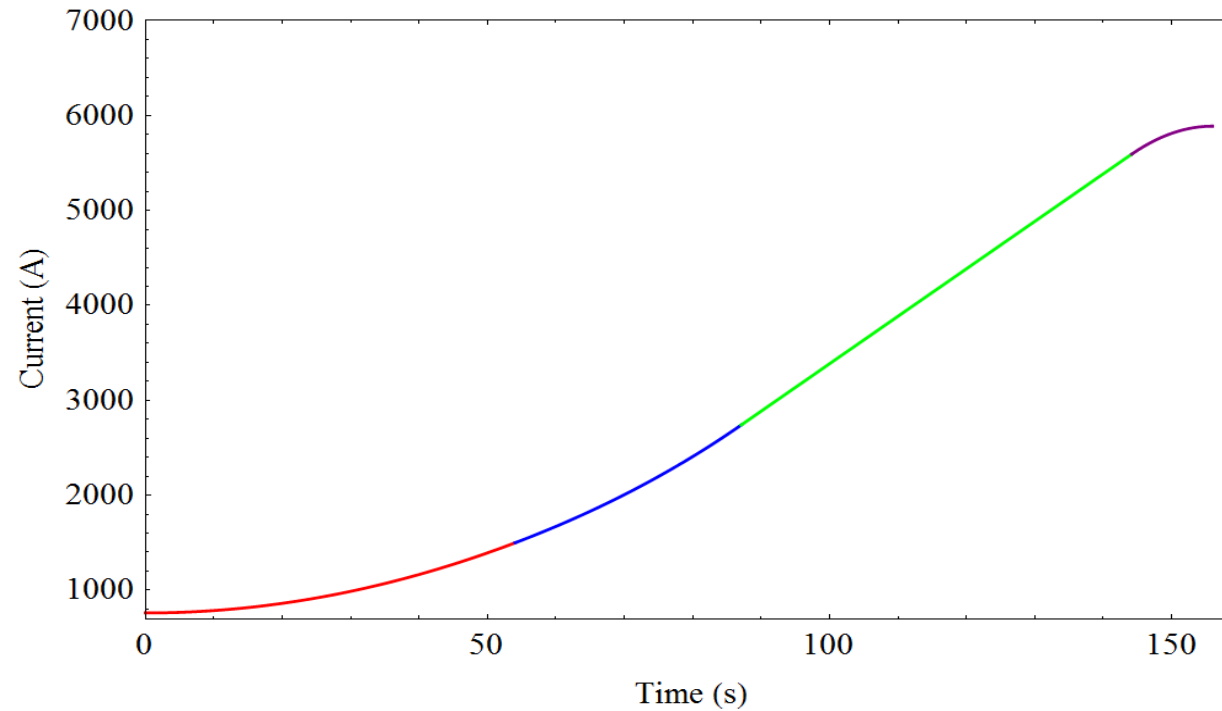- Decommissioning of activated elements (insertions), needs to addressed in more detail

Present Ramp (2012: 4 TeV) - simplified
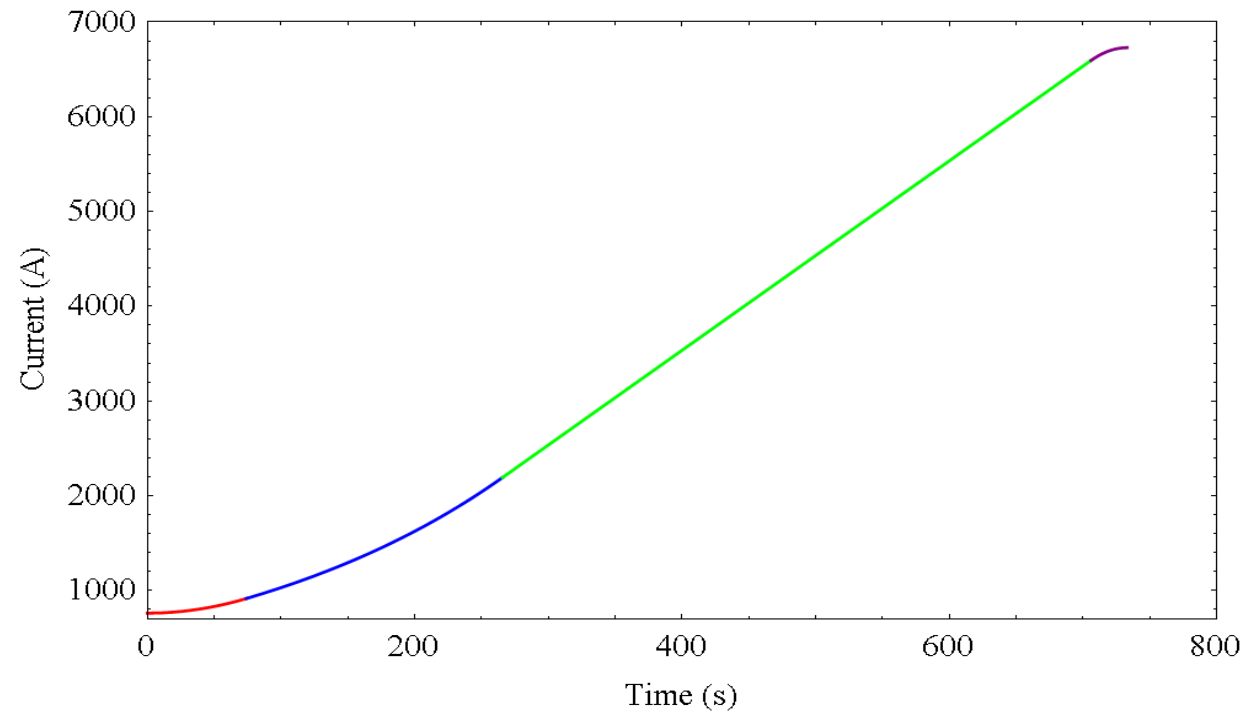
(courtesy M. Lamont)

- $\approx$ **60% of the time in** linear **part:** **10 A/s**

- **Total time** $\approx$ **12 minutes per ramp**
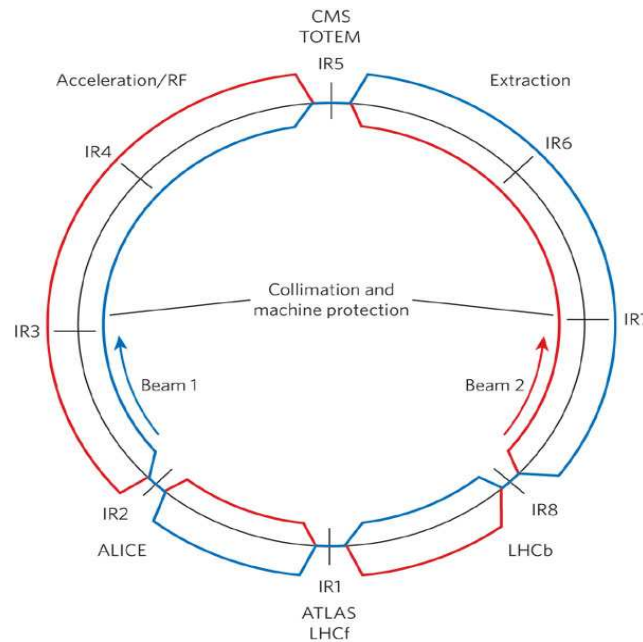
Possible Ramp (3.3 TeV) - simplified

(courtesy M. Lamont)

- ≈ **60%** of the time in **linear** part: **50 A/s**

- Total time ≈ **3 minutes per ramp**

Ramp rate

▷ **Ramp to 3.3 TeV with 50 A/s feasible**

- Quadrupoles can follow dipole ramp rate

- Quench protection not the limit

- Can be handled by cryogenics system

- Needs modified powering

Present layout

- **Eight arcs, 4 experimental and 4 utility straight sections**

- **4 horizontal crossings**

layout and optics

- Beam crossing needed ➡ reduce from 4 to 2 crossings, opposite in azimuth, keep path length the same

- Keep auxiliary straight sections unchanged (2*cleaning, beam dump, RF)

- IR3, IR4, IR6, IR7: unchanged

- Modified straight sections:

  - <u>IR1:</u> no low β^*, extraction to collider and beam crossing
  - <u>IR2:</u> no low β^*, injection beam 1
  - <u>IR5:</u> no low β^*, and beam crossing[*]
  - IR8: no low β^*, injection beam 2, extraction to collider

[*] keep option for low-β^* insertion, but not as base line

Example: Modified straight section - IR5
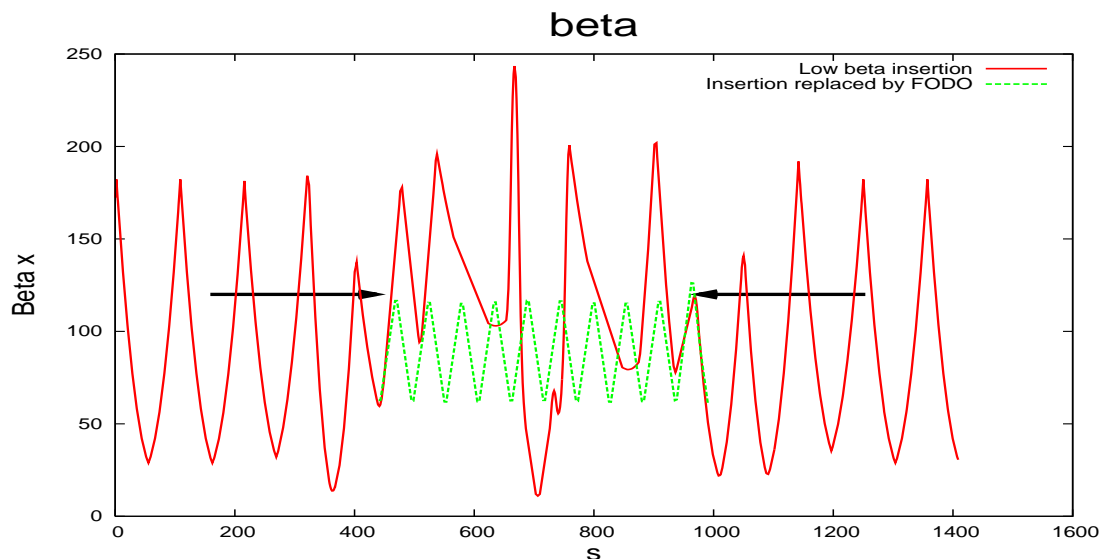
- Example β_x, previous optics, with and without low β^*, regular FODO$^{*)}$ lattice (arrows indicate dispersion suppressor, unchanged)

- Beams cross horizontally using separation dipoles ➡ allows very large crossing angle ($\pm$ 1.5 mrad, at 7 TeV)

$^{*)}$ Not yet optimized. Alternative: medium β^* with long drift

Example: Modified straight section - IR5
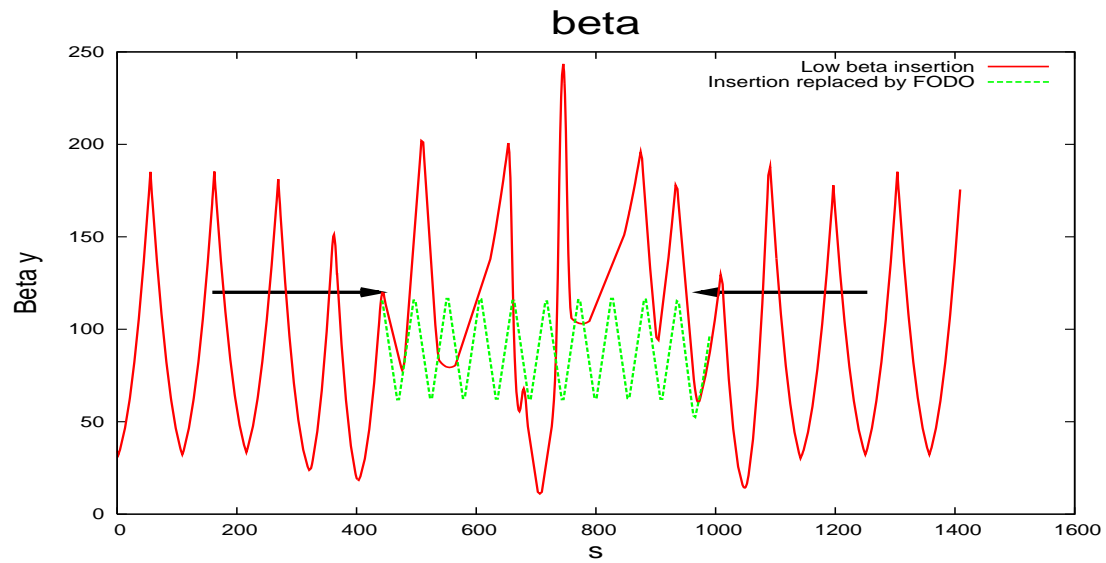
- **As before for** β_y

# Injection into LHC - HEB

- <u>Presently:</u> beam 1 in IR2, beam 2 in IR8

  (should remain the same to keep SPS $\rightarrow$ LHC transfer lines)

- <u>Proposed layout for collider:</u> requires injection into the inside rings (presently outside)

- Needs changes to the layouts and optics in IR2 and IR8

- Example IR2: Requires shift of quadrupoles (Q5), septa, kickers (and re-matching of the optics)

IR2 Optics with shifted elements (beam 1)
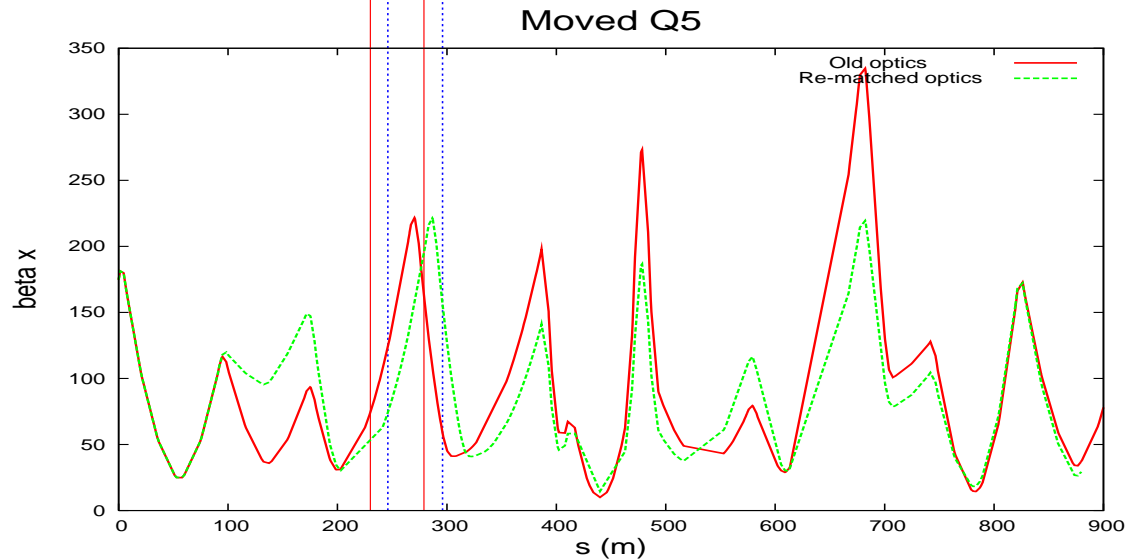
- Horizontal β before and after shift (after re-matching, not optimised)

- Vertical lines indicate positions of septum and kicker before and after shift

IR2 Optics with shifted elements (beam 1)
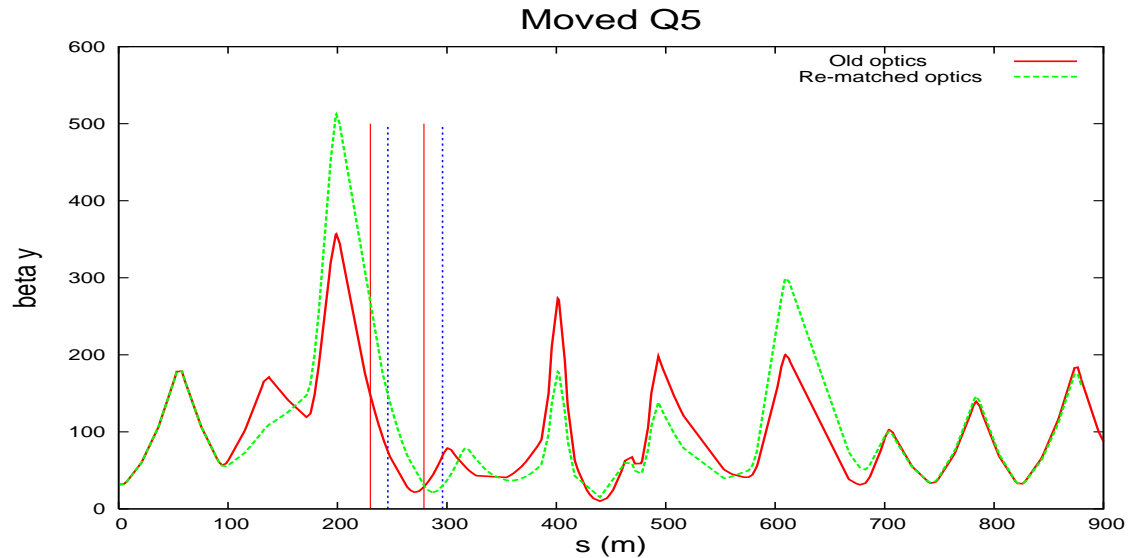
- Vertical β before and after shift (after re-matching, not optimised)

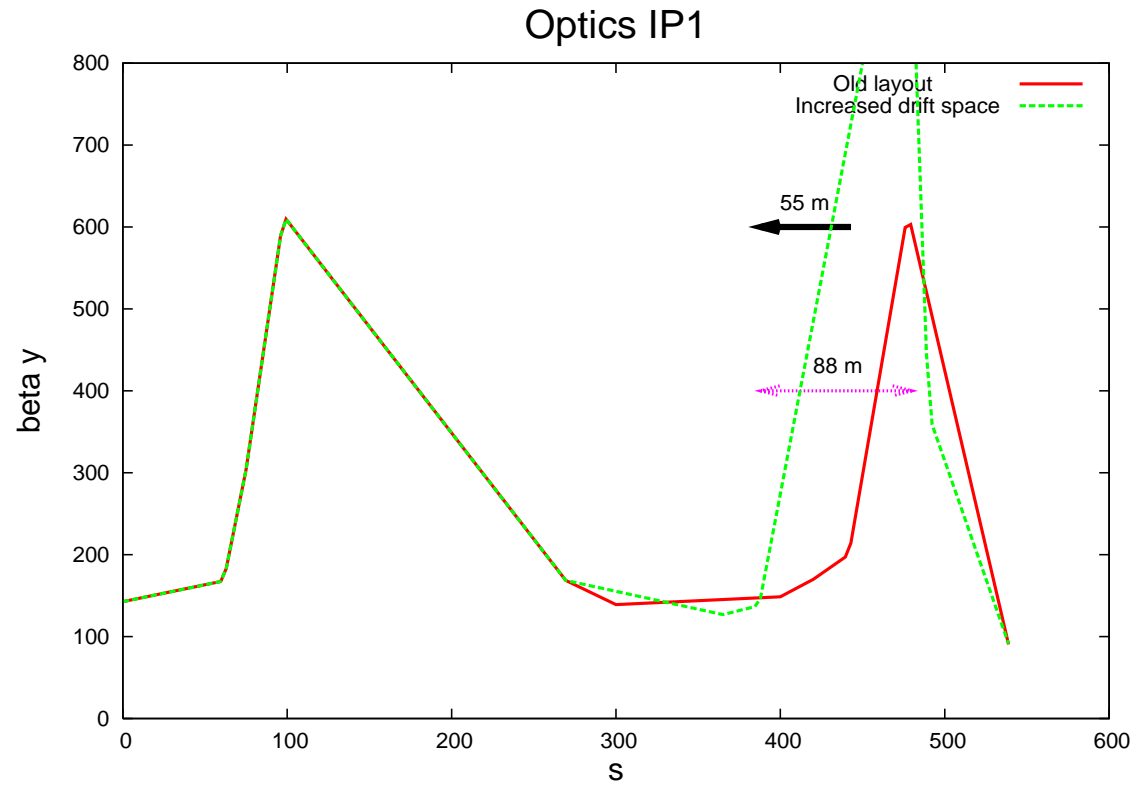- Vertical lines indicate positions of septum and kicker before and after shift

IR1 for extraction

- No low β^* insertion, remove triplet and matching section

- For extraction:
  assume the layout of beam dump insertion (IR6),
  should be designed to extract at $\geq$ 3.3 TeV

- For crossing:
  allow for crossing at 7 TeV, assume use of 4 separation
  dipoles (provide $\geq$ 3 mrad)

- Sufficient space needed (mechanical separation 0.194 m
  $\longrightarrow$ $\approx$ 80 m)

- Provide space by moving quadrupoles $\longrightarrow$ 88 m
  available, need re-matching

Rearranged Extraction optics for IR1

Optics IP1
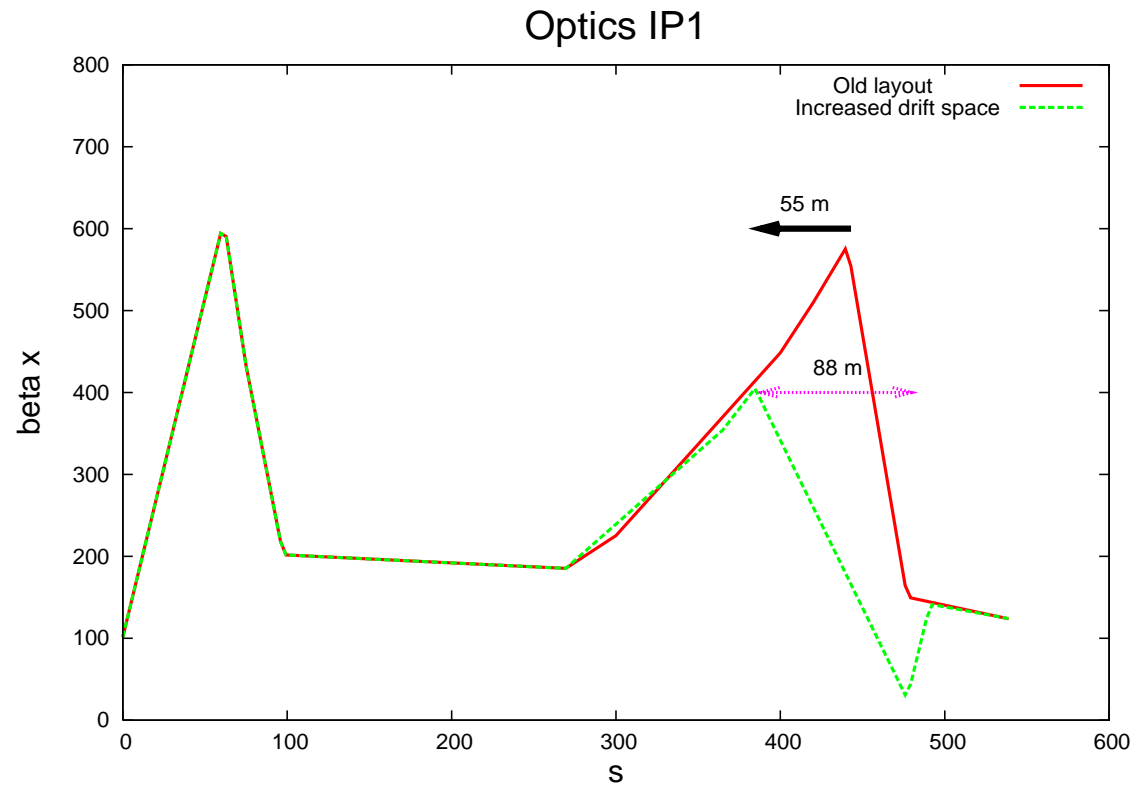
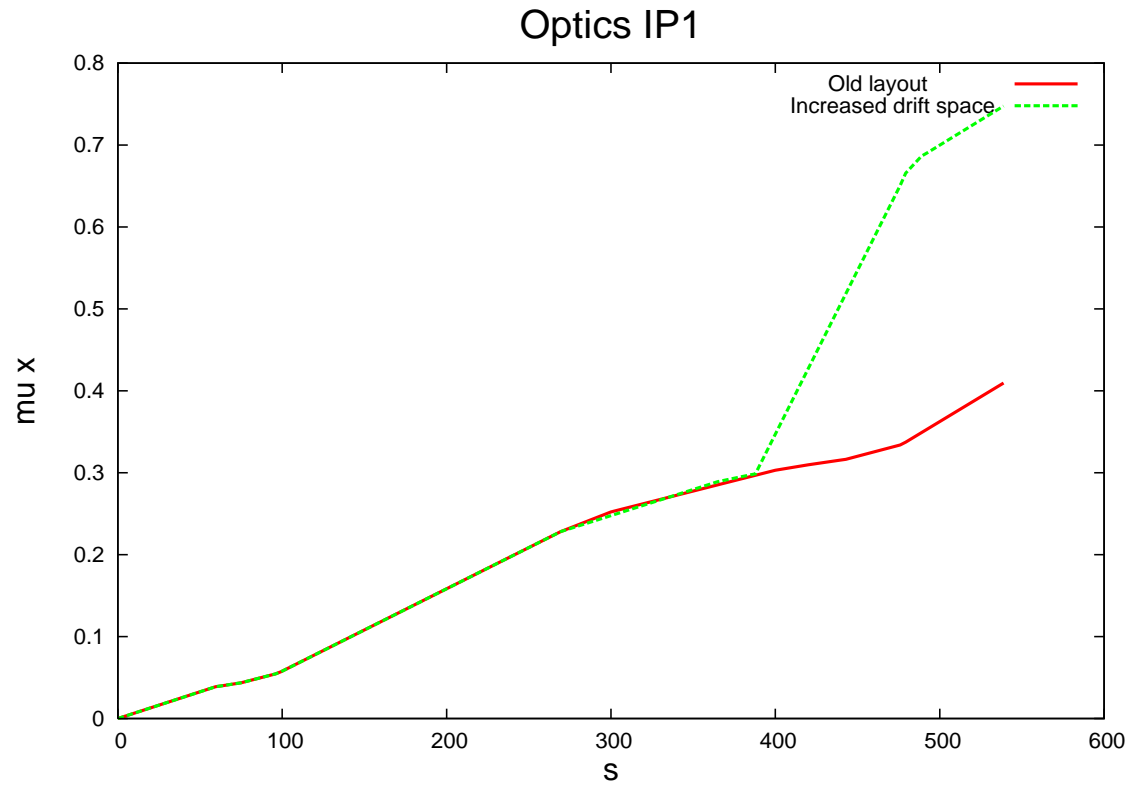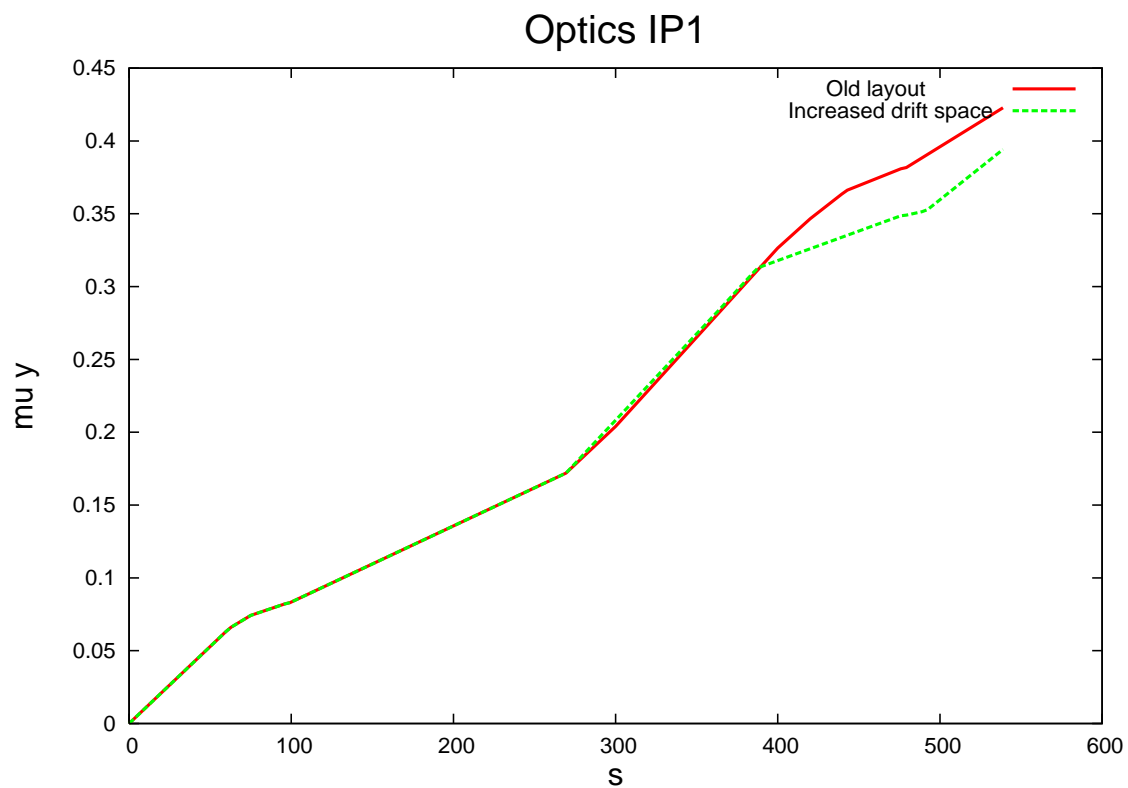# Rearranged Extraction optics for IR1

Rearranged Extraction optics for IR1

Optics IP1

Rearranged Extraction optics for IR1
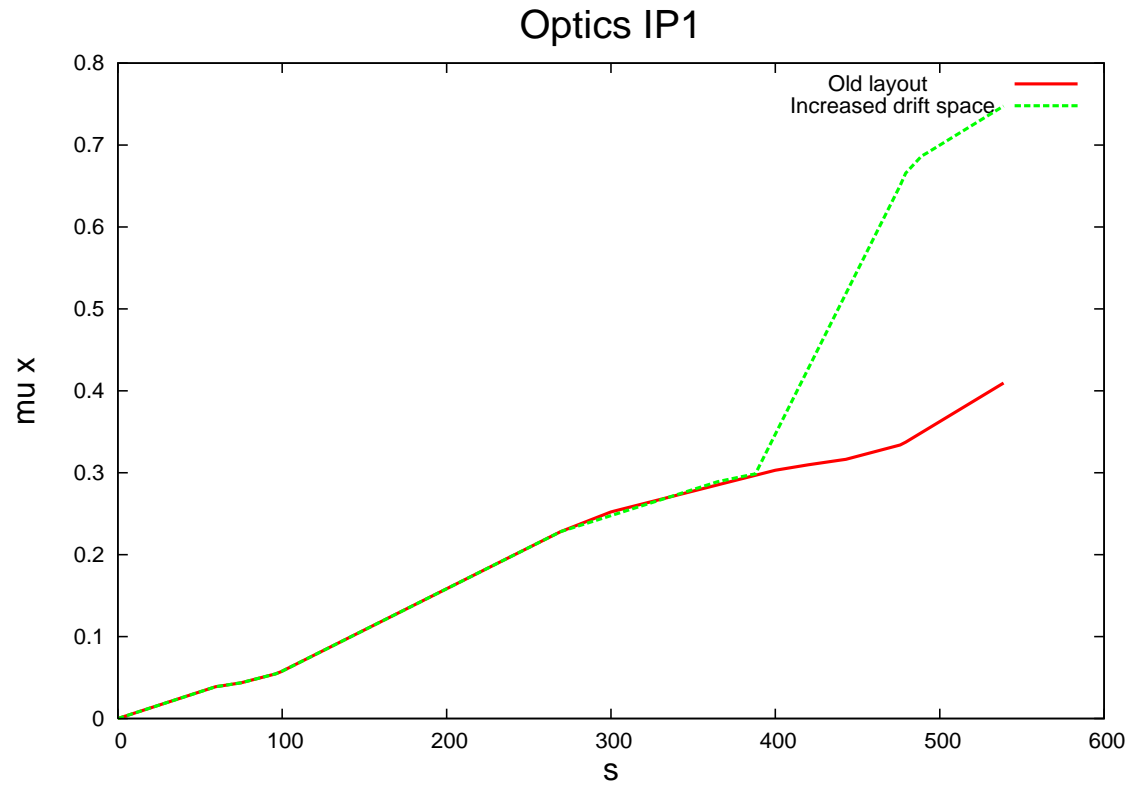
Non base-line options

◼ **Allow possibility for extraction towards a fixed target experiment**

◼ **Option for a (small) colliding beams experiment:**

- **Luminosity $\geq$ 0.5 10^{35} cm^{-2} s^{-1}, no crab crossing**

- **Assuming HL-LHC parameters for emittance and intensity (ϵ_n = 2.5 μm, N = 2.2 10^{11} p/bunch):**

- **Luminosity is feasible with $\beta^* = $ 0.15 - 0.40 m**

- **Polarised beams ??**

Summary ...

- The reuse of the LHC as High Energy Booster was studied

- Initial studies show the feasibility:

  Filling time (number of injections, ramp rate) fulfil the requirements

  Proposals for minimum changes to the LHC configuration and lattice seem feasible (injection, extraction, crossing)

- Other issues: decommissioning of activated elements ?

-   BACKUP SLIDES   -

Rearranged Extraction optics for IR1

Optics IP1

Rearranged Extraction optics for IR1