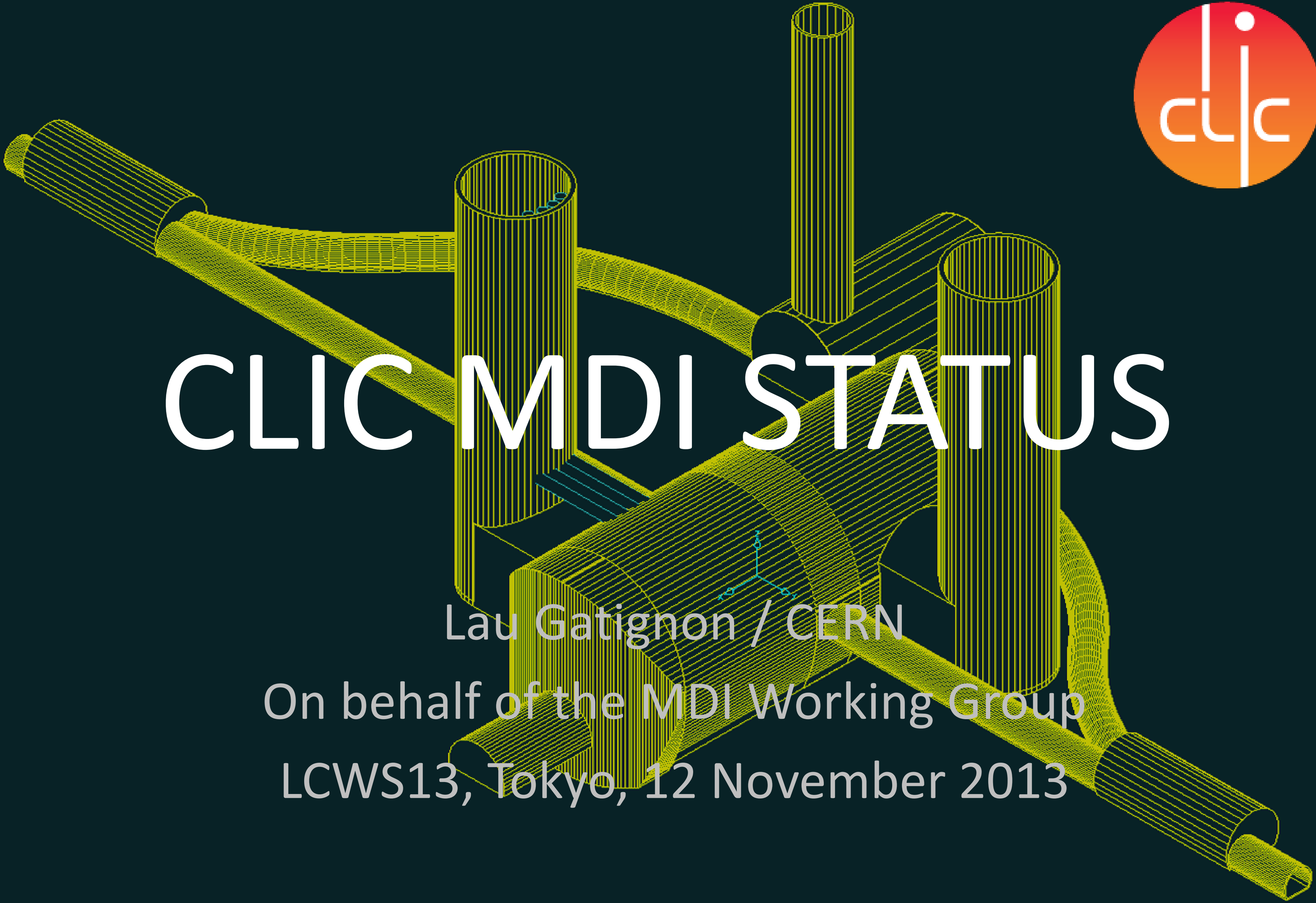


CLIC MDI STATUS

Lau Gatignon / CERN

On behalf of the MDI Working Group

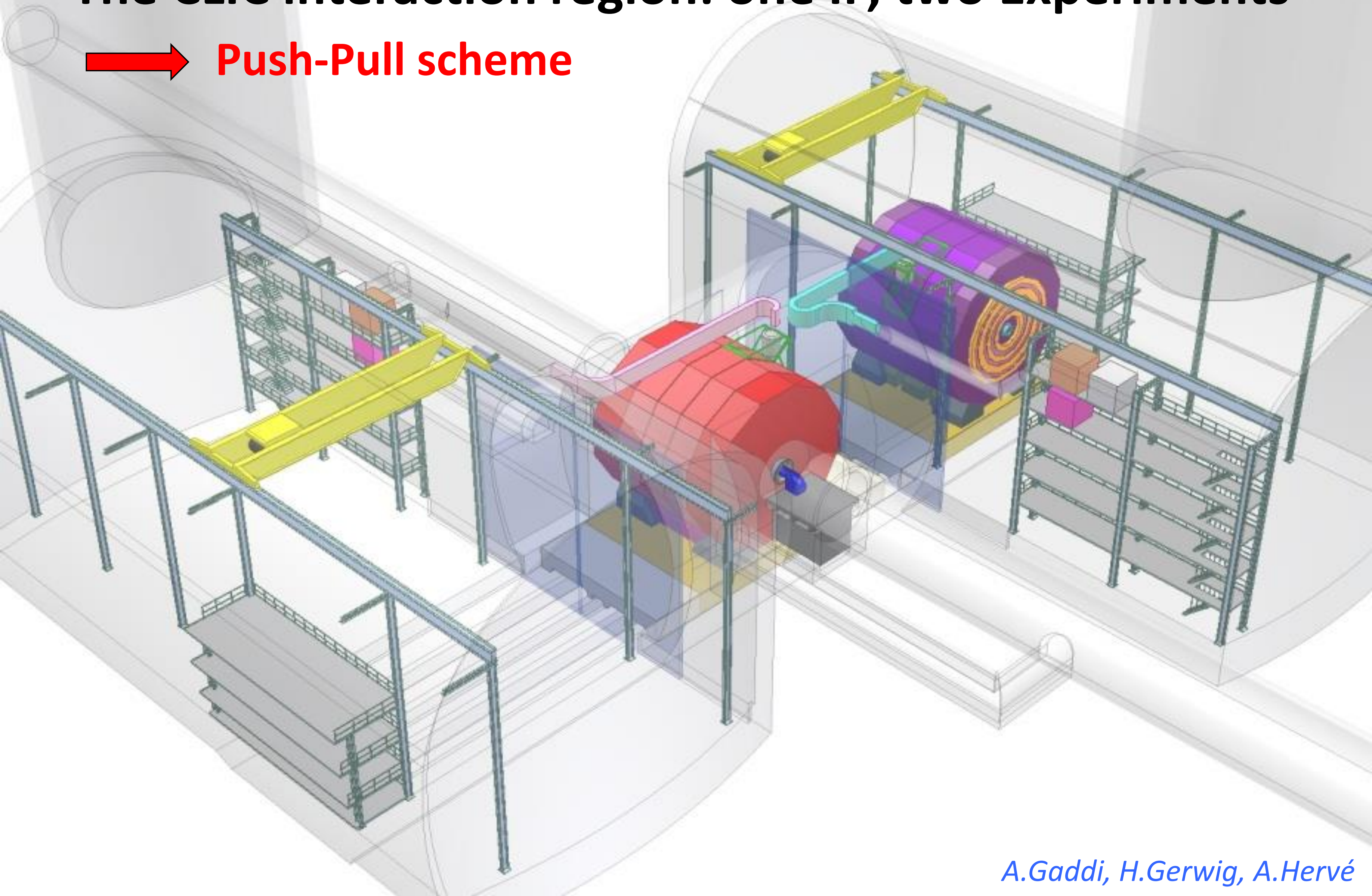
LCWS13, Tokyo, 12 November 2013

OUTLINE

- **Introduction**
- QD0 prototype measurements
- QD0 pre-alignment
- QD0 stabilisation
- IP feedback
- Anti-solenoid compensation
- Post-collision line (back to MDI since 2012)
- Coming soon: can QD0 be moved to the tunnel?
- Possibilities for CLIC-ILC collaboration?

The CLIC interaction region: one IP, two Experiments

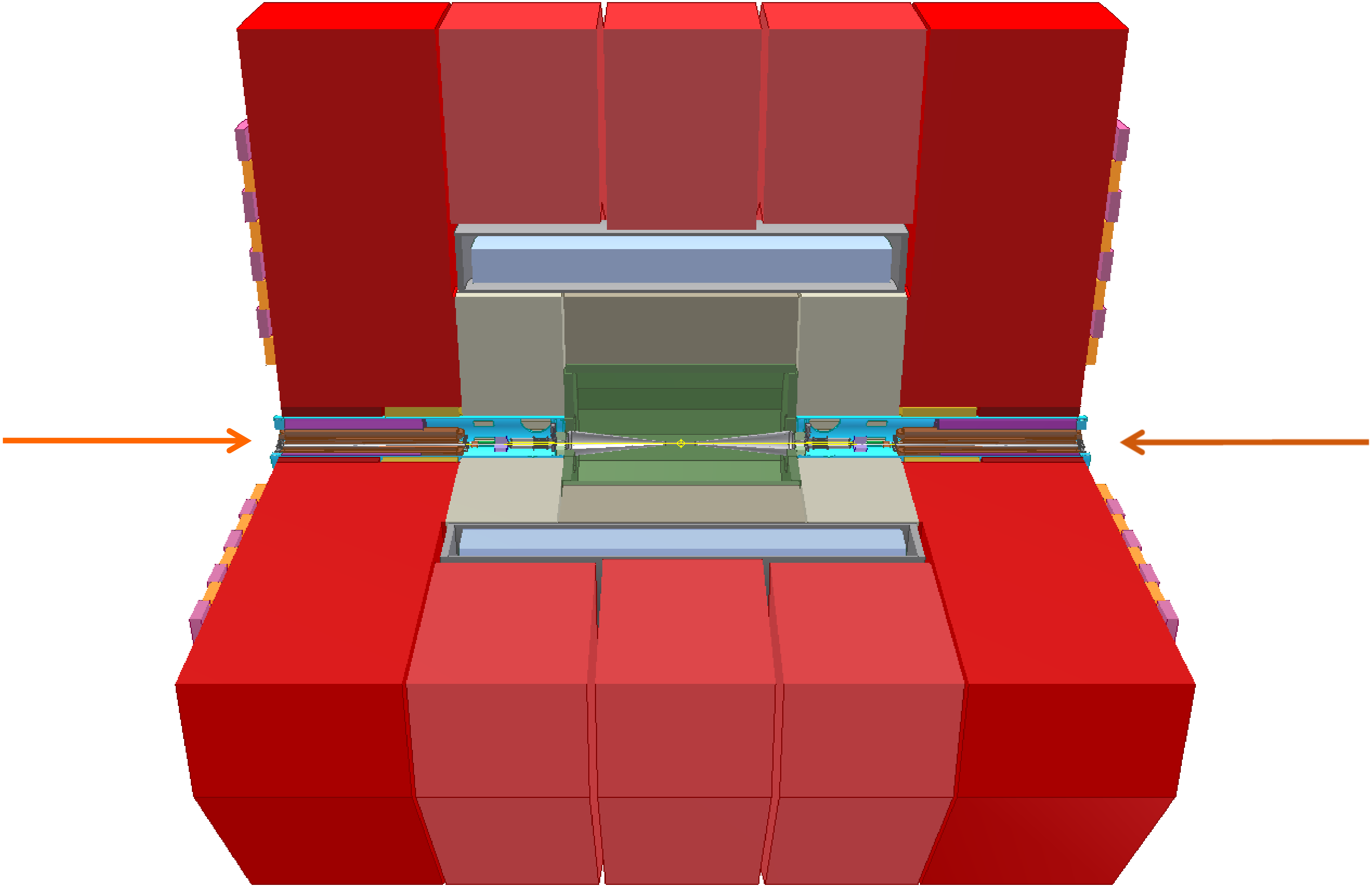
→ Push-Pull scheme



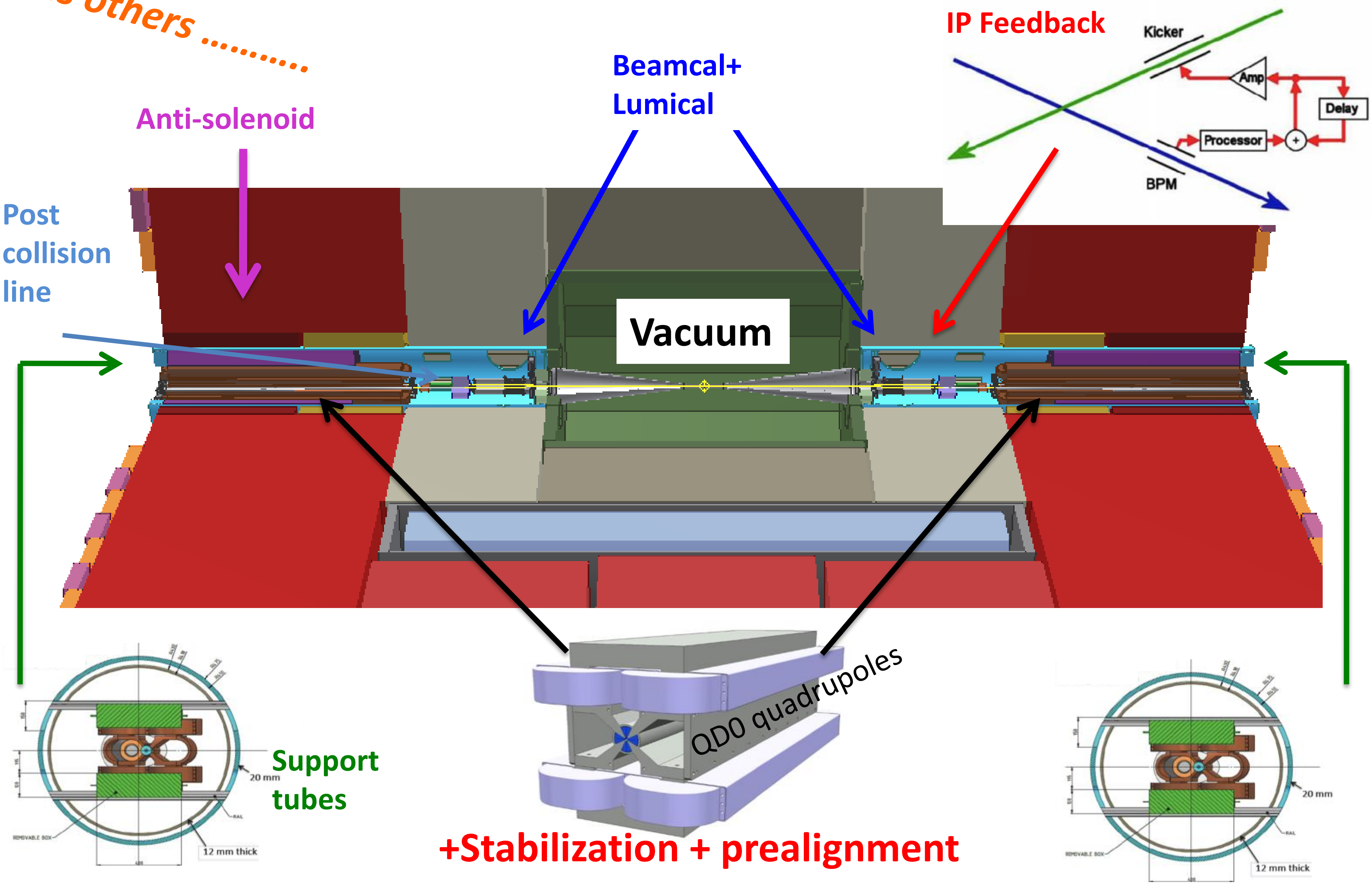
A.Gaddi, H.Gerwig, A.Hervé

e.g.: CLIC_SID DETECTOR

N.Siegrist, H.Gerwig



MACHINE DETECTOR INTERFACE



Plus others ……….

IP Feedback

Beamcal+ Lumical

Anti-solenoid

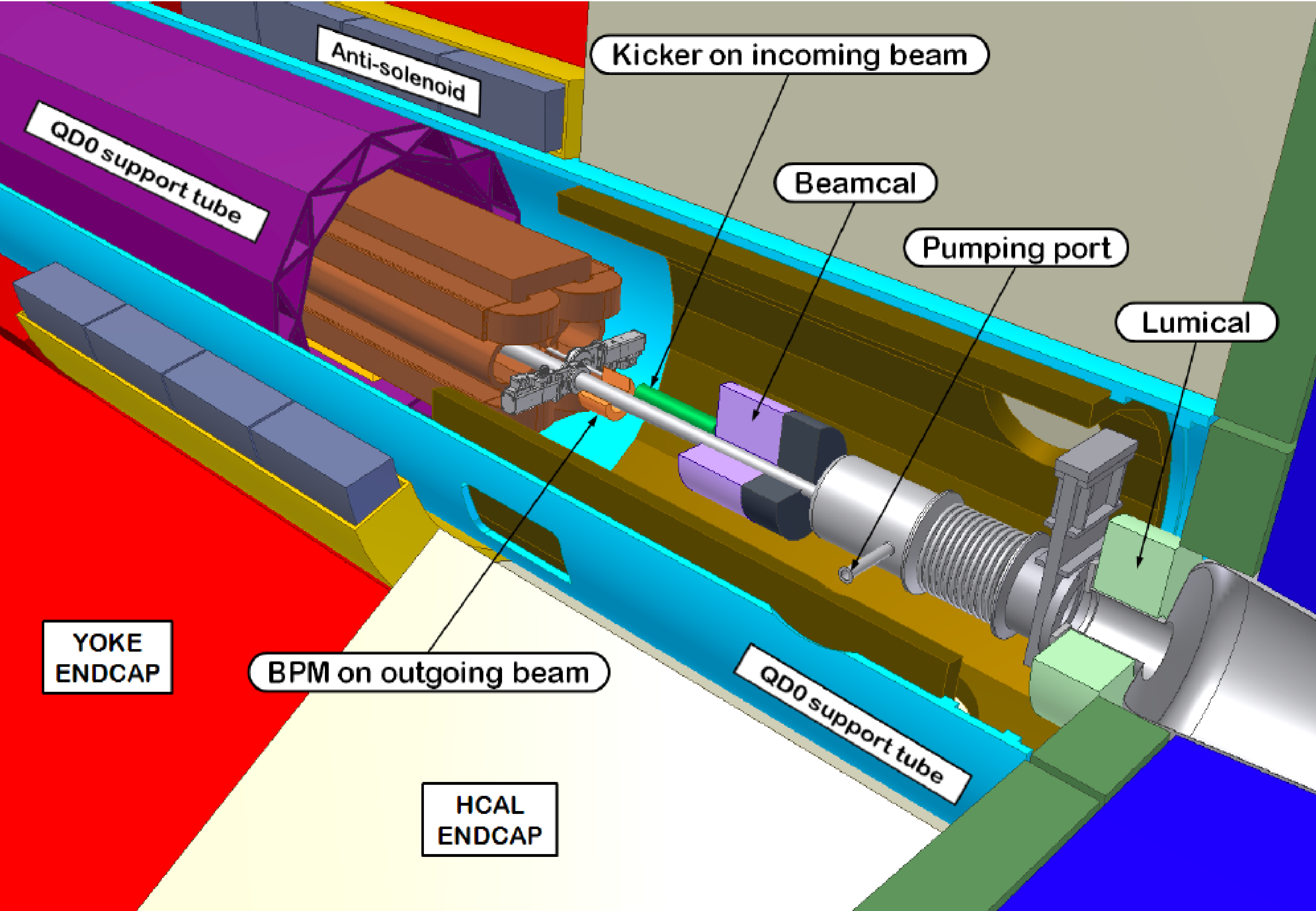
Post collision line

Vacuum

Support tubes

QD0 quadrupoles

+Stabilization + prealignment


Kicker on incoming beam
Anti-solenoid
QD0 support tube
Beamcal
Pumping port
Lumical
YOKE ENDCAP
BPM on outgoing beam
QD0 support tube
HCAL ENDCAP

- Introduction
- **QD0 prototype measurements**
- QD0 pre-alignment
- QD0 stabilisation
- IP feedback
- Anti-solenoid compensation
- Post-collision line (back to MDI since 2012)
- Coming soon: can QD0 be moved to the tunnel?
- Possibilities for CLIC-ILC collaboration?

QD0 study & design requirements

QD0 Baseline Parameter	*Value*
Nominal target for field gradient	575 T/m
Magnetic length	2.73 m
Magnet aperture (required for beam)	7.6 mm
Magnet bore diameter	8.25 mm* ** Including a 0.30 mm vacuum chamber thickness*
Good field region (GFR) radius	1 mm
Integrated field gradient error inside GFR	< 0.1%
Gradient adjustment	+0 to -20%

Magnet design boundary conditions:

- *As much as possible **compact design** (to be compatible with an L* of 3.5 m, so minimizing the solid angle subtracted to the experiment Detector)*
- *Compatible with **magnet active stabilization** (i.e. minimize magnet weight and vibration sources, ex. coil water cooling)*
- *Presence of the **post-collision line beam vacuum chamber** (in its closer position at 35 mm from beam axis)*

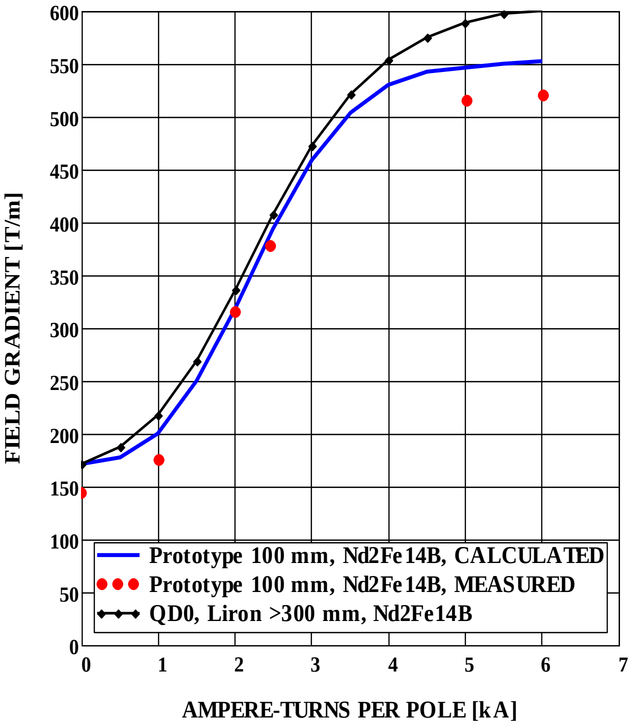
M.Modena et al

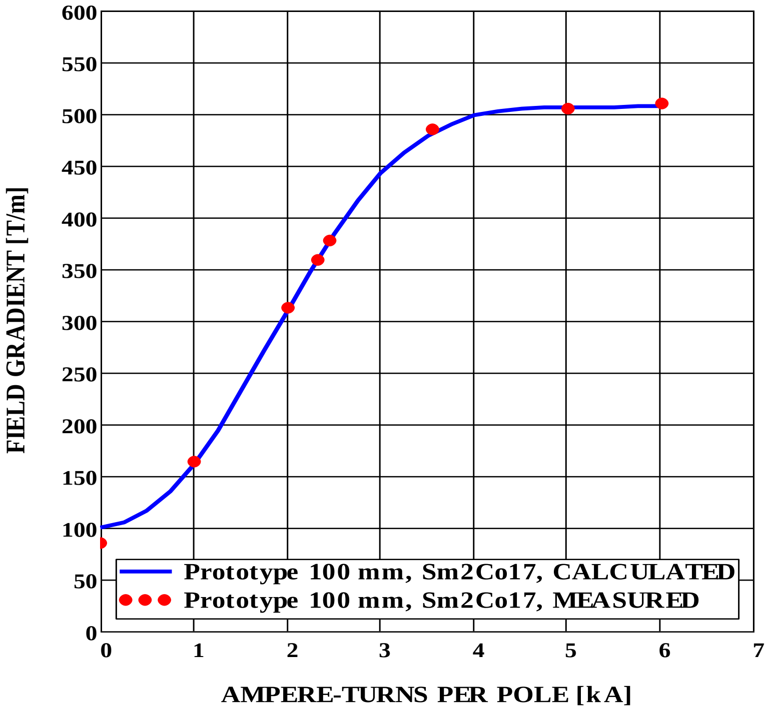
***Two** campaign of measurements were done in 2012 with QD0 prototype in two different configuration:*

*- in January 2012: the magnet equipped with the **$Nd_2Fe_{14}B$** blocks was measured with the Vibrating wire system*

*- in August 2012: the same type of measurement was done for the configuration with **Sm_2Co_{17}** blocks .*

Here below are shown the measurements of the MEASURED Gradient (red dots) (extrapolated from the INTEGRATED GRADIENT effectively measured), together with the COMPUTED Gradient (blue curves).





See talks by
M.Modena
on Thursday
afternoon
In BDS/MDI

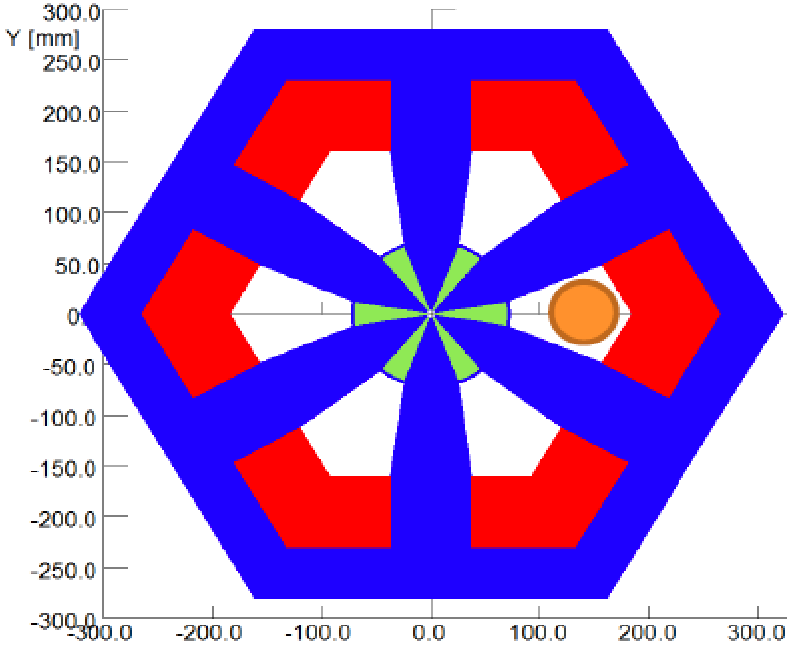
The measured Gradient in the configuration with Sm_2Co_{17} blocks it is in very good agreement with the FEA computation. This is not the case for the $Nd_2Fe_{14}B$ blocks were a difference of ~ - 6% is visible. This could have 2 possible explanation but the 1st was then excluded by a 2nd FEA cross-check:

-The Permendur saturate at lower level than expected. → The magnetization curve extracted from the Test Report of the raw material provided by the Supplier was utilized for the FEA computation that confirm that the problem is not coming by the Permendur quality.

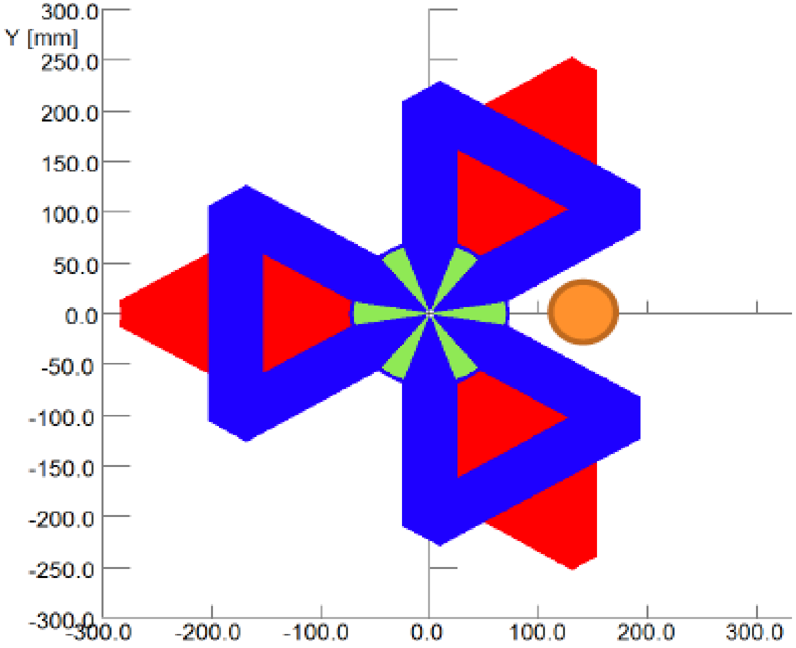
-The quality (magnetization module and/or direction) of the $Nd_2Fe_{14}B$ PM blocks is not the expected one → we should get more indication of this possibility when the PM blocks measuring device (by Helmholtz coils) will be delivery to the MM Section.

2. *Preliminary considerations for CLIC SD0 sextupole design:*

"Closed yoke" version:



"Open yoke" version:



🟥 Coils
🟦 1010 steel yoke
🟩 Permanent magnet blocks (NdFeB)
🟧 Post-collision line

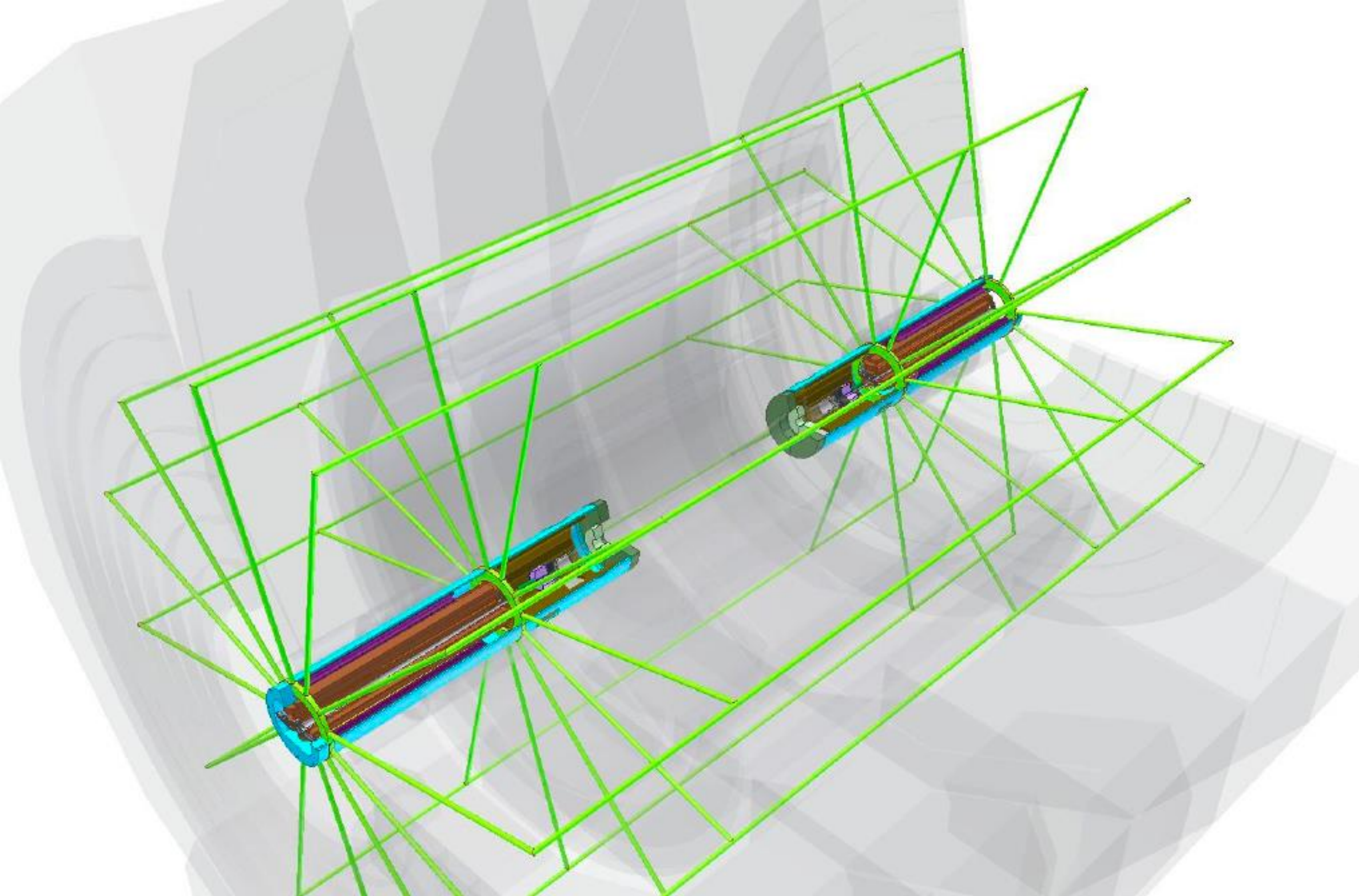
Main parameters:

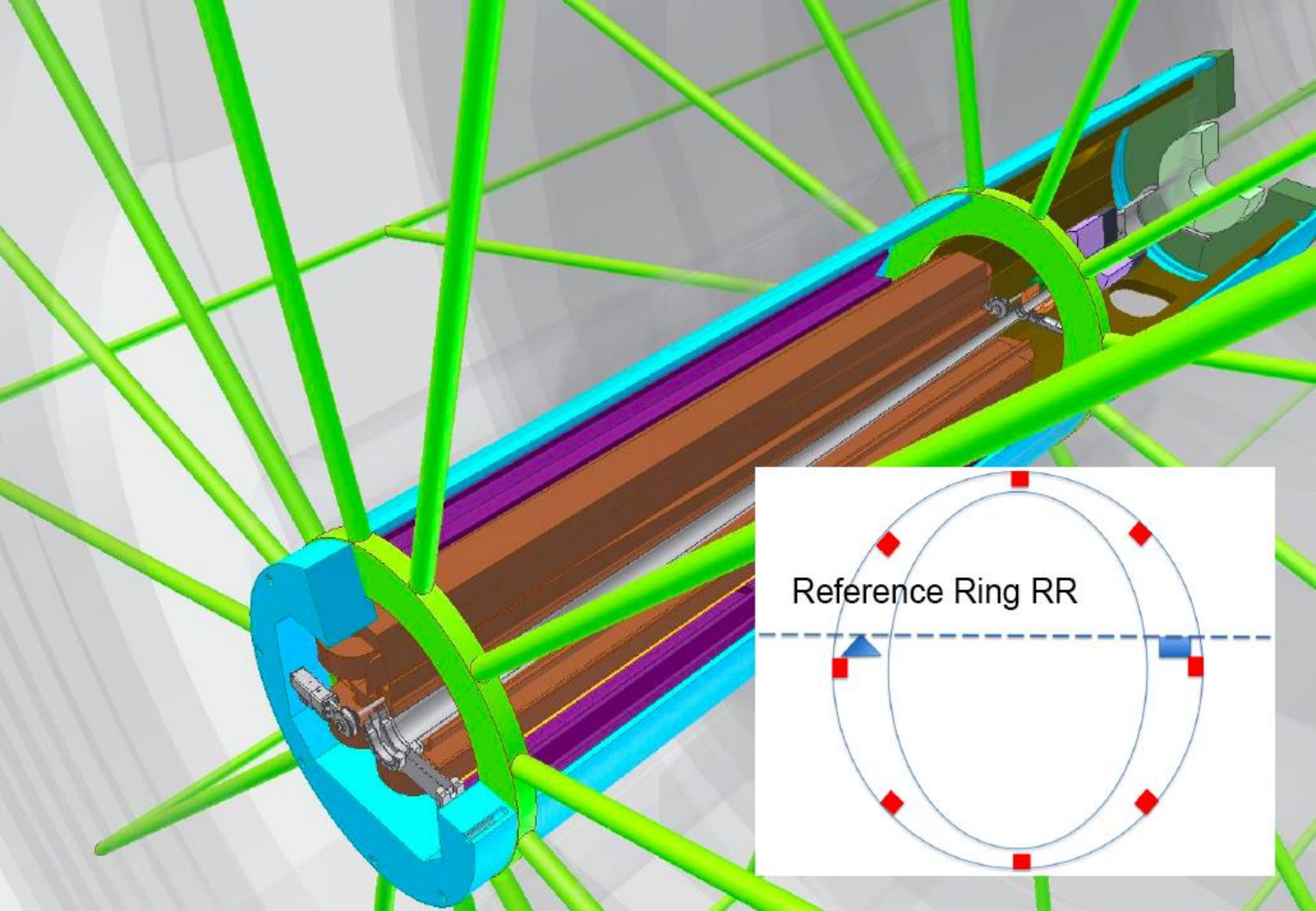
Aperture (radius):	4.3 mm
Max. Achievable Sextupole gradient:	220 000 T/m^2
Magnetic length	250 mm
Amperturns NI	5300 Amps

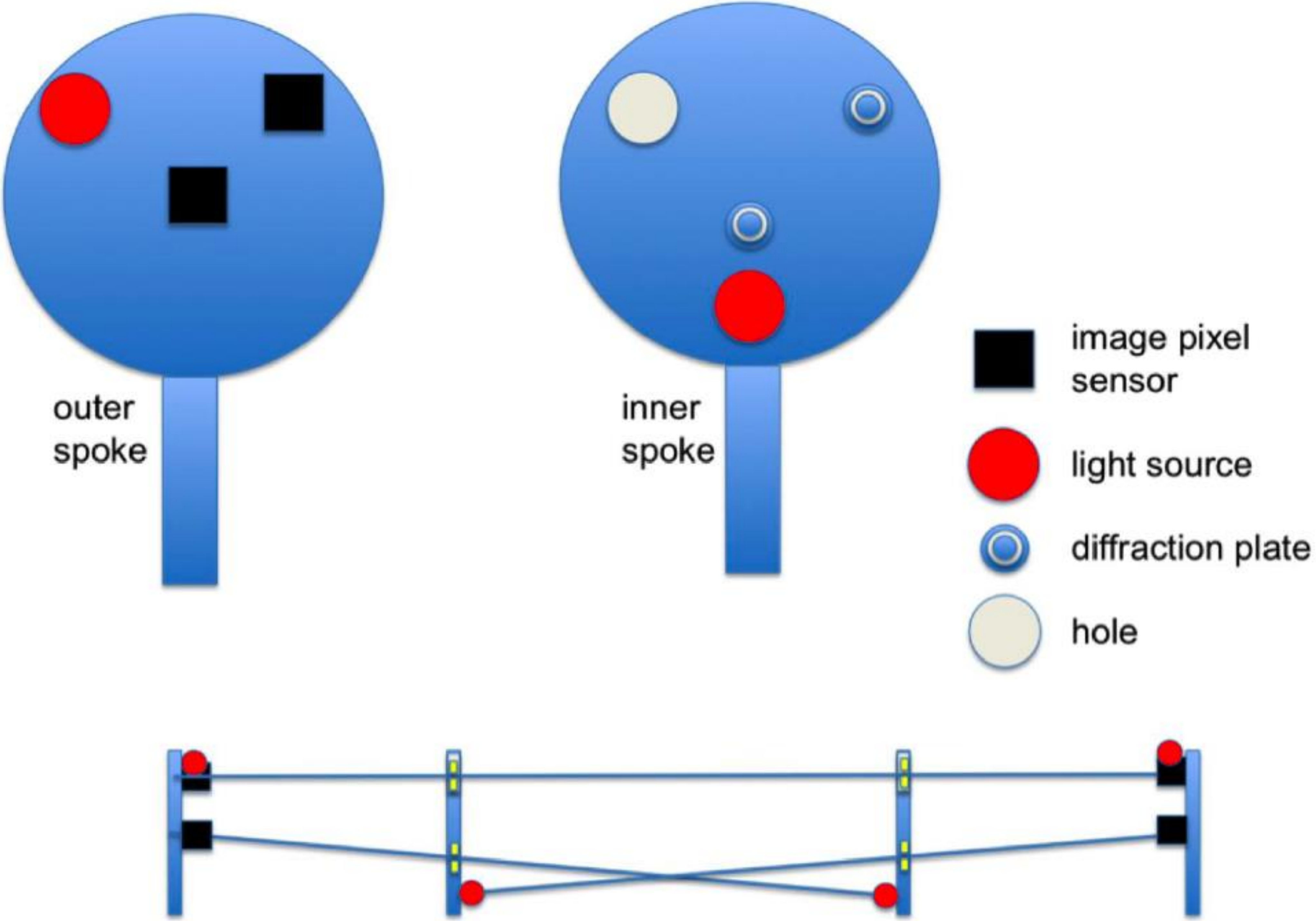
A. Aloev, M. Modena at: "29th MDI meeting": 14th December 2012

- Introduction
- QD0 prototype measurements
- **QD0 pre-alignment**
- QD0 stabilisation
- IP feedback
- Anti-solenoid compensation
- Post-collision line (back to MDI since 2012)
- Coming soon: can QD0 be moved to the tunnel?
- Possibilities for CLIC-ILC collaboration?

Harry van der Graaf / NIKHEF, H.Mainaud / CERN




Reference Ring RR


outer spoke
inner spoke
image pixel sensor
light source
diffraction plate
hole

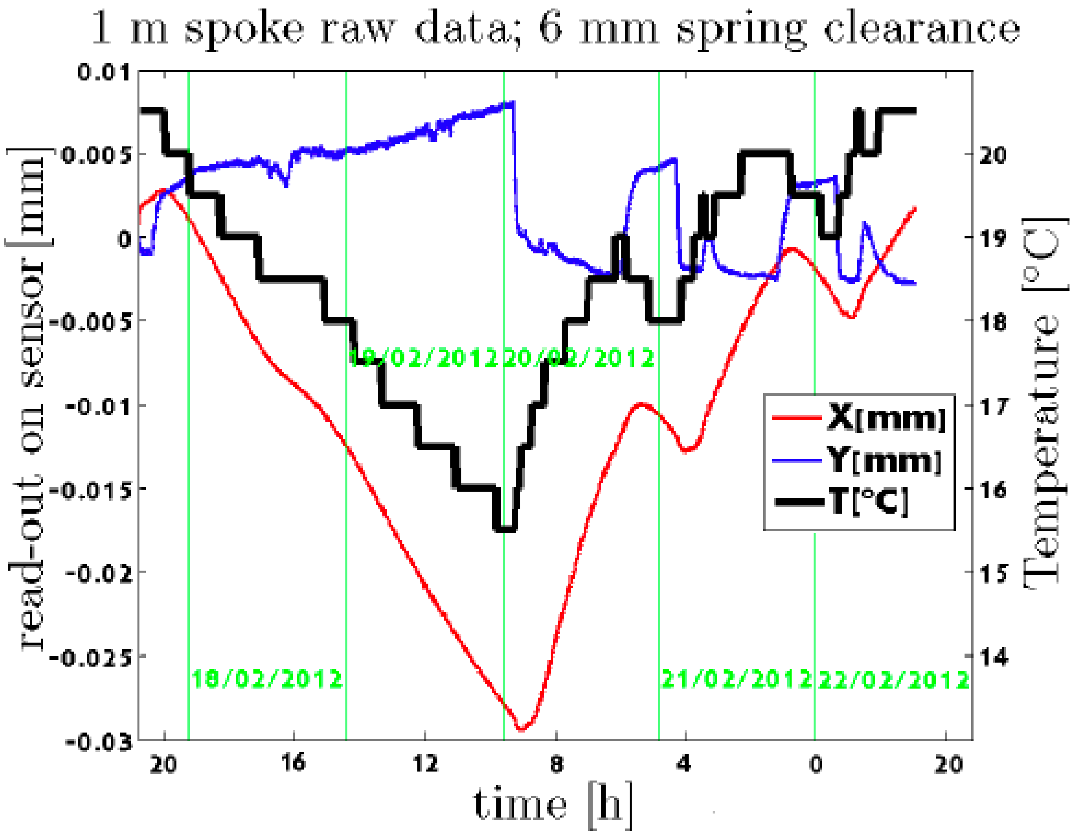
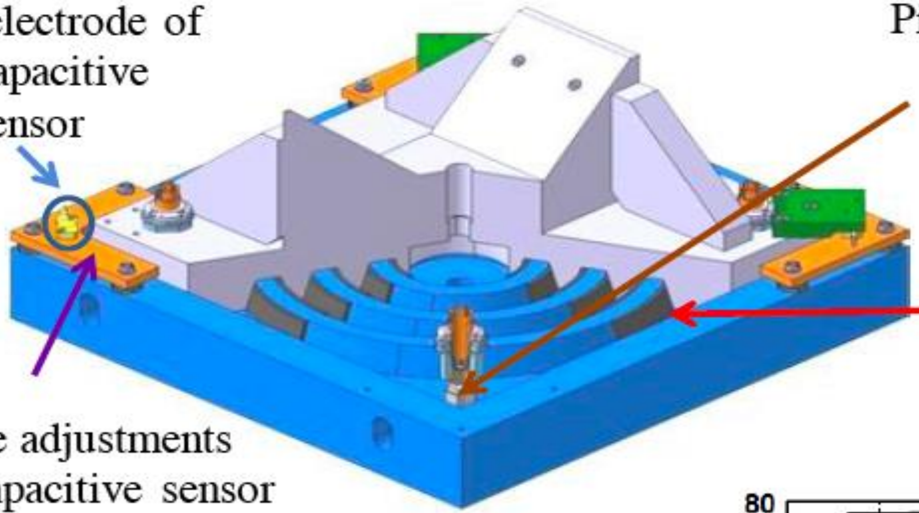


Figure 7.10: 4 day Rasnik measurement of the expansion of granite table and temperature. The x coordinate is in the length direction of the 1 m Zerodur spoke

See presentation by H.Mainaud Durand on Thursday afternoon for details on pre-alignment

- Introduction
- QD0 prototype measurements
- QD0 pre-alignment
- **QD0 stabilisation**
- IP feedback
- Anti-solenoid compensation
- Post-collision line (back to MDI since 2012)
- Coming soon: can QD0 be moved to the tunnel?
- Possibilities for CLIC-ILC collaboration?

-*Active foot*:

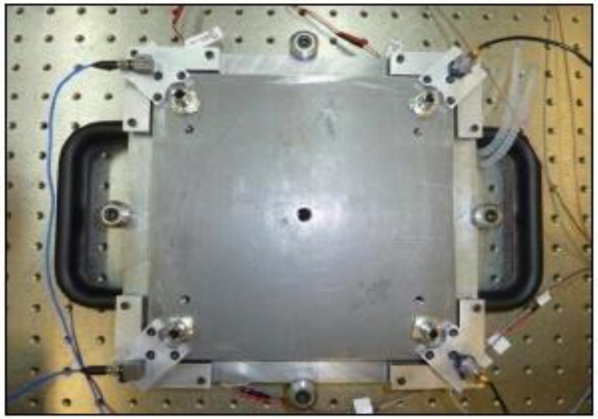


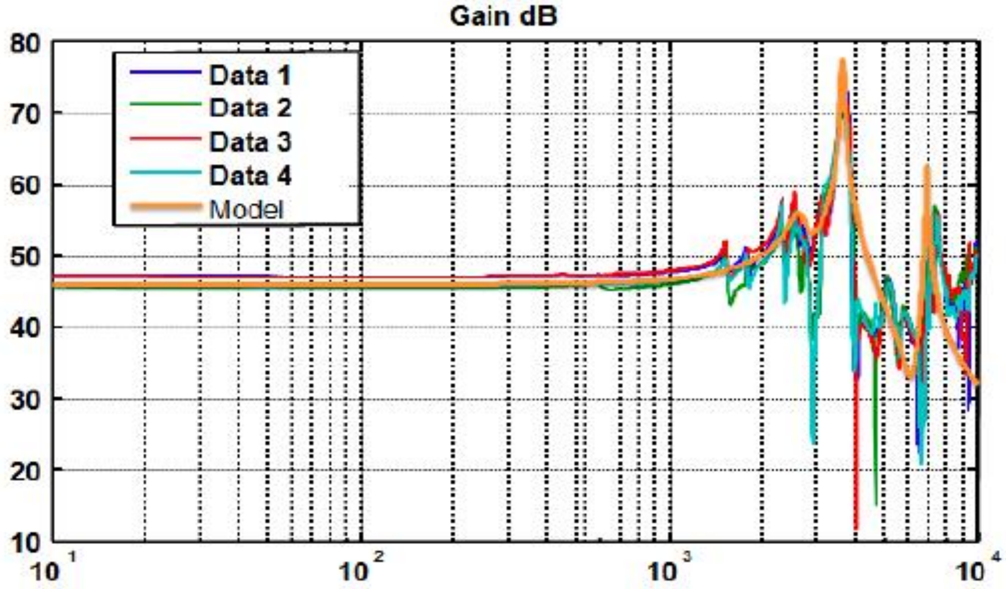
Lower electrode of the capacitive sensor

Piezoelectric actuator

Elastomeric strips for guidance

Fine adjustments for capacitive sensor (tilt and distance)





Mechanical active stabilisation – experimental setup

- *Control architecture :*

Matlab and dSPACE ControlDesk
For monitoring and analysis

- <u>*Used sensors :*</u>

- Geophones : GURALP CMG-6T
- Accelerometers : WILCOXON 731A

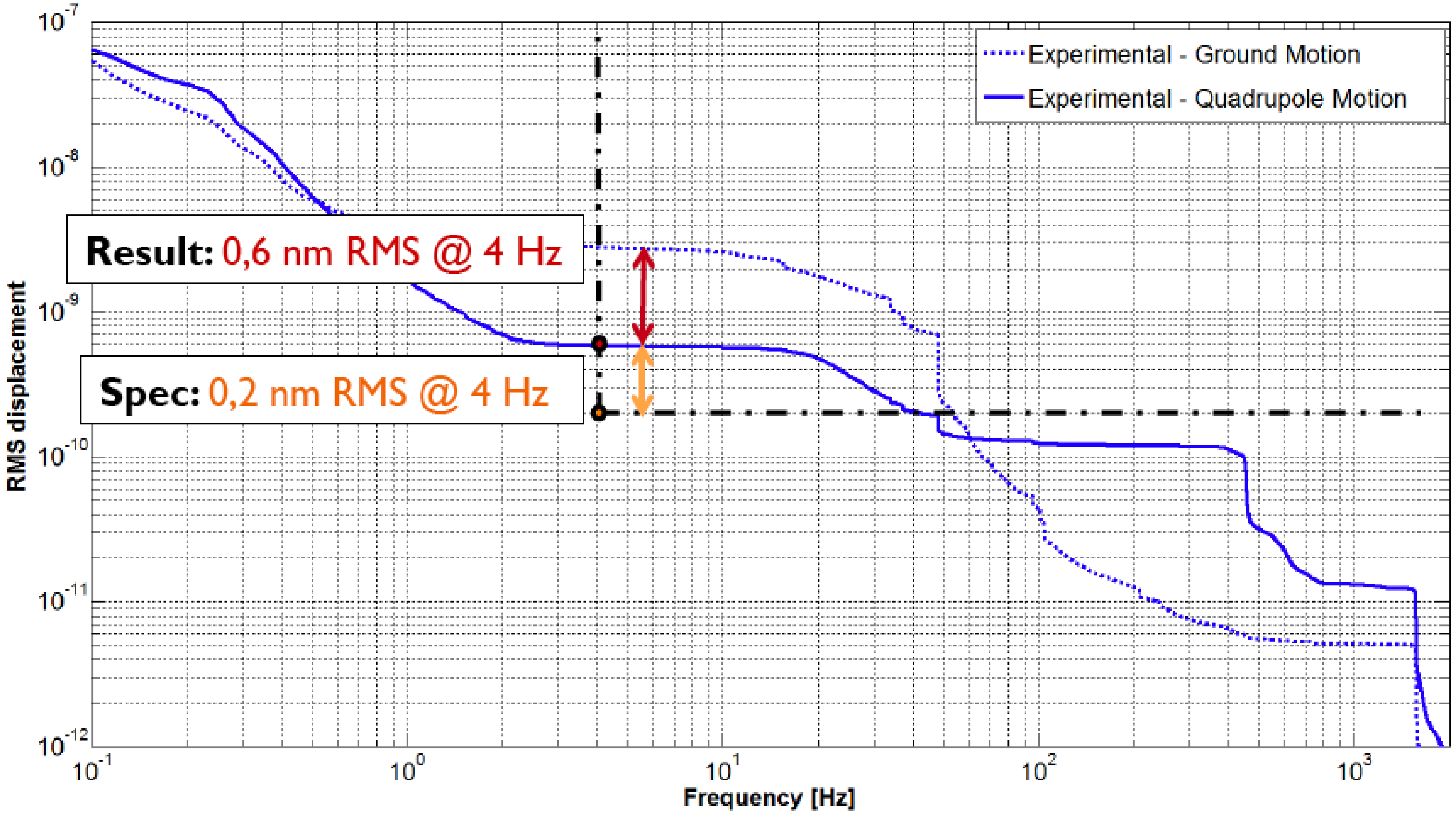
Amplifiers, filters input/output board
for signal conditioning

dSPACE
Real time hardware for
Rapid Control Prototyping

✓ **All is taken into account in simulation (noise, ADC, DAC…).**

Mechanical active stabilisation – Results

- *Simulation and experimental results (RMS) :*



Result: 0,6 nm RMS @ 4 Hz

Spec: 0,2 nm RMS @ 4 Hz

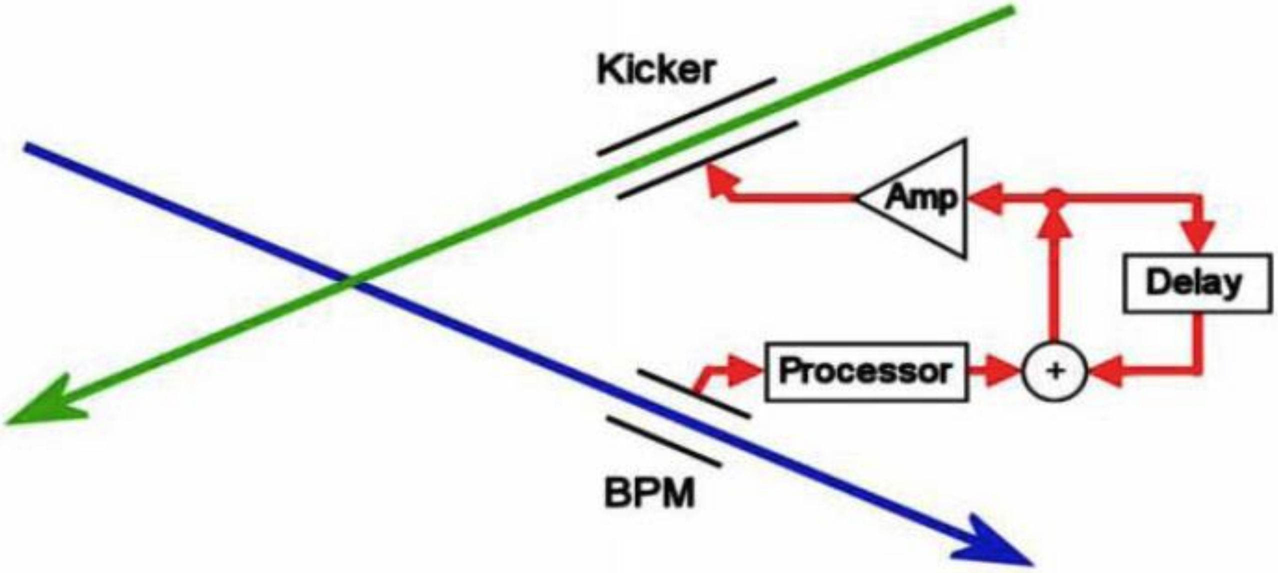
➢ **Publication in progress (accepted) : Balik et al, "Active control of a subnanometer isolator", JIMMSS.**

Limited by sensor noise – working on better sensors
See presentation by L.Brunetti on Wednesday morning

- Introduction
- QD0 prototype measureme**nts**
- QD0 pre-alignment
- QD0 stabilisation
- **IP feedback**
- Anti-solenoid compensation
- Post-collision line (back to MDI since 2012)
- Coming soon: can QD0 be moved to the tunnel?
- Possibilities for CLIC-ILC collaboration?

LC intra-train feedback system - concept

- Last line of defence against relative beam misalignment
- Measure vertical position of outgoing beam and hence beam-beam kick angle
- Use fast amplifier and kicker to correct vertical position of beam incoming to IR



FONT – Feedback On Nanosecond Timescales

IP FB Design Status: CLIC

Conceptual design developed and documented in CLIC CDR (2011)

NB primary method for control of beam collision overlap is via vibration isolation of the FF magnets, and dynamic correction of residual component motions

IP position feedback:

allows IP beam position correction of +- 50 nm of vertical beam motion,

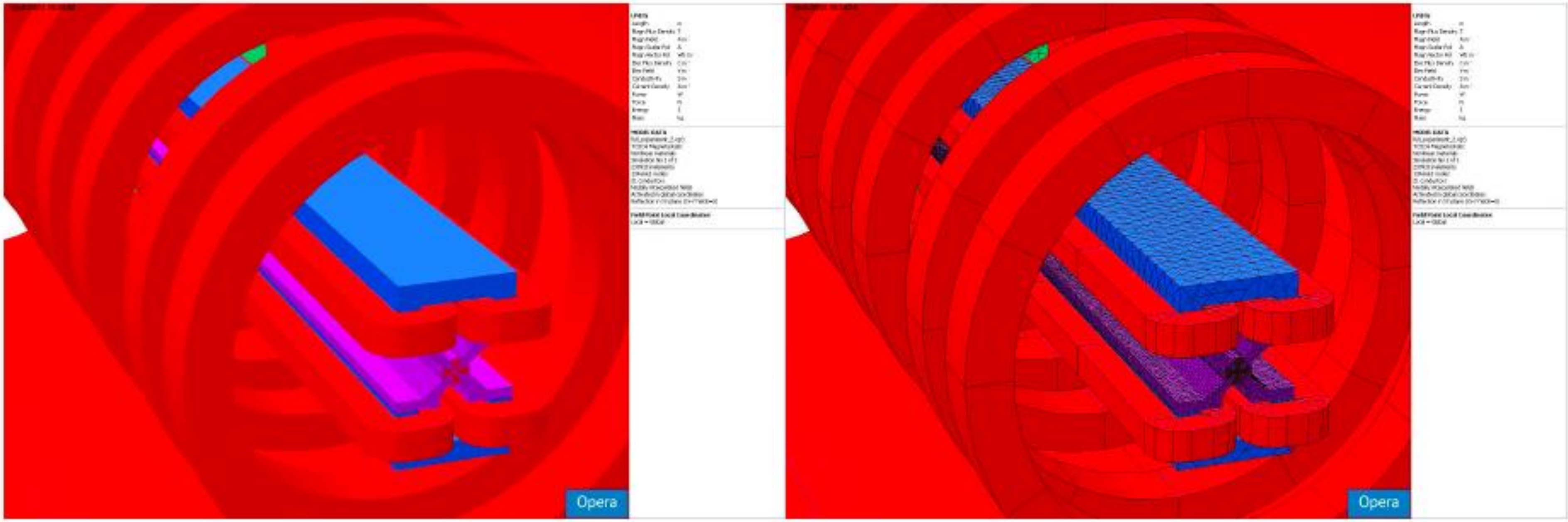
and possibility to correct within bunchtrain duration

More realistic engineering design can be developed in next project phase

For details see talk by Ph.Burrows on Thursday morning

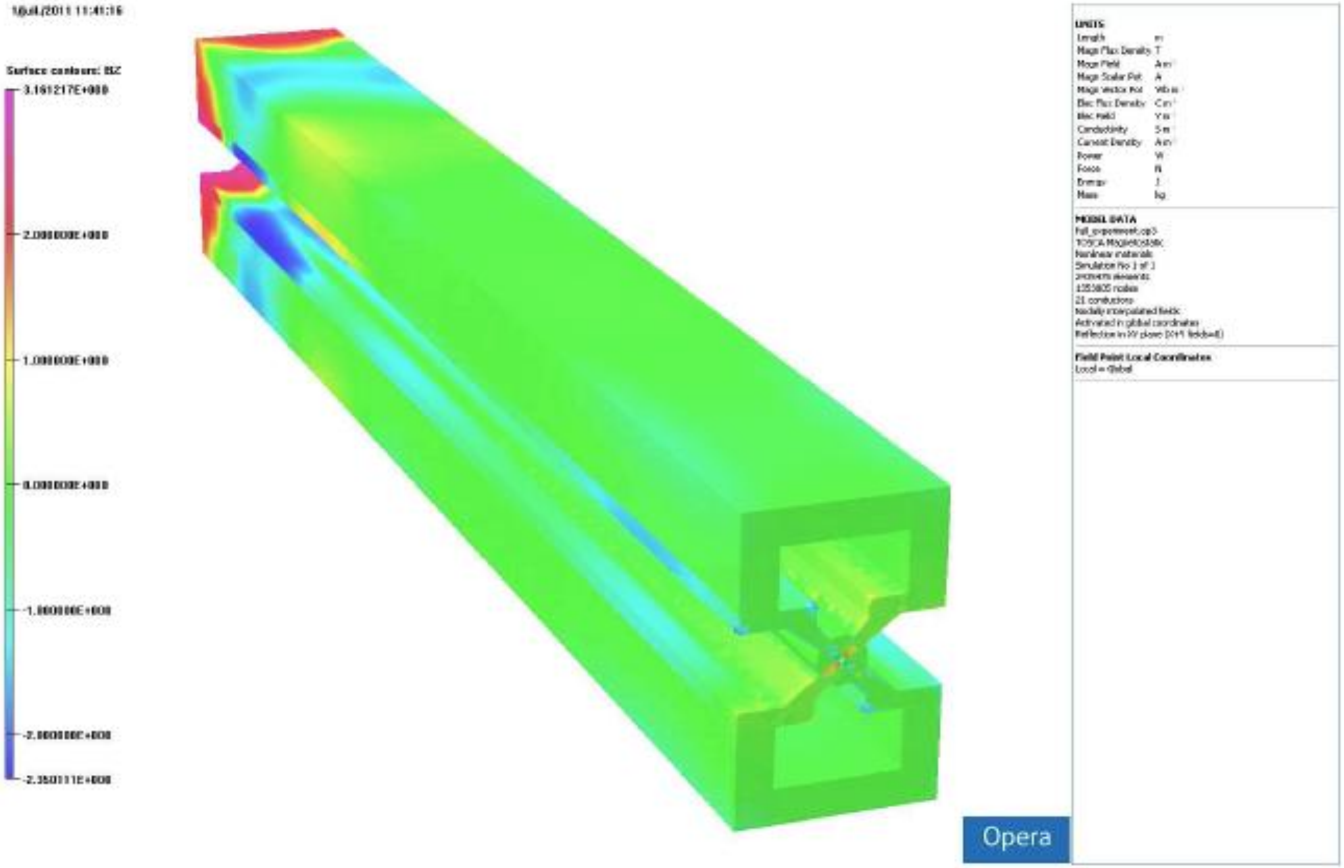
- Introduction
- QD0 prototype measurements
- QD0 pre-alignment
- QD0 stabilisation
- IP feedback
- **Anti-solenoid compensation**
- Post-collision line (back to MDI since 2012)
- Coming soon: can QD0 be moved to the tunnel?
- Possibilities for CLIC-ILC collaboration?

The 3D model, a zoom in the QD0 region



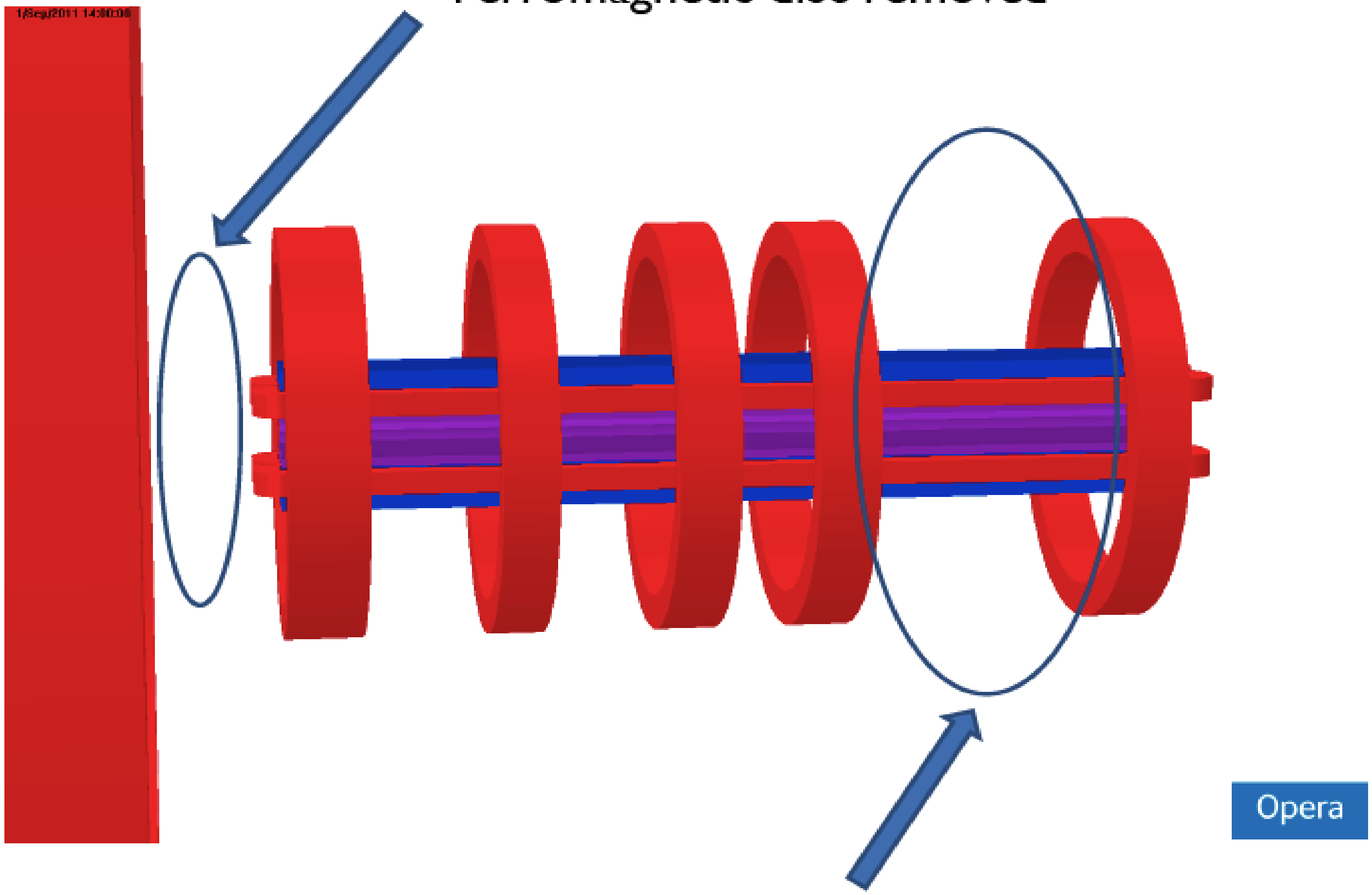
A.Bartalesi, M.Modena

Residual field (BZ) inside QD0



Excellent performance of anti-solenoid,
still some issues at the QD0 extremity

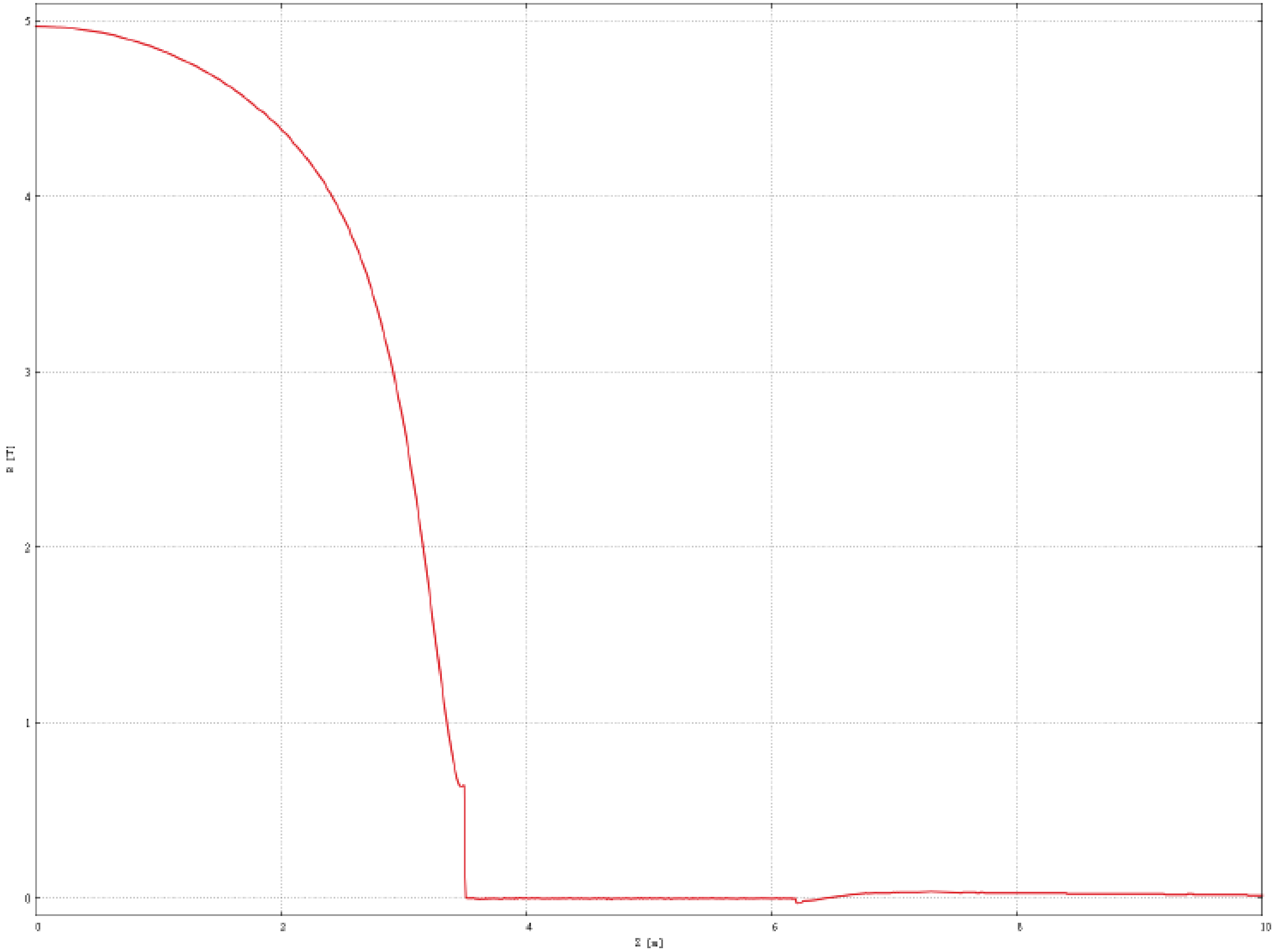
Main improvements



Ferromagnetic disc removed

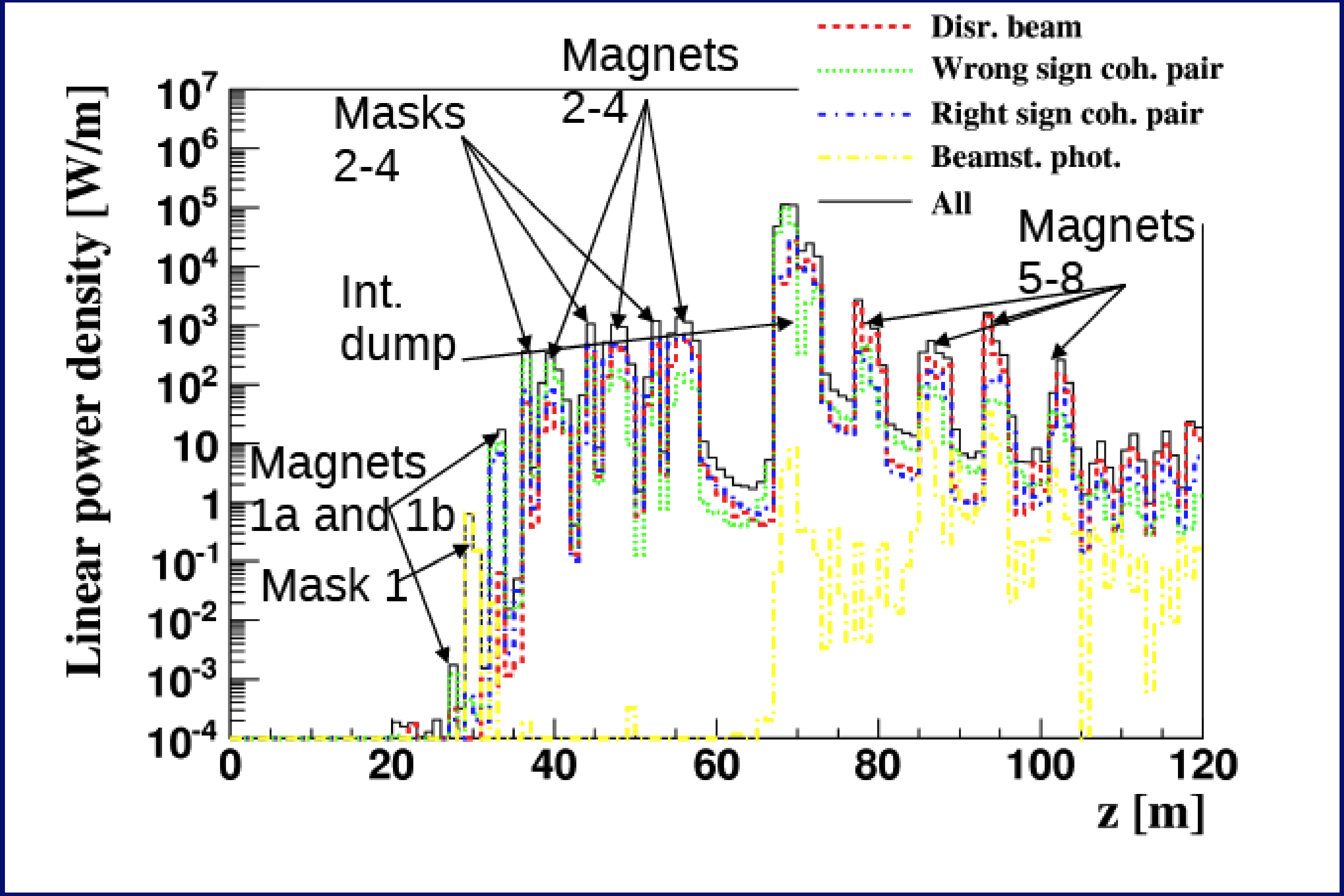
One coil removed (now 5 coils in total)

Field maps – BZ



- Introduction
- QD0 prototype measurements
- QD0 pre-alignment
- QD0 stabilisation
- IP feedback
- Anti-solenoid compensation
- **Post-collision line** (back to MDI since 2012)
- Coming soon: can QD0 be moved to the tunnel?
- Possibilities for CLIC-ILC collaboration?

Energy deposition in beamline components



- **IPAC 11, TUPC023**
- As much energy lost in magnets as in masks
- For energy loss in ***coils*** of magnets 5-8, wrong sign coherents dominate.

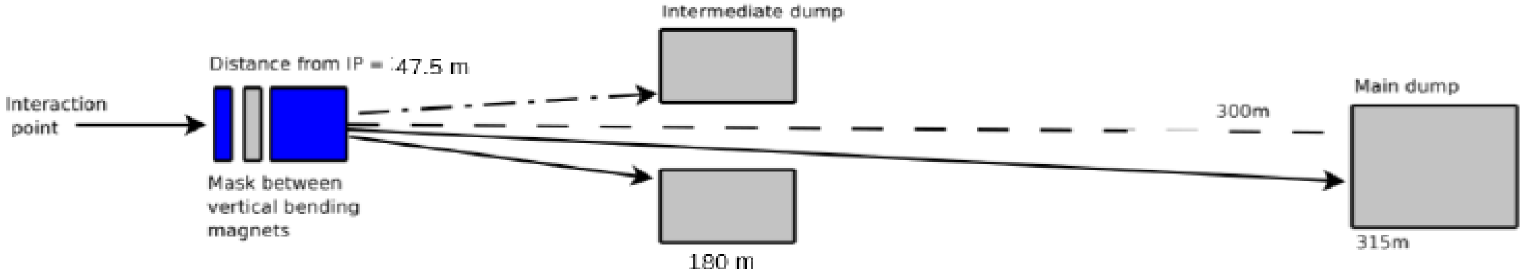
L.Deacon

Magnet lifetime

- **[TUPC028 IPAC 2011]**, V1 is the original post-collision line, V2 is the changed version with iron masks and 2m longer intermediate dump.

Component	Rate of E. dep. In coils [W] – v1	Rate of E. dep. In coils [W] – v2	Volume of coils [cm3]	Mass of coils [kg]	Lifetime [year] – v1	Lifetime [year] – v2
1a + 1b	0.37	4.57	327152	2931.28	2525.47	203.18
2	250.78	39.57	503936	4515.27	5.71	36.16
3	1338.49	216.88	579120	5188.92	1.23	7.58
4	1739.05	256.71	755904	6772.9	1.23	8.36
5	229.63	102.16	921600	8257.54	11.4	25.61
6	207.84	133.28	921600	8257.54	12.59	19.63
7	137.01	79.03	921600	8257.54	19.1	33.11
8	15.37	11.28	921600	8257.54	170.26	232.02

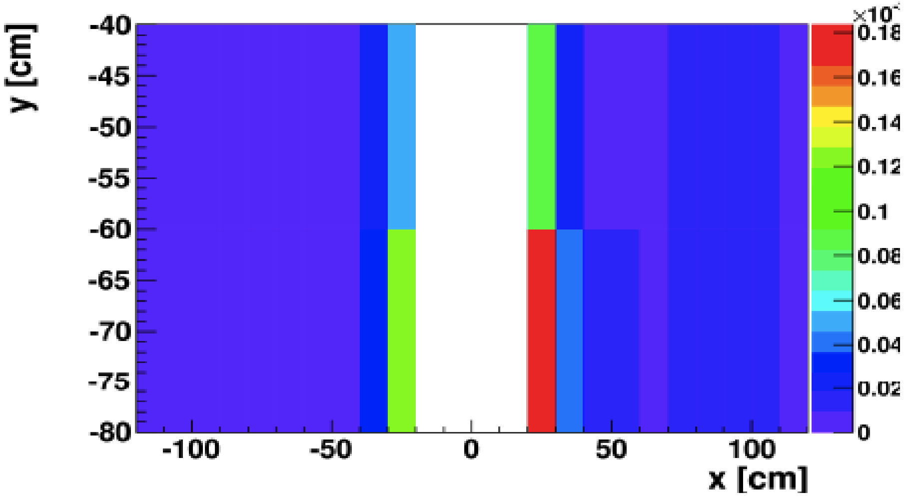
New layout

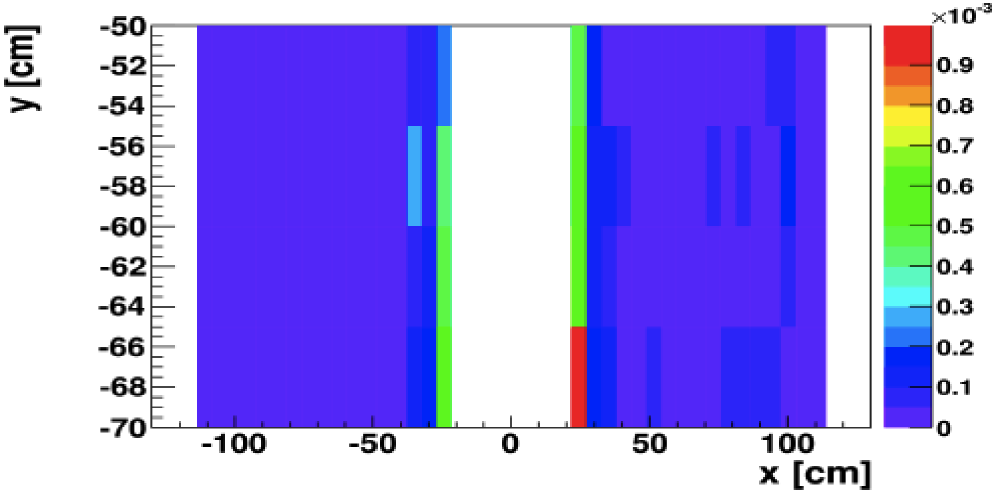


- We need to consider the back scatter to the detector – photons, electrons, neutrons scattered back to detector from intermediate dump
- Assuming time window of 150ns (bunch train) + ~100ns (detector integration time) particles scattered back from <40m could cause background to the detector
- So better to have magnet at 47.5m than 27.5m (old CDR design)

Magnet lifetime study - new PCL

- New results
  - *Right:* energy dep. In magnet coil insulation material [W/cm^2]
  - *Top right:* 1 litre voxels, magnet lifetime is 68000 +/- 7000
  - *Bottom right:* 125 cm^3 voxels lifetime 900 +/- 100 years

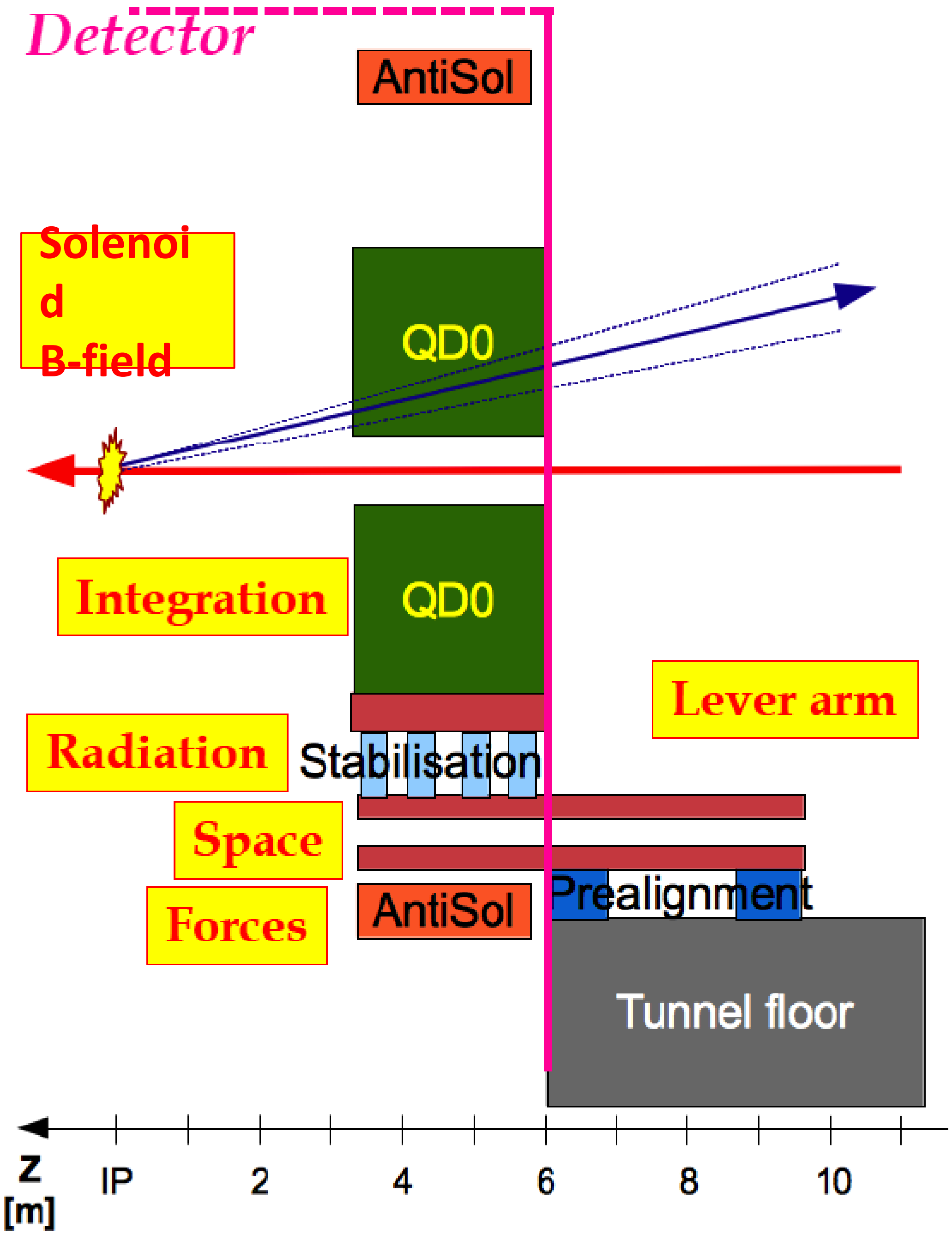




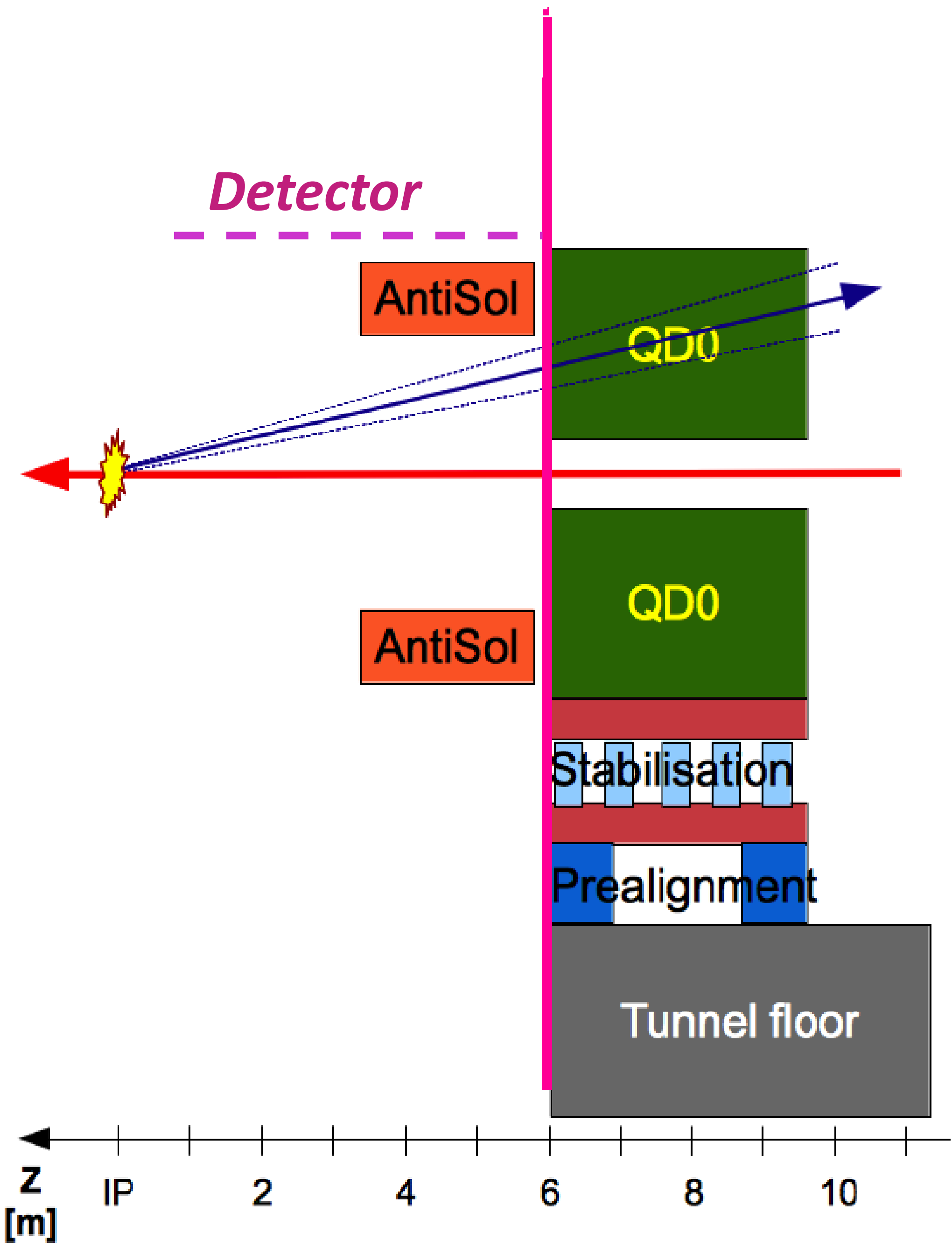
L.Deacon

- Introduction
- QD0 prototype measurements
- QD0 pre-alignment
- QD0 stabilisation
- IP feedback
- Anti-solenoid compensation
- Post-collision line (back to MDI since 2012)
- Coming soon: **Can QD0 be moved to the tunnel?**
- Possibilities for CLIC-ILC collaboration?

L* = 3.5 m


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

L* = 6.5 m


Detector
AntiSol
QD0
AntiSol
QD0
Stabilisation
Prealignment
Tunnel floor
Z [m]
IP
2
4
6
8
10

The first questions for L* are

- How much luminosity does one loose (on paper)?
- How much acceptance can one gain (on paper)?
- How serious is the luminosity loss with respect to the difficulties to keep it stable inside the detector environment, i.e. are there effective luminosity losses due to such issues for the short L* ?
- What is the net balance between luminosity and acceptance in terms of the physics reach?

This will soon be addressed

Possibilities for CLIC-ILC cooperation?

MDI is very different between ILC and CLIC:

- Organization wise (ILC in experiments, CLIC on machine side)
- QD0 technology (ILC cold, CLIC warm)
- Time structure of beam arrival
- IP feedback (ILC digital, CLIC analog)

Still worth looking for synergies:

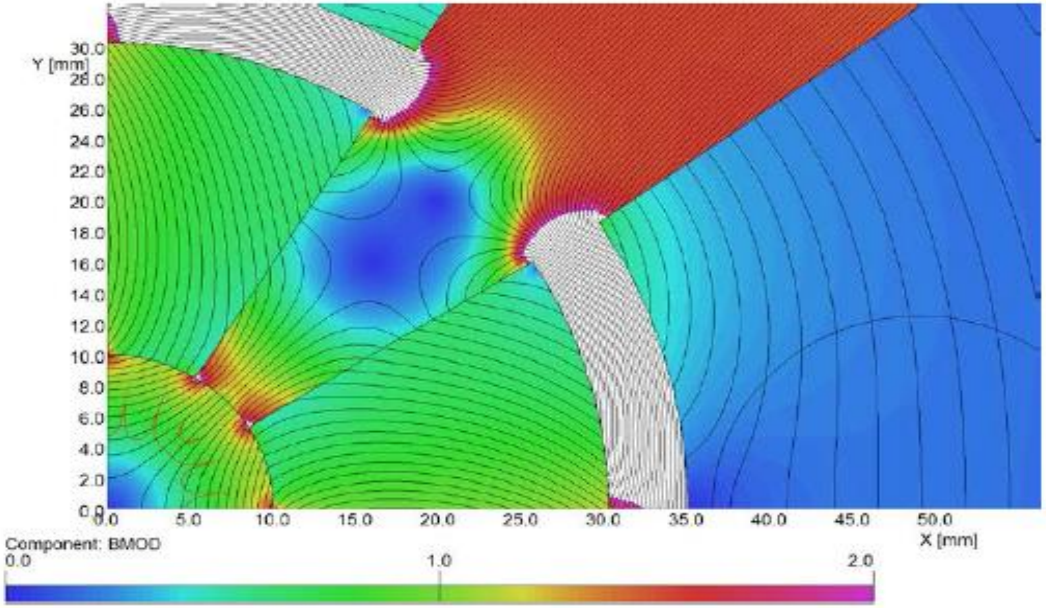
- Can hybrid QD0 technology be applied to ILC? Consequences?
- Spent beam design could be more similar
- Muon sweeping in BDS (BDS or MDI?)
- QD0 and BDS alignment
- Others?

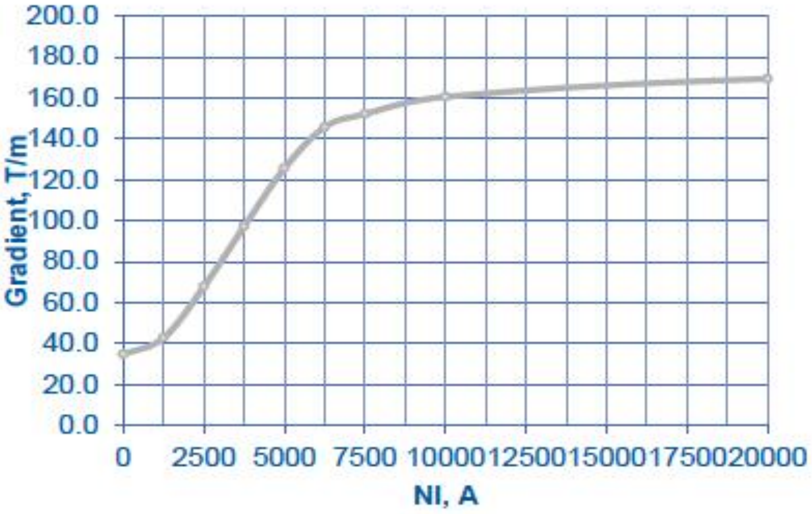
Hybrid QD0

- CLIC went for hybrid, warm technology.
  Choice mainly driven by stabilization requirements.
- This choice impacts on many aspects in MDI:
  - QD0 design itself
  - Anti-solenoid is imperative for PM protection
  - No cryo-pumping 'for free'
  - Integration issues…….
- The s.c. magnet is more compact, the hybrid solution is easier to stabilize and align
- Michele Modena has had a first look at QD0 adaptation to ILC.
  → ***See Michele's presentation***
- Many related aspects go well beyond QD0 itself and involve MDI.
- Hybrid technology could also be an option at ATF2

A hybrid QD0 for ILC ?

We have tried to "scale" our CLIC QD0 design taking into account the ILC layout and geometric conditions but also starting an optimization of the main parameter toward a wider field quality range for the demanded tunability.





"red line" inside the aperture: area where ΔG/G ≤1 unit (good field region)

NI	A	0	1250	2500	3750	5000	6250	7500	10000	20000	40000
Gradient	**T/m**	**34.7**	**42.8**	**67.8**	**97.3**	**125.7**	**145.8**	**152.2**	**160.6**	**169.4**	**174.9**
b6	**units**	61.2472	45.2059	19.9428	6.8605	-0.0183	-3.3895	-4.2944	-5.3982	-6.4427	-7.0075
b10		0.1978	0.1510	0.0769	0.0386	0.0215	0.0173	0.0173	0.0182	0.0201	0.0217
b14		0.000192	4.51E-04	8.62E-04	1.07E-03	1.16E-03	1.16E-03	0.001148	0.001123	0.001086	0.001056
b18		0.003501	2.58E-03	1.14E-03	3.89E-04	-4.59E-06	-1.98E-04	-0.00025	-0.00031	-0.00037	-0.0004

Main multipoles estimated at r = 3 mm; 5000 NI is the nominal working point (125 T/m)

(Computation: courtesy A. Aloev)

Michele Modena, CERN "Progress with FFS magnets for CLIC, ILC and ATF2" « Common paths for CLIC and ILC BDS » ,30 Aug. 2013

Pre-alignment

The pre-alignment approach in the MDI sector has been described before.

Helene Mainaud Durand will describe the CLIC approach for MDI and BDS in more detail on Thursday.

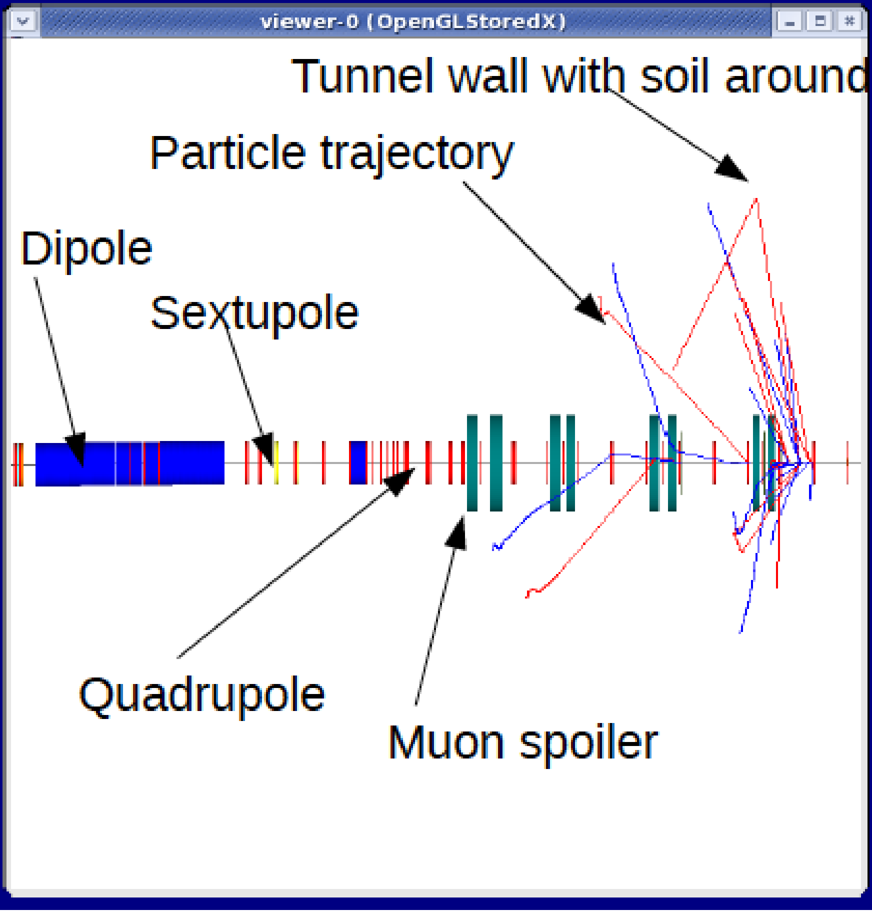
Spent Beam

- Both in ILC and CLIC the spent beam must be transported away cleanly through the experiment onto the beam dumps.
- On the CLIC side a new design has been presented at the Hamburg workshop by Lawrence Deacon.
  This new design has many advantages w.r.t. the old one:
  - Magnet lifetime
  - Power consumption
  - Cost

  It may be considered whether a similar design could be applied to ILC.

Muon Sweeping

- In ILC the muon sweeping is based on **dipole magnets**.
  - Need precise machining
  - Bulky
  - Costly
  - Effect on main beam to be compensated (hence radiation)
- For CLIC we propose **toroidal fields**
  - Zero field on the beam
  - Therefore weaker requirements on engineering precision
  - Less bulky, do not obstruct the tunnel
  - Cheaper
- Maybe a combination of the two can be considered
  - Initial sweeping with dipoles (both polarities present)
  - Then toroids

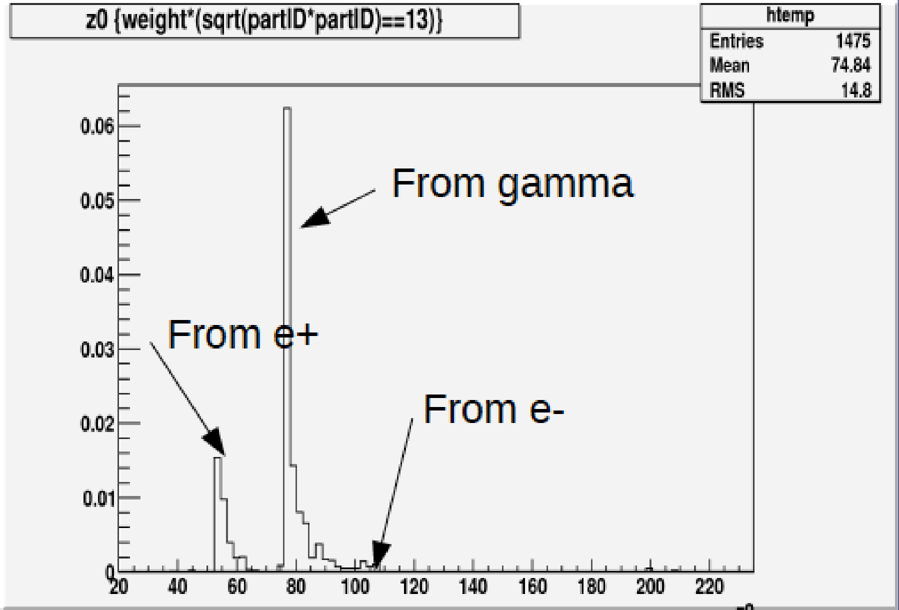


- Left: screen shot, 1 event, beam travels right to left
- Tunnel included
- Muon spoilers 55cm outer radius, 1cm inner radius, 1.5T toroid field, ~100m downstream of collimators.

Gain factor 15 on muon flux.

Most of the surviving ones are created in the final dipole (via conversion of synchrotron photons).

Maybe collimation of e$^{\pm}$ and γ can help?



MDI members and contributors

Julie Allibe, Alexander Aloev, Robert Appleby, Armen Apyan, Kurt Artoos,
Guillermo Zamudio Ascensio, Jerome Axensalva, Antonio Bartalesi,Marco Battaglia,
Gerjan Bobbink, Enrico Bravin, Laurent Brunetti, Helmut Burkhardt, Phil Burrows,
Francois Butin, Christophe Collette, Barbara Dalena, Fernando Duarte Ramos,
Lawrence Deacon, Konrad Elsener, Arnaud Ferrari, Andrea Gaddi, Mark A. Gallilee,
Martin Gastal, Lau Gatignon, Hubert Gerwig, Christian Glenn, Harry van der Graaf,
Christian Grefe, Edda Gschwendtner, Michel Guinchard, Alain Hervé,
Andréa Jérémie, Michel Jonker, YoungIm Kim, Andrea Latina, Thibaut Lefèvre,
Yngve Levinsen, Lucie Linssen, Helène Mainaud Durand, Sophie Mallows,
Dirk Mergelkuhl, Michele Modena, John Osborne, Thomas Otto, Colin Perry,
Javier Resta Lopez, Giovanni Rumolo, André Philippe Sailer, Hermann Schmickler,
Daniel Schulte, Jochem Snuverink, Markus Sylte, Rogelio Tomàs Garcia,
Davide Tommasini, Raymond Veness, Joachim Vollaire, Alexey Vorozhtsov,
Volker Ziemann, Franck Zimmermann