# Progress with long L*

Lau Gatignon / EN-MEF
On behalf of the MDI working group

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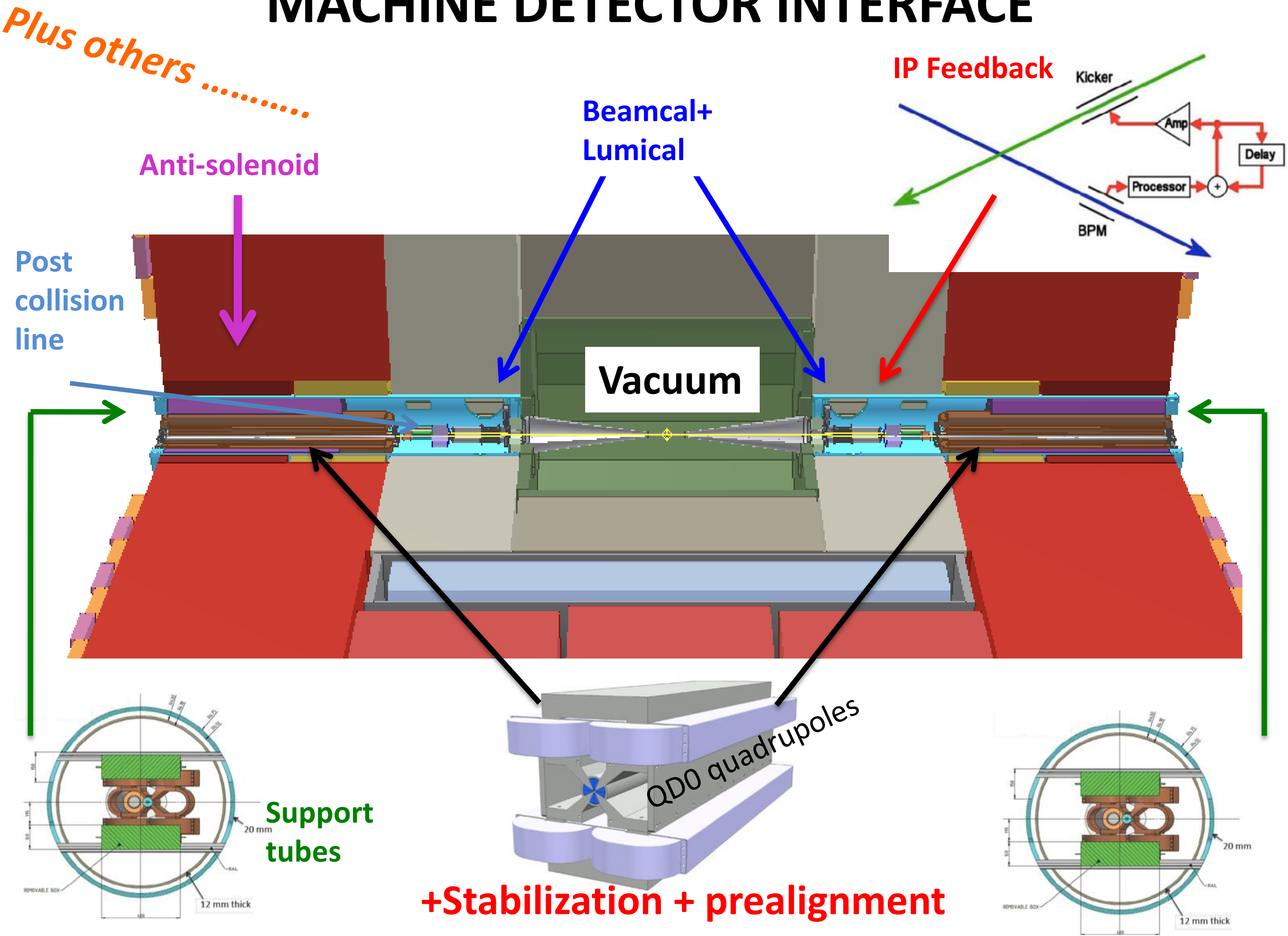
# Outline

- What is MDI
- Announced changes to detector model
- Rationale for new L*
- New QD0 and QF1 parameters
- Do we still need an anti-solenoid?
- Some other implications
- Plans

# What is MDI

- The Machine Detector Interface must ensure optimum luminosity for the experiment(s) with minimal backgrounds and includes the local environment and infrastructure.It integrates the post-collision line.
- The baseline for the CDR was based on a concept with two detectors operating in push-pull mode and with the final focus quadrupoles QD0 as close as possible to the interaction point (L* = 3.5 m), i.e. in the detectors.
- The MDI design included concepts for the QD0 design as well as its stabilisation and pre-alignment, but also IP feedback, BeamCal and Lumical integration, vacuum layout, cavern layout, and so forth.

# MACHINE DETECTOR INTERFACE



# Some justifications for the CDR choice

The choice of short L* was justified by the fact that

- this option would provide the **maximum (peak) luminosity**
- this layout is the most **challenging**
  (If you have a plausible solution for short L*, the longer L* should be easier for the stabilisation, radiation, B-field, etc)
- at the time the **pre-alignment tolerance** was considered unrealistic (2 μm for L*=8 m, 10 μm for L* = 3.5.m).
  Since then significant progress has been made in the BDS optics.

# Announced changes to the detector model

- The detector team has decided to concentrate for the time being on a **single** detector with all-silicon tracking.

**No more push-pull**

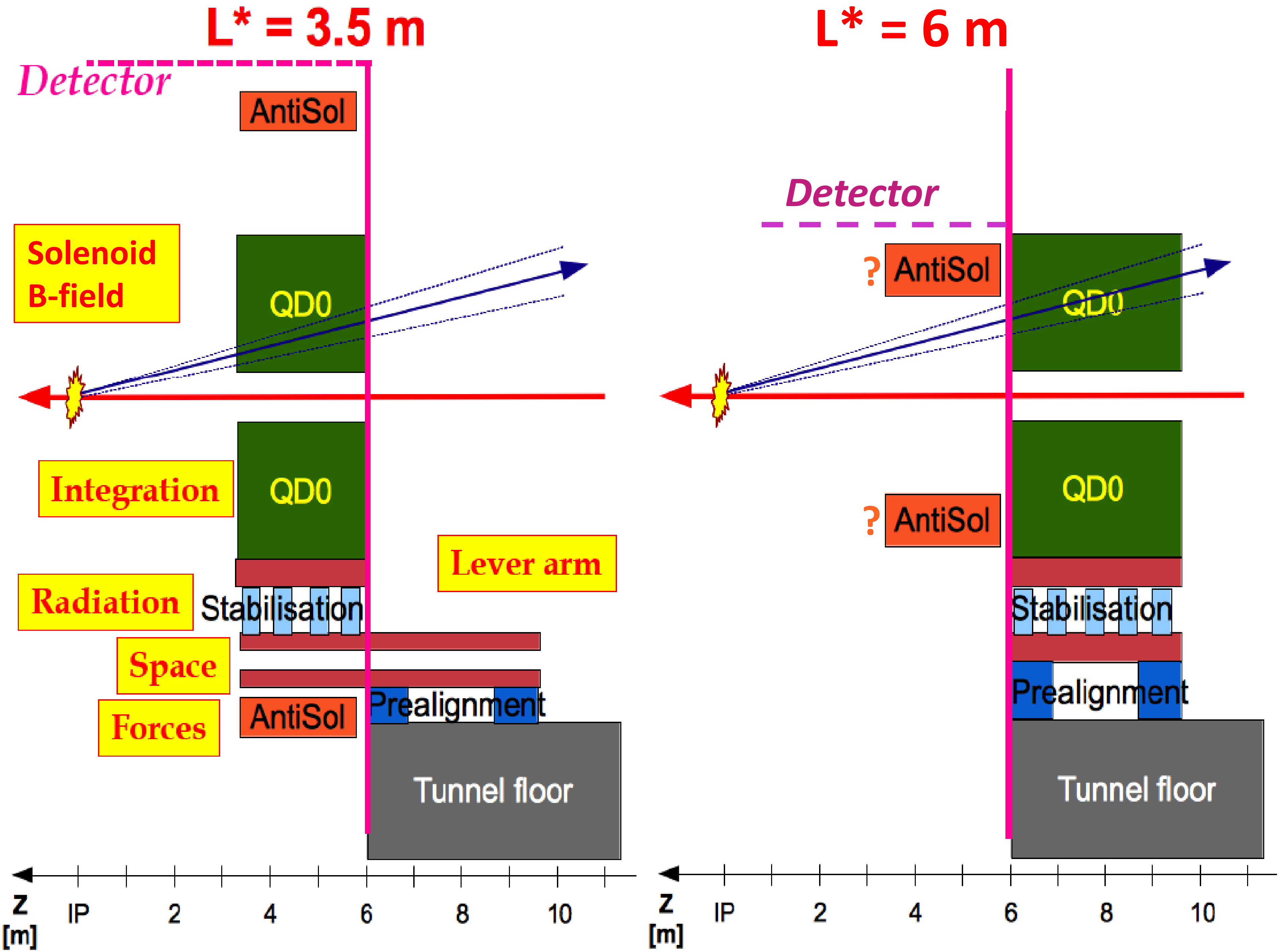
- A number of **parameters have been** frozen to allow consistent studies on detector optimisation and performance.
- For the forward region design they concentrate now on the long L* solution with **QD0 in the tunnel**, i.e. outside the detector.
  The exact value of L* had to be defined precisely.

**This has major implications for MDI**

# QD0 in the tunnel or not

- QD0 in the detector takes away a significant fraction of the **acceptance in the forward region**. **Although with recent super-ferric magnet technology it may be possible to reduce the loss.**
- Due to the presence of a **strong magnetic field**, **higher radiation** and **lack of space and access** inside the detector some critical components may require more or longer interventions, leading to loss of integrated luminosity.
- For the **chosen L* value** the **BDS optics must be re-optimised** (impact on QD0 parameters, required pre-alignment precision, etc).
- In case QD0 moves to the tunnel, the question is legitimate whether the **anti-solenoid** and/or **IP feedback** are still required inside the detector and how their implementation must be revised.

In the end a fair comparison between short and long L* in terms of physics performance can be made.



L* = 3.5 m
Detector
AntiSol
Solenoid B-field
QD0
QD0
Integration
Lever arm
Radiation
Stabilisation
Space
Forces
AntiSol
Prealignment
Tunnel floor
Z [m]
IP
2
4
6
8
10
L* = 6 m
Detector
? AntiSol
QD0
? AntiSol
QD0
Stabilisation
Prealignment
Tunnel floor
Z [m]
IP
2
4
6
8
10

# What are the new parameters?

- Need to **fix L***
- What are the **QD0 parameters**?
- Which impact on luminosity and bandwidth?
- Can we simplify the construction and other issues?

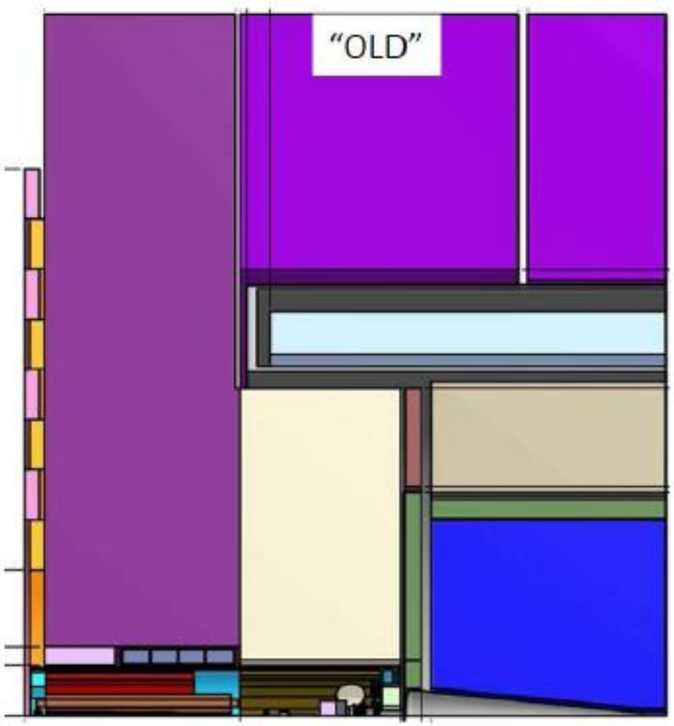
**Baseline design:**

CLIC_ILD from CLIC CDR 2012.

**New draft baseline design:**

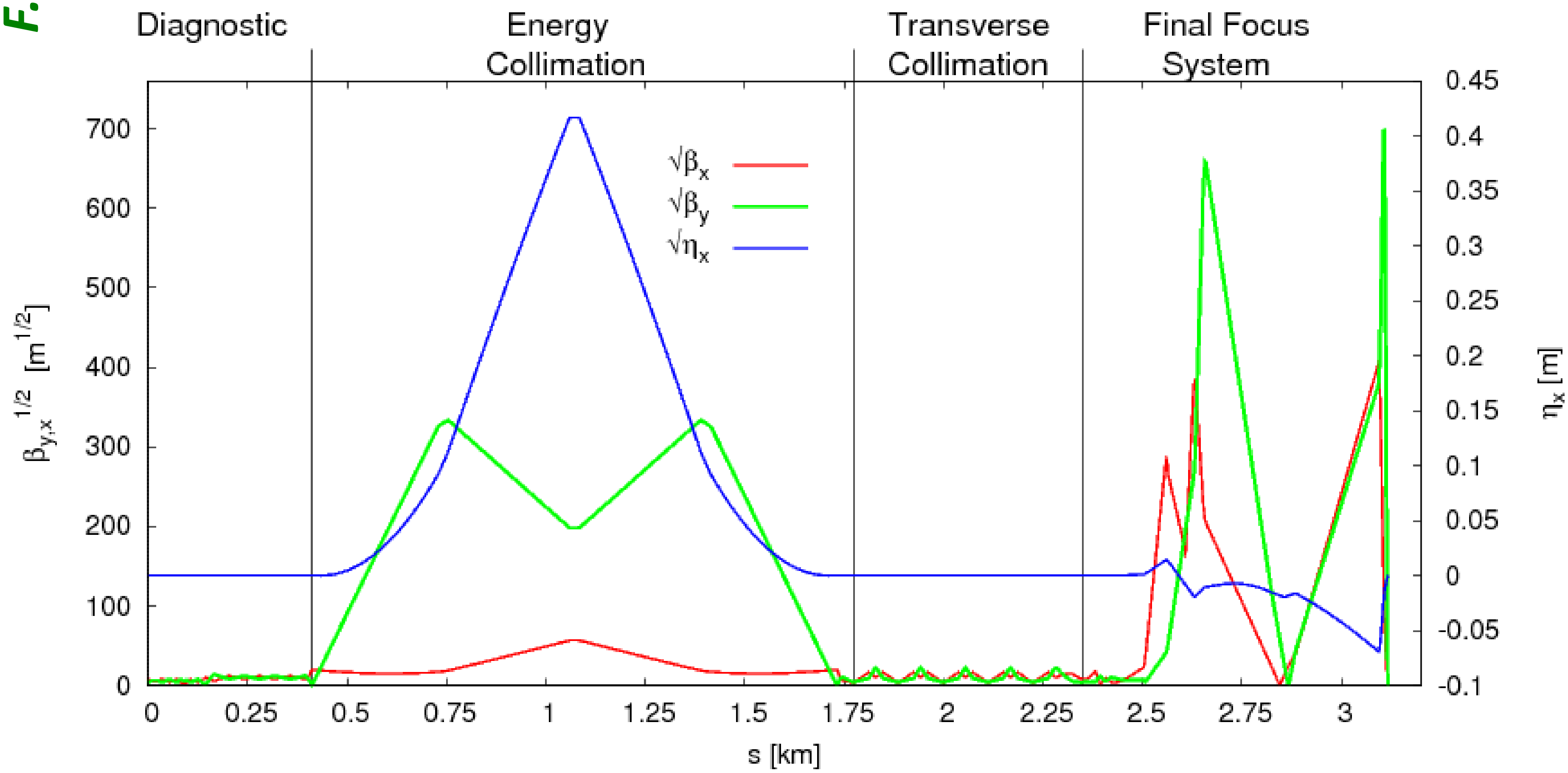
New L*=6m,
Reduced end-cap and barrel yoke.

**L* = 6 m**




# BDS Optics for L* = 6 m

*F.Plassard*

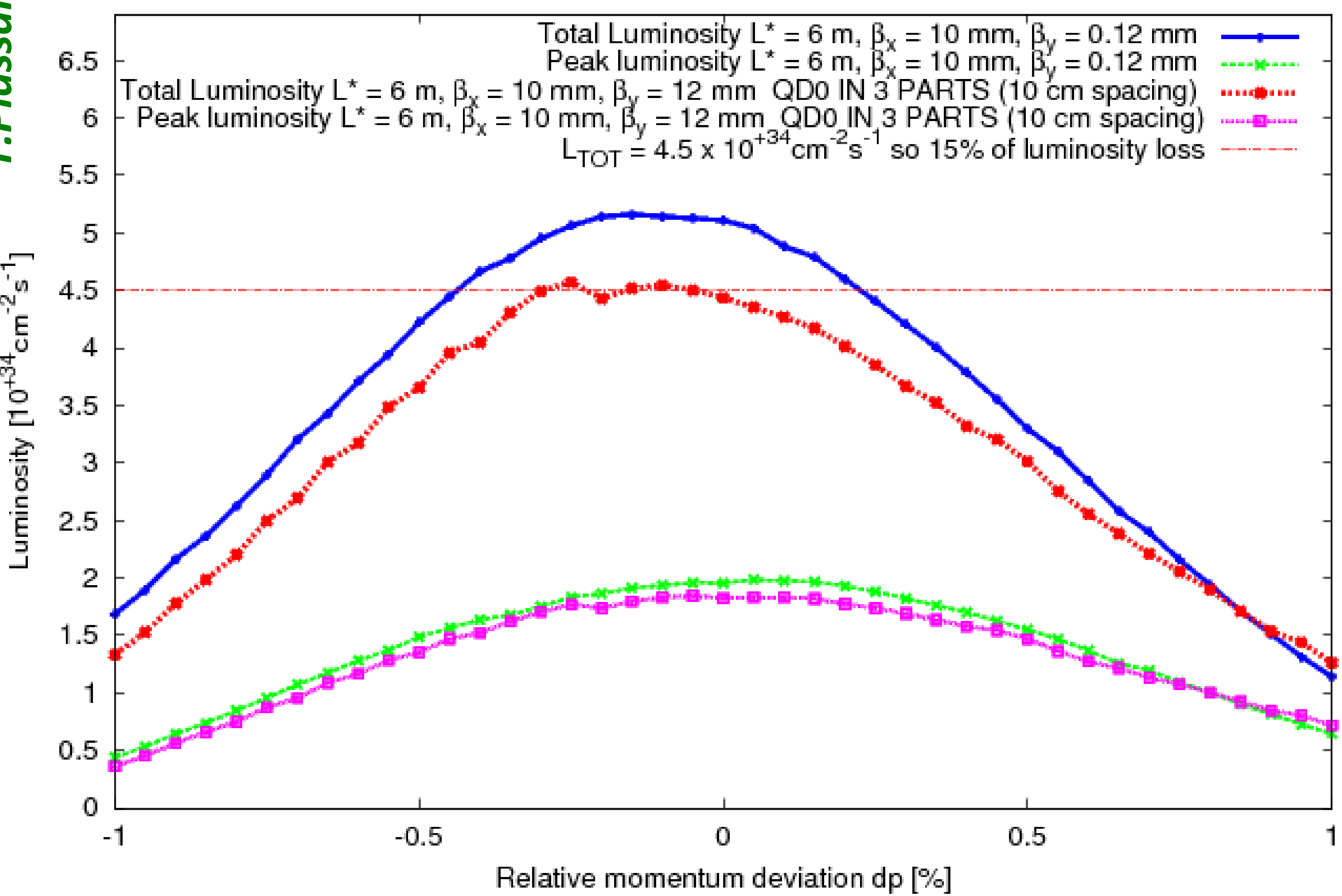


# What are the parameters for 3 TeV?

| Parameter | L* = 6 m | L* = 3.5 m |
|---|---|---|
| Total luminosity ($10^{34}$ $cm^{-2}$ $s^{-1}$) | **5.2** | **5.9** |
| Length of QD0 (m) | 4.7 | 2.73 |
| Minimum aperture radius (mm) | 3.8 | 3.83 |
| Gradient (T/m) | 197 | 575 |
| Field at the pole tip (T) | 0.74 | 2.20 |
| Length of QF1 (m) | 5.6 | 3.26 |
| Minimum aperture radius (mm) | 3.8 | 4.69 |
| Gradient (T/m) | 196.8 | 200 |
| Field at the pole tip (T) | 0.74 | 0.94 |

***F.Plassard***

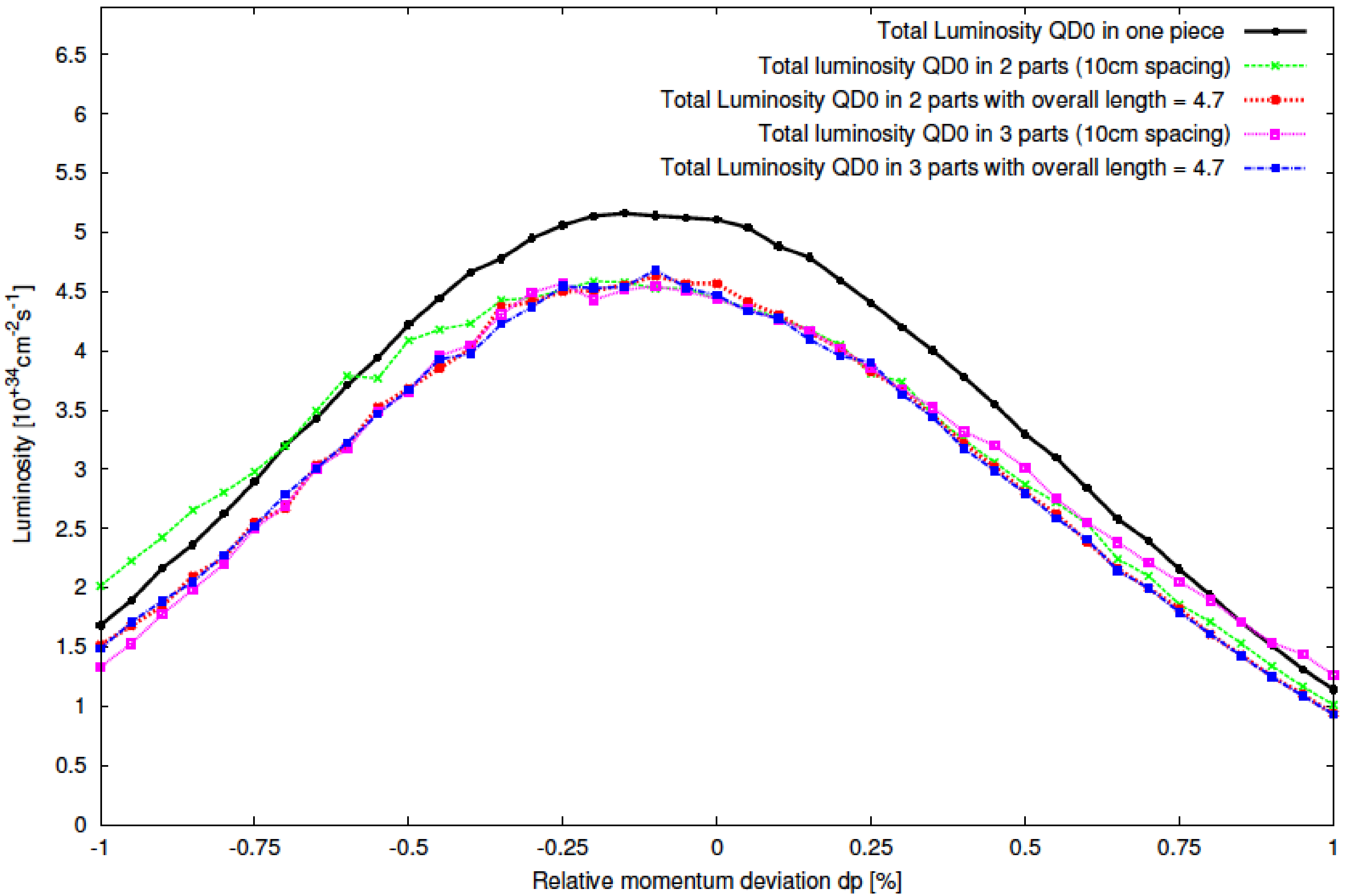
F.Plassard



Total Luminosity L* = 6 m, βx = 10 mm, βy = 0.12 mm
Peak luminosity L* = 6 m, βx = 10 mm, βy = 0.12 mm
Total Luminosity L* = 6 m, βx = 10 mm, βy = 12 mm QD0 IN 3 PARTS (10 cm spacing)
Peak luminosity L* = 6 m, βx = 10 mm, βy = 12 mm QD0 IN 3 PARTS (10 cm spacing)
LTOT = 4.5 x 10+34cm-2s-1 so 15% of luminosity loss
Luminosity [10+34cm-2s-1]
Relative momentum deviation dp [%]
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
-1
-0.5
0
0.5
1

# CLIC 3 TeV BDS bandwidth with QD0 splitted

F.Plassard



# CLIC 3 TeV BDS performances with QD0 splitted

F.Plassard

| QD0 design | $\sigma_x^*$ [nm] | $\sigma_y^*$ [nm] | $L_{TOT}/L_{1\%}$ $[cm^{-2}s^{-1}]$ | Ap. [mm] | $k_1$ $[\mathrm{m}^{-2}]$ | $G$ [T/m] | $B$ [T] |
|---|---|---|---|---|---|---|---|
| 1 block | 60 | 1.7 | 5.2/2.1 | 3.8 | -0.0394 | -196.8 | 0.74 |
| 3 p. | 61.1 | 1.8 | 4.5/1.9 | 6.2 | -0.03922 | -195.9 | 1.21 |
| 3 p. lenght cst | 61 | 1.77 | 4.7/1.9 | 3.2 | -0.0412 | -206.25 | 0.66 |
| 2 p. | 61.9 | 1.78 | 4.53/1.9 | 3.15 | -0.03927 | -196.82 | 0.62 |
| 2 p. lenght cst | 60.5 | 1.77 | 4.63/1.9 | 3.13 | -0.402 | -201.3 | 0.63 |

**Beam sizes and luminosity calculated with synchrotron radiation and** $dp = 0\%$
$L^* = 6$ m / $\beta_x^* = 10$ mm and $\beta_y^* = 0.12$ mm

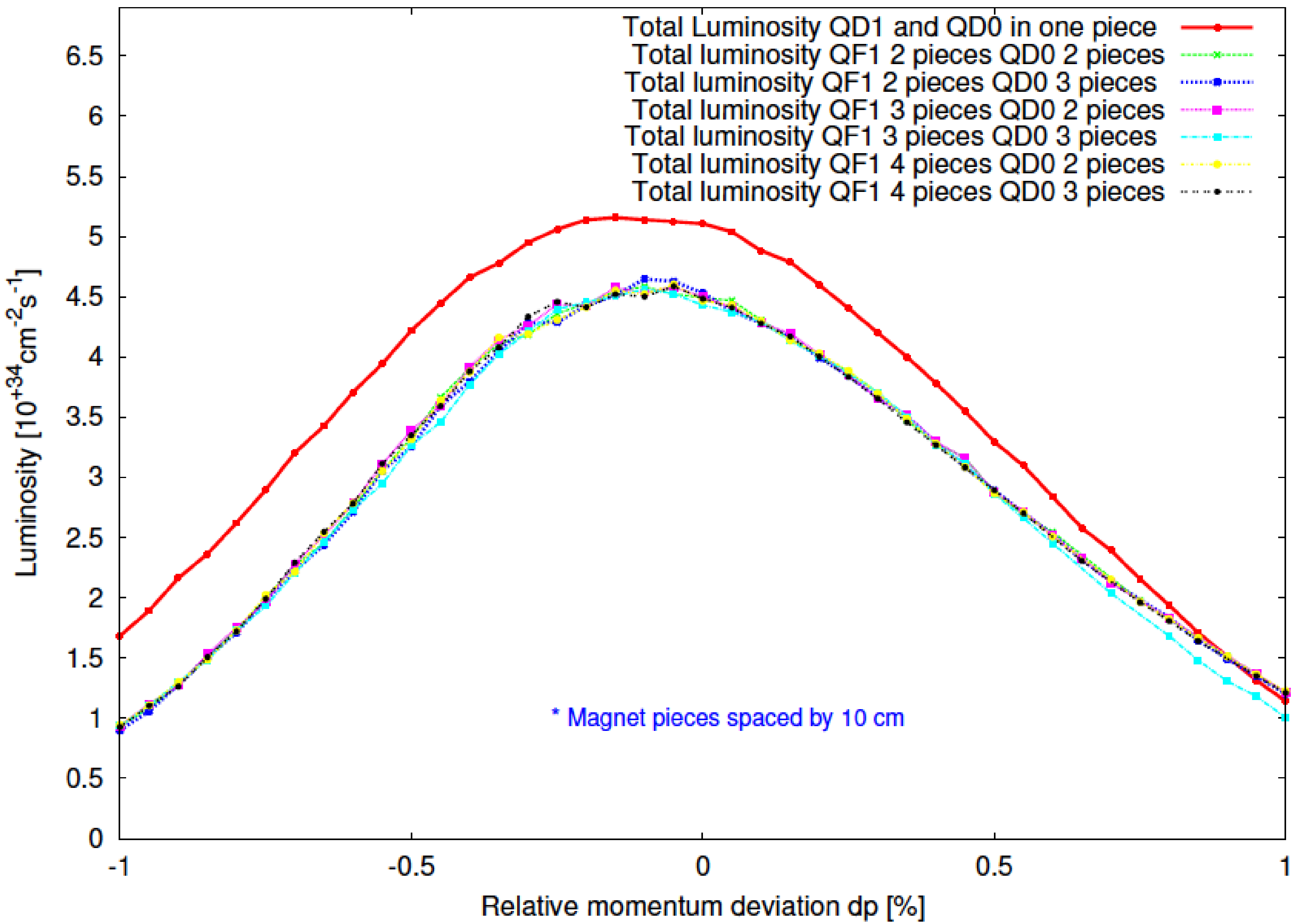
**The best performance is achieved by QD0 splitted in 2 or 3 parts with the overall length constant and the luminosity loss from the one block design is 12.3% and 10.7% respectively**

# Conclusion on QD0

- QD0 is now **4.7 m long** with a minimal aperture radius of 3.8 mm and field at the pole tip of 0.74 T, i.e. a gradient of 197 T/m. The loss of peak luminosity is 12% with respect to the L* = 3.5 m implementation, i.e. 5.2 instead of 5.9 $10^{34}$ $cm^{-2}$ $s^{-1}$.
- The **bandwidth is correct** also for the longer L* value.
- **Splitting QD0 in 3 parts** leads to an extra loss of luminosity of 10.7%, but is indicated for a realistic magnet design. **Each magnet is then 1.5 m long**.
  The aperture radius increases to 5.9 mm, **the gradient to 205.7 T/m** and the field at the pole tip to 1.21 T.
- It was checked that at **lower energy** (500 and 380 GeV) this approach gives promising first results and the luminosity might be even closer to the values for L*=3.5 m.
- Please note that in the new optics **QF1 is even longer: L = 5.6 m**.

# CLIC 3 TeV BDS bandwidth with QD0 and QF1 splitted

*F.Plassard*



# CLIC 3 TeV BDS performances with QD0 and QF1 splitted

*F.Plassard*

| QF1 + QD0 design | $\sigma_x^*$ [nm] | $\sigma_y^*$ [nm] | $L_{TOT}/L_{1\%}$ [$cm^{-2}s^{-1}$] | Ap. [mm] | $k_1$ [$m^{-2}$] | $G$ [T/m] | $B$ [T] |
|---|---|---|---|---|---|---|---|
| 1 block | 60 | 1.7 | 5.2/2.1 | 3.8 | -0.0394 | -196.8 | 0.74 |
| 2p + 2p | 61.13 | 1.8 | 4.5/1.9 | 5.9 | -0.0403 | -201.1 | 1.19 |
| 2p + 3p | 61.2 | 1.84 | 4.6/1.9 | 5.8 | -0.0412 | -205.7 | 1.193 |
| 3p + 2p | 61.2 | 1.81 | 4.5/1.87 | 5.82 | -0.0403 | -201.13 | 1.17 |
| 3p + 3p | 62.4 | 2 | 4.45/1.85 | 5.9 | -0.0412 | -205.7 | 1.21 |
| 4p + 2p | 61.3 | 1.82 | 4.48/1.9 | 5.82 | -0.0403 | -201.14 | 1.17 |
| 4p + 3p | 61.1 | 1.8 | 4.49/1.9 | 6 | -0.0412 | -206 | 1.23 |

**Beam sizes and luminosity calculated with synchrotron radiation and** $dp = 0\%$
$L^* = 6$ m / $\beta_x^* = 10$ mm and $\beta_y^* = 0.12$ mm

**The best performance is achieved by QF1 splitted in 2 pieces (2 x 2.75m) and QD0 splitted 3 pieces (3 x 1.5 m) and the luminosity loss from the one block design is 13%**

# Conclusions on QD0 and QF1

| Magnet | $L_{tot}$ (m) | G (T/m) | $B_{max}$ (T) | Parts | $R_{ap}$ (mm) |
|---|---|---|---|---|---|
| QD0 | 4.7 | 205.7 | 1.21 | 3 | 5.9 |
| QF1 | 5.6 | 71 | 0.314 | 3 | 4.42 |

QD0, QF1 in 3 parts is easier:

- Each part is lighter, may allow **commercial actuators**
- Very long magnets are **not stiff enough** to be adequately stabilised to 0.2 nm
- One must now investigate if the three parts can be **stabilised coherently**

Now magnet design and stabilisation studies can start.

# Do we still need an anti-solenoid?

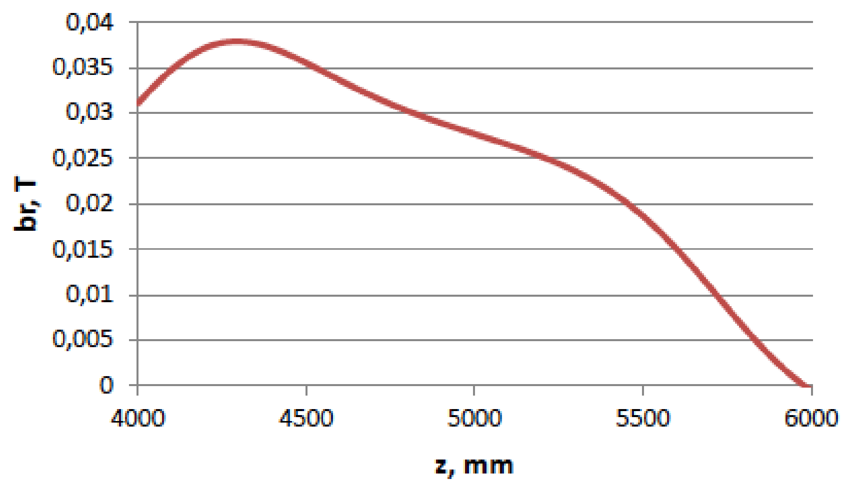
- A stray field in the end-cap region may affect the luminosity
- A stray field in the tunnel may affect eventual permanent magnets in QD0
  However, QD0 may be built without permanent magnets (tbd)
- End-coils may decrease the field outside the detector, but consume lots of power.
- The stray field in the end cap depends on the radius of the hole in the end cap.
- A satisfactory situation is obtained for R = 500 mm even without anti-solenoid and without end coils.
  In that case the stray field around the barrel remains acceptable.
- **This needs final confirmation by detailed beam optics studies**.

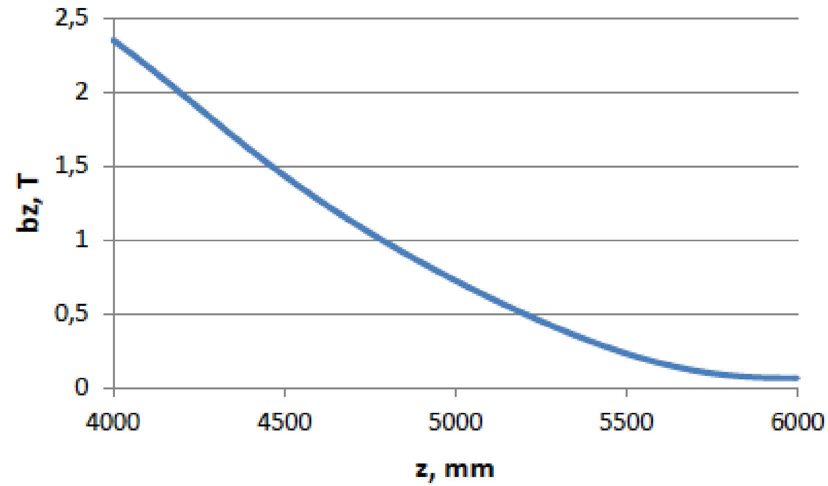
See B.Cure

**B-Field on beam axis** in EC region (from Alexander Aloev)

Beam axis inclined by **0.01 rad** with respect to the detector axis.

Target : **br < 0.04 T (value at IP with 4 T and 0.01 rad)**




*A.Aloev*

=> The specification is met **without anti-solenoid** in the end cap aperture.

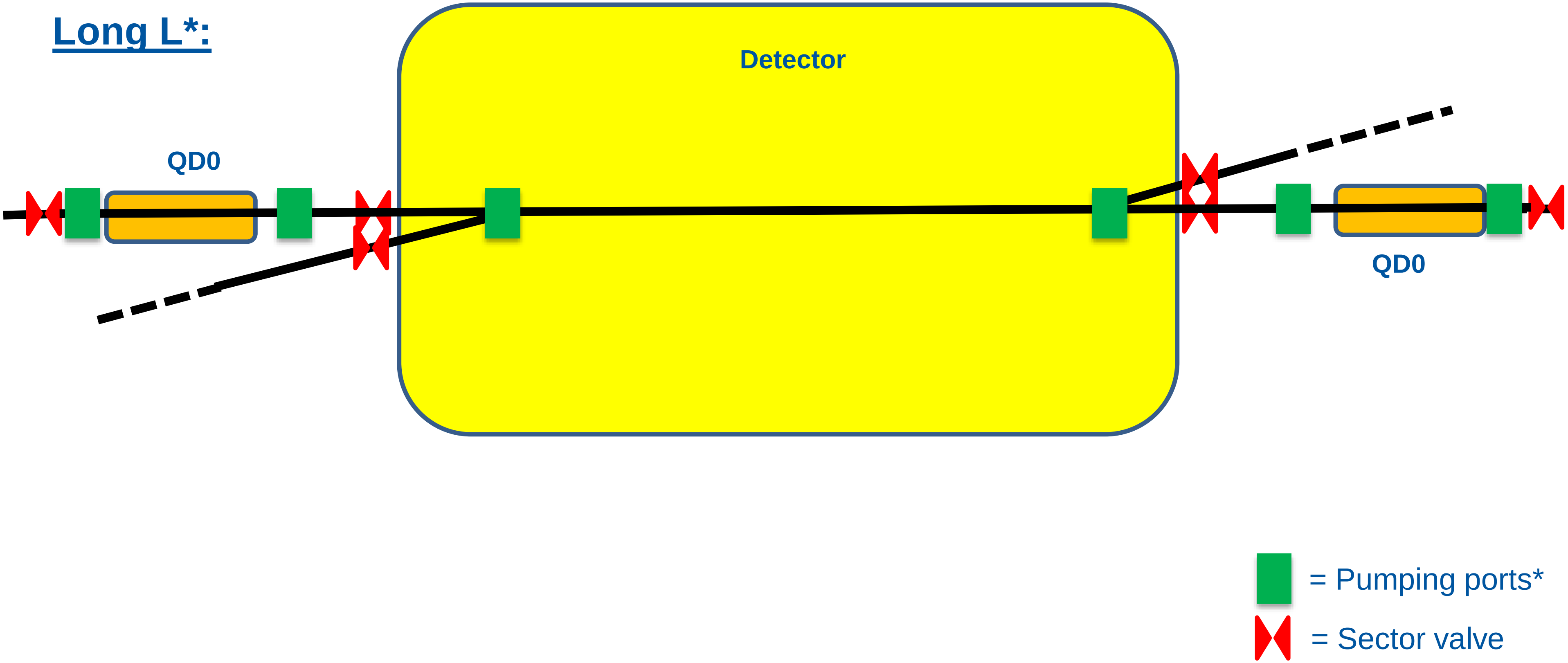
# Some other consequences

- The **vacuum sectorisation** can be simplified
- The QD0 **pre-alignment** can be simplified, but may have more stringent requirements (earlier studies suggested 8 μm)
- The **IP feedback** system can stay where it is (or only slightly moved)

C.Garion

# Beam Line Sectorisation Scheme

## Long L* option

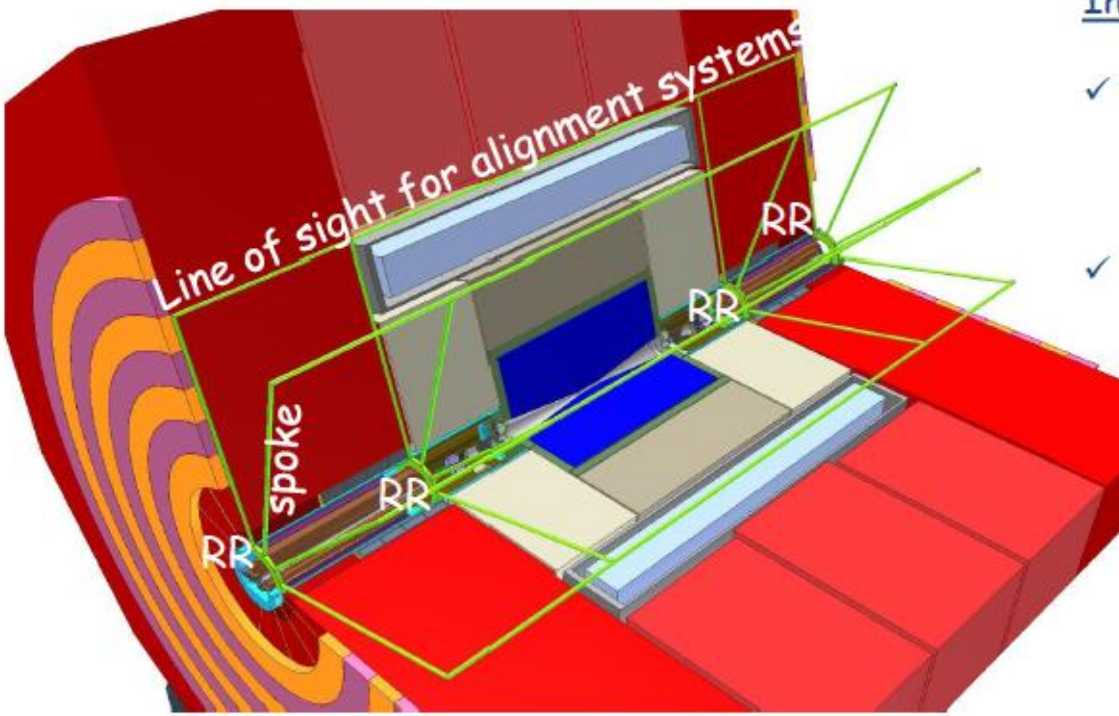



*Pumping port number and position could change depending on pressure requirements or space constraints…

# MDI: monitoring of left QD0 w.r.t right QD0

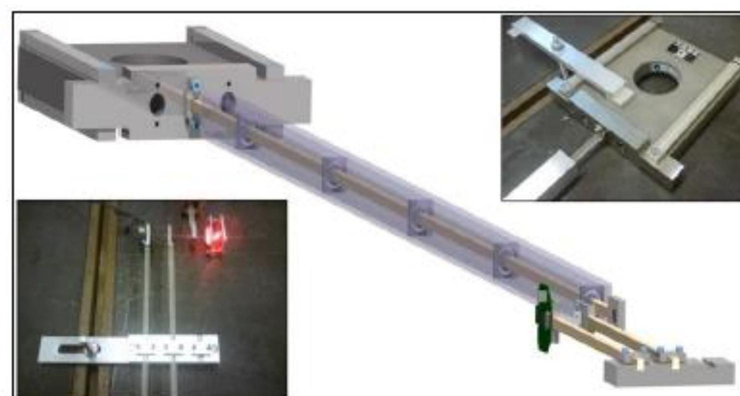
## Concept

- ✓ 4 Reference Rings (RR) located at each extremity of QD0, supported from outer tube
- ✓ 6 radial spokes per RR




## In two steps:

- ✓ A monitoring of the position of QD0 w.r.t RR thanks to proximity sensors. (initial calibration of their position performed on a CMM)
- ✓ A transfer of the position of RR thanks to 6 spokes to alignment systems. By combination of redundant information, the position of the center of 4 RR is computed.



## Status:

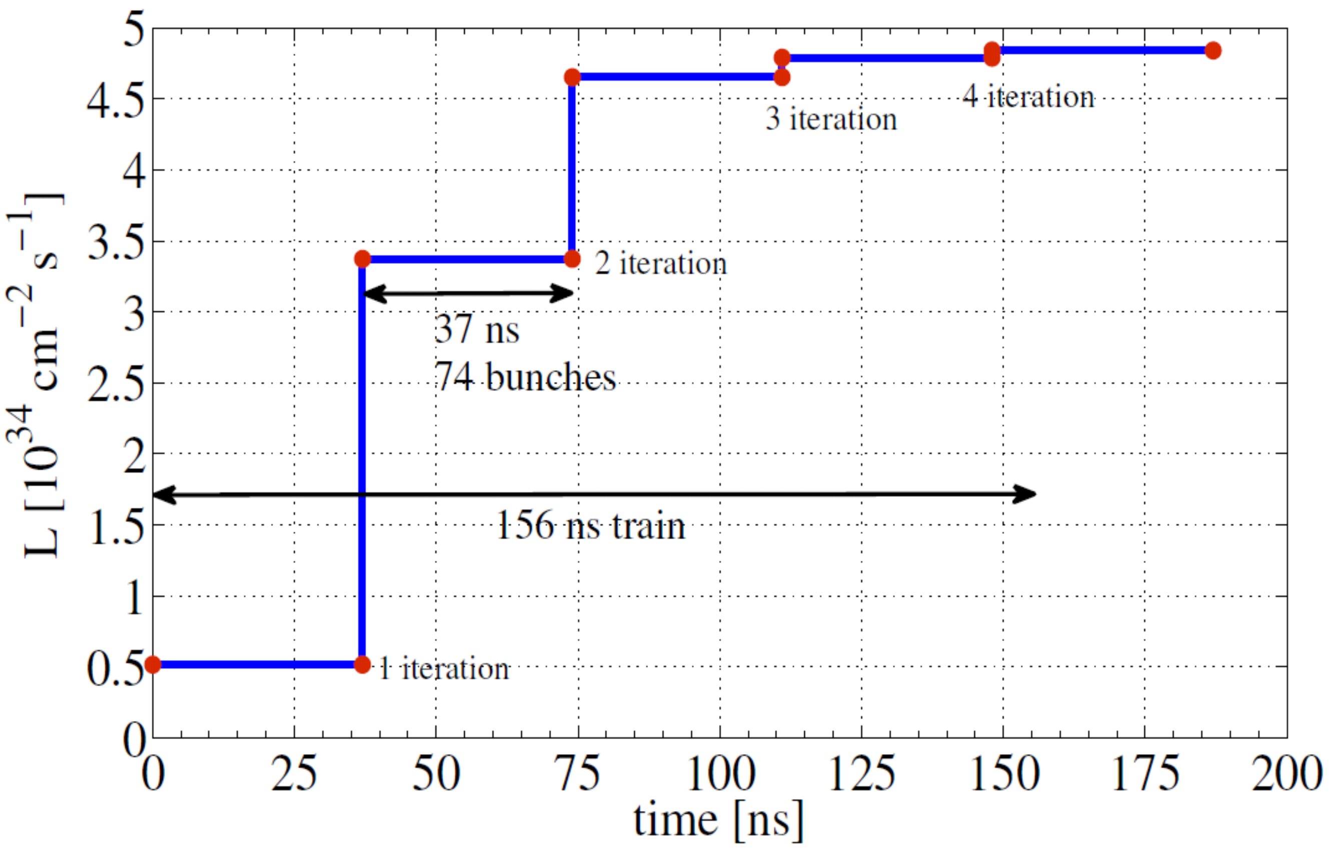
- ✓ 1m long spoke built and validated
- ✓ Sensors under validation on the Two Beam Module



H.Mainaud Durand

# CLIC IP FB Performance (CDR)

**Single random seed of GM C, CDR implementation**




**Ph. Burrows, Resta Lopez**

# Plans

- Design in detail the new QD0 and QF1 magnets, based on the new parameters. Compare classical, hybrid and super-ferric solutions
- Study implications for stabilisation, once the QD0 and QF1 design is better known. This includes stiffness of magnet, availability of commercial actuators, coupling between magnets, sensors with more space available in tunnel, etc
- Have to evaluate requirements on pre-alignment and a technical solution to achieve it
- Do we still need a pre-isolator?
- In collaboration with the detector teams, go in more detail on layout and integration issues inside the detector (IP FB, vacuum, etc)
- Finalise studies for anti-solenoids and ring coils
- Revisit issues like radiation, shielding, stray field, cavern (and galleries) layout, ….

# The MDI working group

A.Hervé, A.Aloev, A.Vorozhtsev, A.Gaddi, A.Jeremie, A.Latina, A.Sailer, B.Cure, B.Dalena, B.Pilicer, L.Brunetti, C.Garion, C.Collette, C.Perry, D.Schulte, D.Tommasini, D.Mergelkuhl, E.Bravin, F.Duarte Ramos, F.Butin, F.Plassard, F.Zimmermann, G.Christian, G.Bobbink, H.Mainaud Durand, H.Burkhardt, H.Gerwig, J.Resta Lopez, J.Axensalva, J.Vollaire, J.Snuverink, J.Osborne, K.Elsener, K.Artoos, L.Linssen, M.Battaglia, M.Gastal, M.Guinchard, M.Modena, P.Burrows, R.Tomas, S.Mallows, T.Lefevre, Th.Otto, H.van der Graaf, V.Ziemann, Y.Levinsen, Y.Kim

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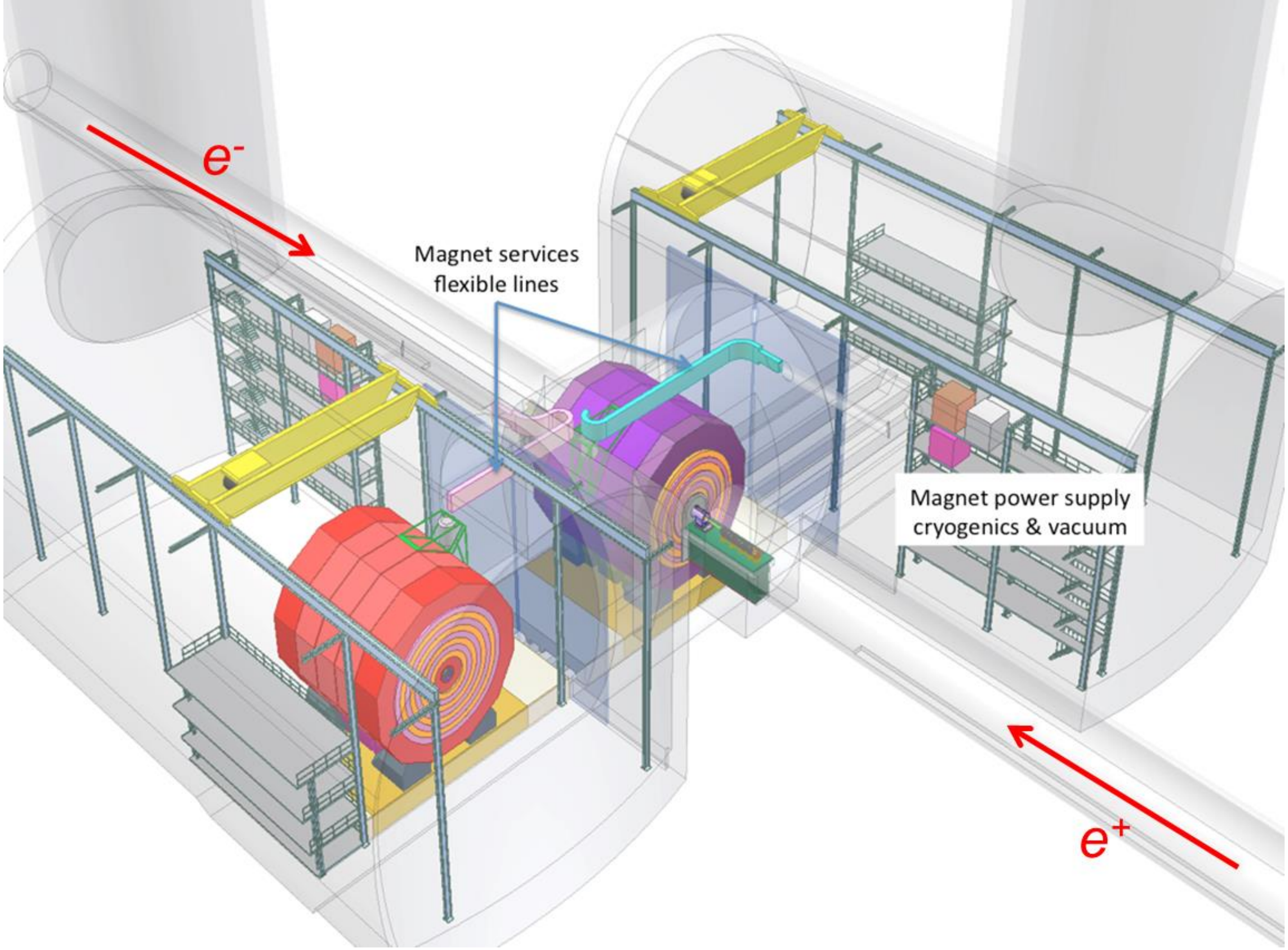
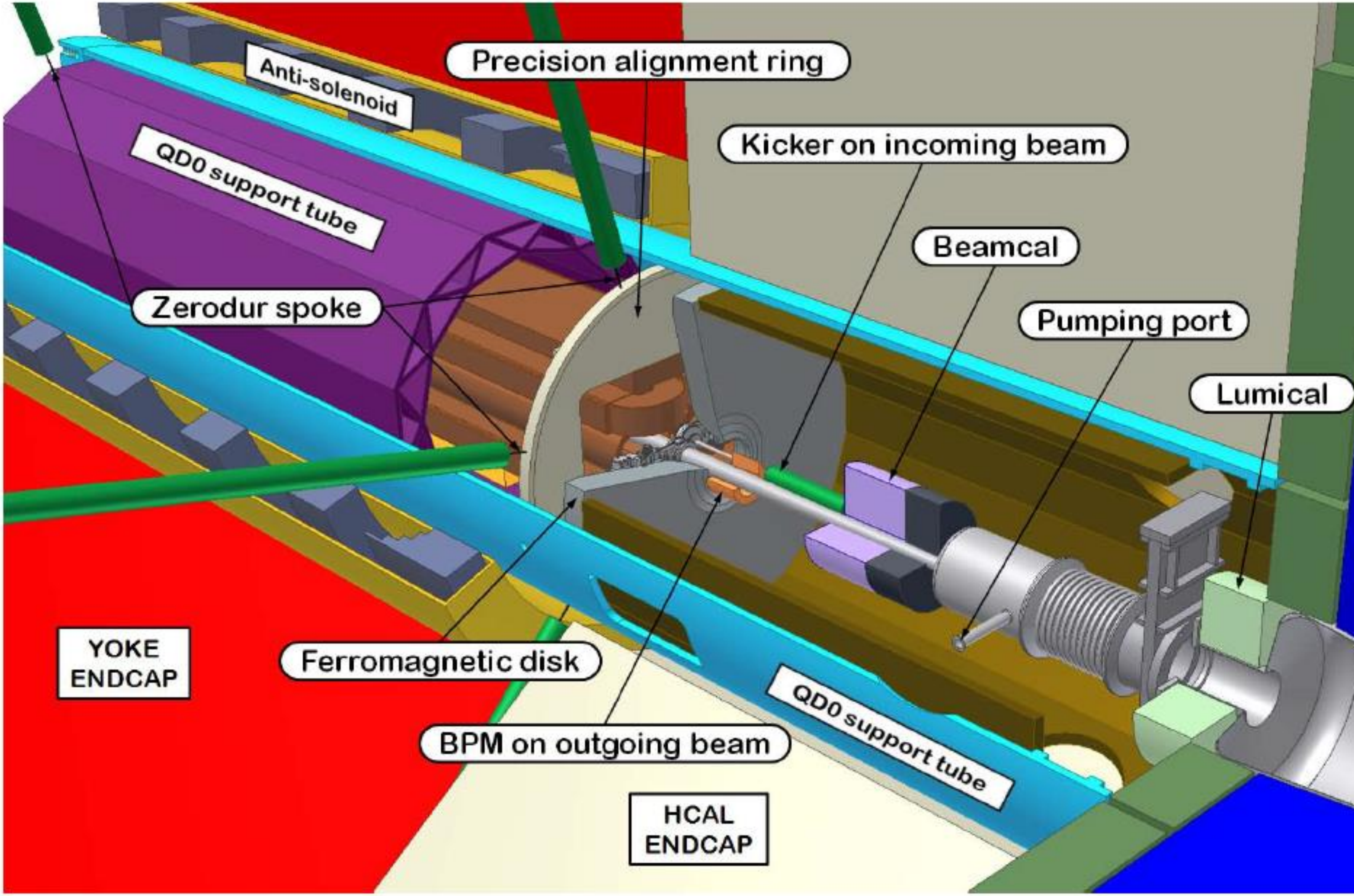
# The CDR concept:




Anti-solenoid
Precision alignment ring
QD0 support tube
Kicker on incoming beam
Beamcal
Zerodur spoke
Pumping port
Lumical
YOKE
ENDCAP
Ferromagnetic disk
BPM on outgoing beam
QD0 support tube
HCAL
ENDCAP

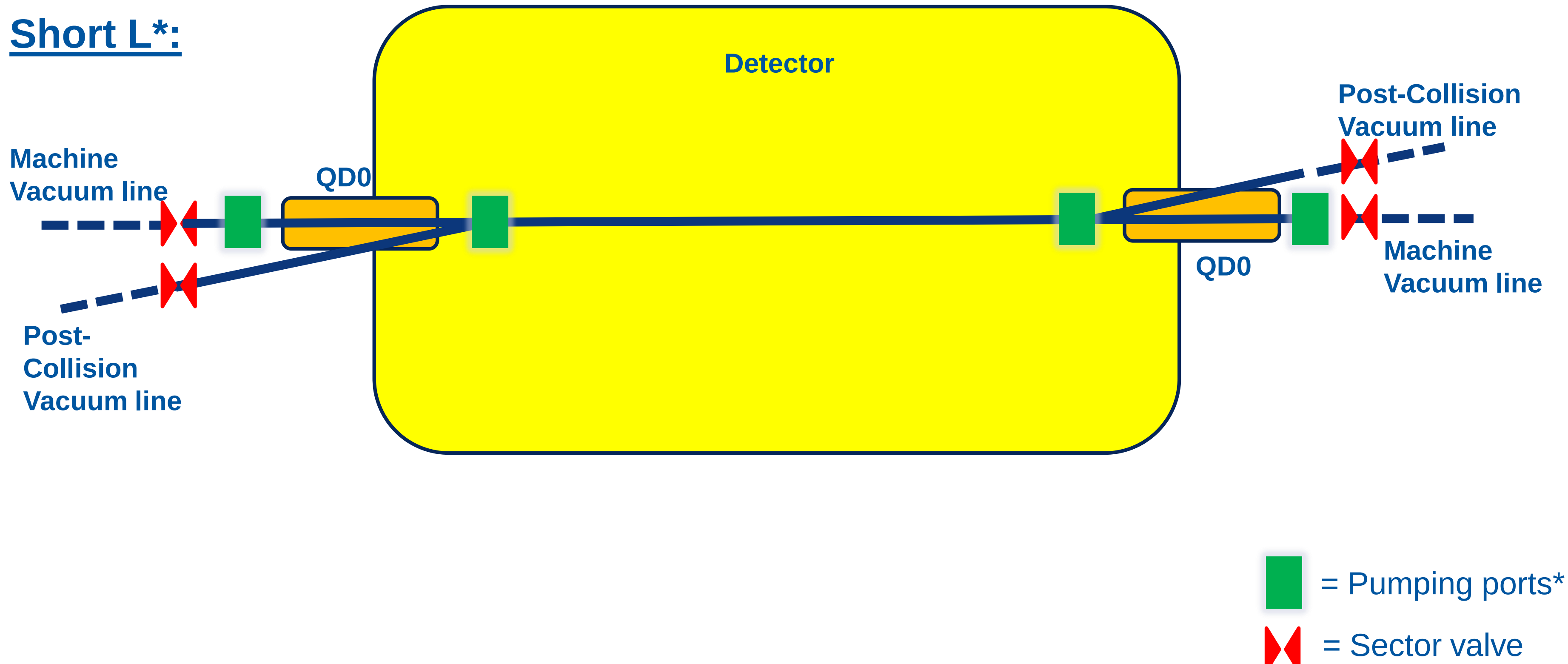
# What if no push-pull

- A number of constraints for **access to QD0** and/or vacuum connections could be dropped.
  Also the need to isolate the QD0 vacuum tube may no longer be so imperative.
- Cedric Garion from TE/VSC has e.g. had a first look at the vacuum layout implications: see next slide.
- **Opening of the detector** and access to equipment may become simpler.
- QD0 and QF1 must still be stabilised and pre-aligned, hence stay with warm technology

C.Garion

# Beam Line Sectorisation Scheme

## Short L*, no push-pull




*Pumping port number and position could change depending on pressure requirements or space constraints…

# IP FB with long L*

- Current CDR geometry:
  time of flight IP → BPM → kicker → IP ~ 24 ns
- Demonstrated FONT3 electronics latency = 13ns
- Estimated IPFB latency = 37ns
- In principle, change of L* need not affect IPFB position and latency, but needs to be engineered carefully, considering other beam line components