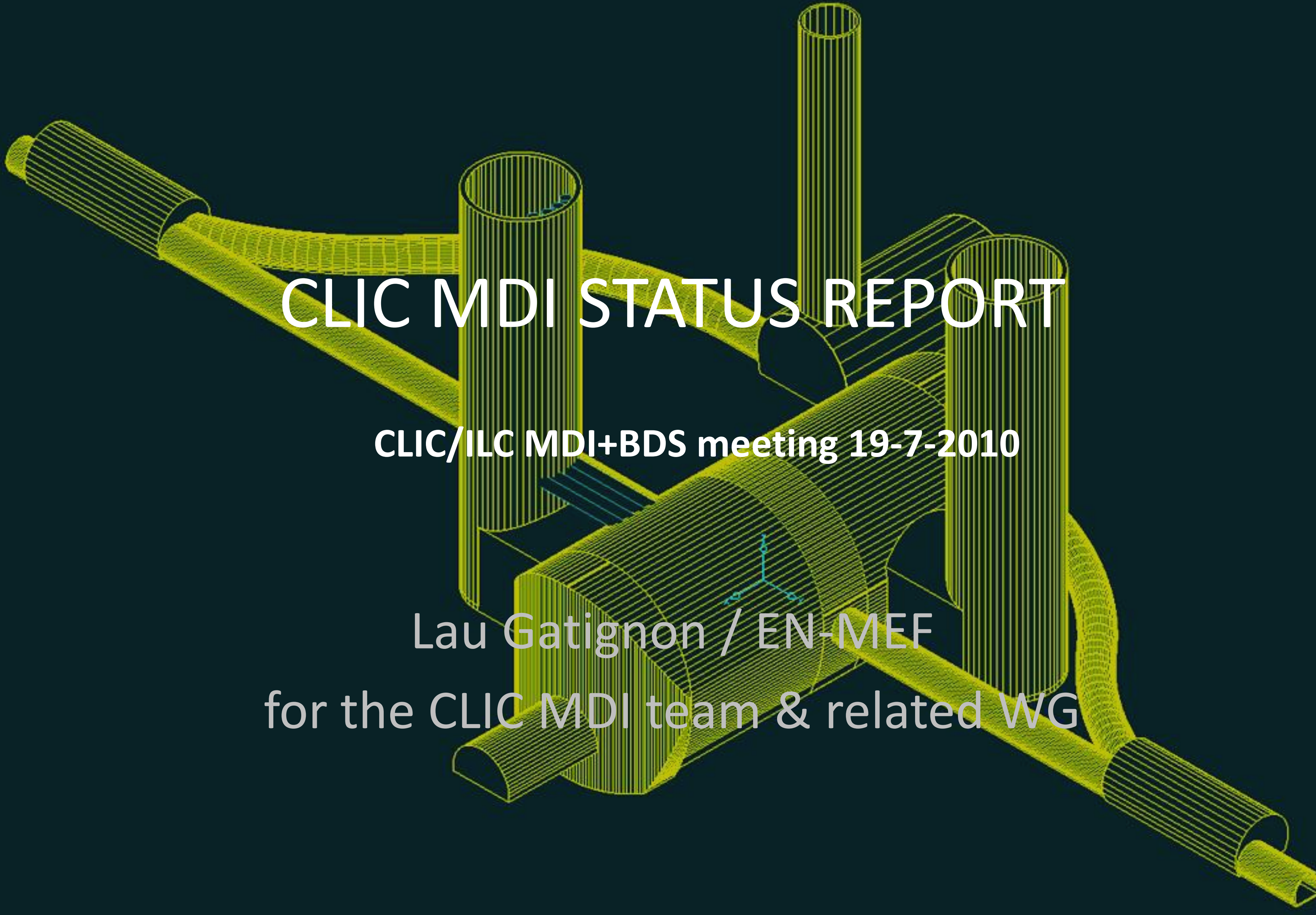


CLIC MDI STATUS REPORT

CLIC/ILC MDI+BDS meeting 19-7-2010

Lau Gatignon / EN-MEF
for the CLIC MDI team & related WG

MDI members

Robert Appleby, Armen Apyan, Marco Battaglias, Enrico Bravin,
Helmut Burkhardt, Phil Burrows, Francois Butin, Barbara Dalena,
Konrad Elsener, Arnaud Ferrari, Andrea Gaddi, Martin Gastal,
Lau Gatignon, Hubert Gerwig, Christian Grefe, Edda Gschwendtner,
Michel Guinchard, Alain Hervé, Andréa Jérémie, Thibaut Lefèvre,
Lucie Linssen, Helène Mainaud Durand, Sophie Mallows,
Michele Modena, John Osborne, Thomas Otto, Colin Perry,
Javier Resta Lopez, André Philippe Sailer, Hermann Schmickler, Daniel Schulte,
Jochem Snuverink, Markus Sylte,
Rogelio Tomàs Garcia, Davide Tommasini, Raymond Veness,
Alexey Vorozhtsov, Volker Ziemann, Franck Zimmermann

And input from many others, e.g.

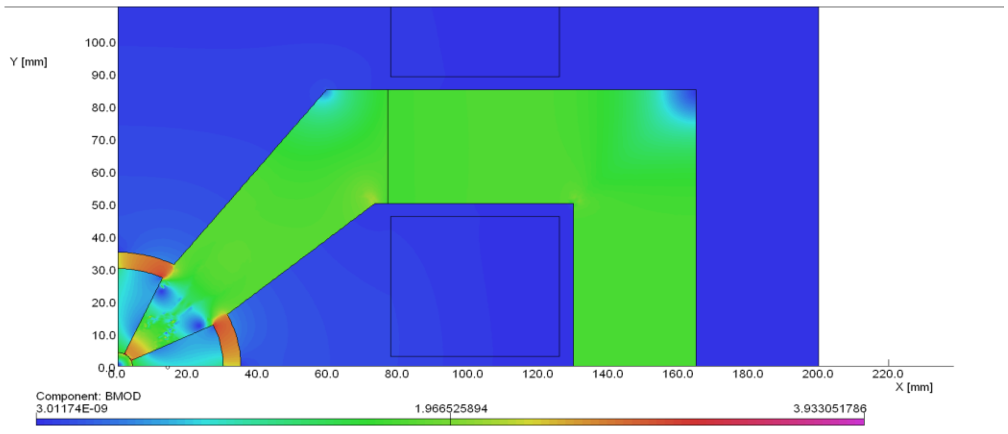
Michel Jonker, Giovanni Rumolo, Guillermo Zamudio Ascencio

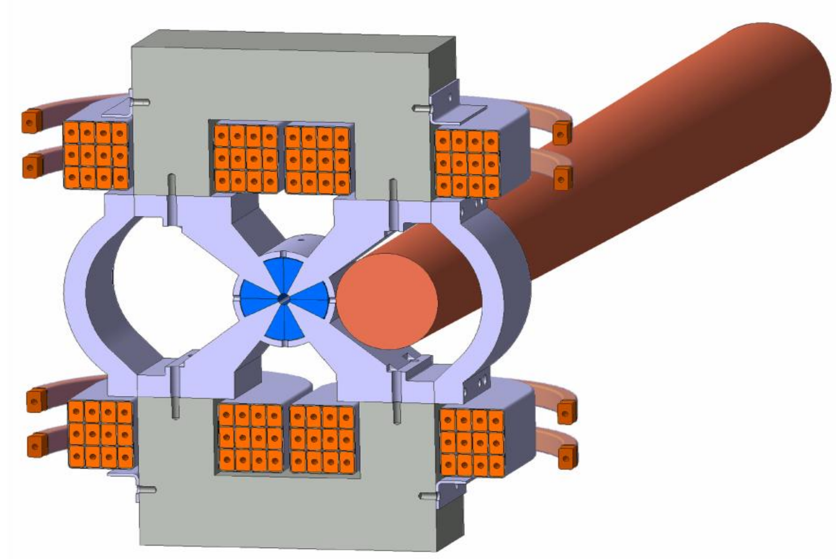
Outline

- Introduction
- The QD0 magnet
- Anti-solenoid
- Detector layout
- QD0 integration in detector
- Pre-alignment of QD0
- QD0 stabilisation
- Fallback solution with QD0 in tunnel
- IP feedback
- Vacuum
- Input for cavern layout with Push-pull
- Summary and Outlook

The QD0 MAGNET

“Hybrid” approach, Version 2:





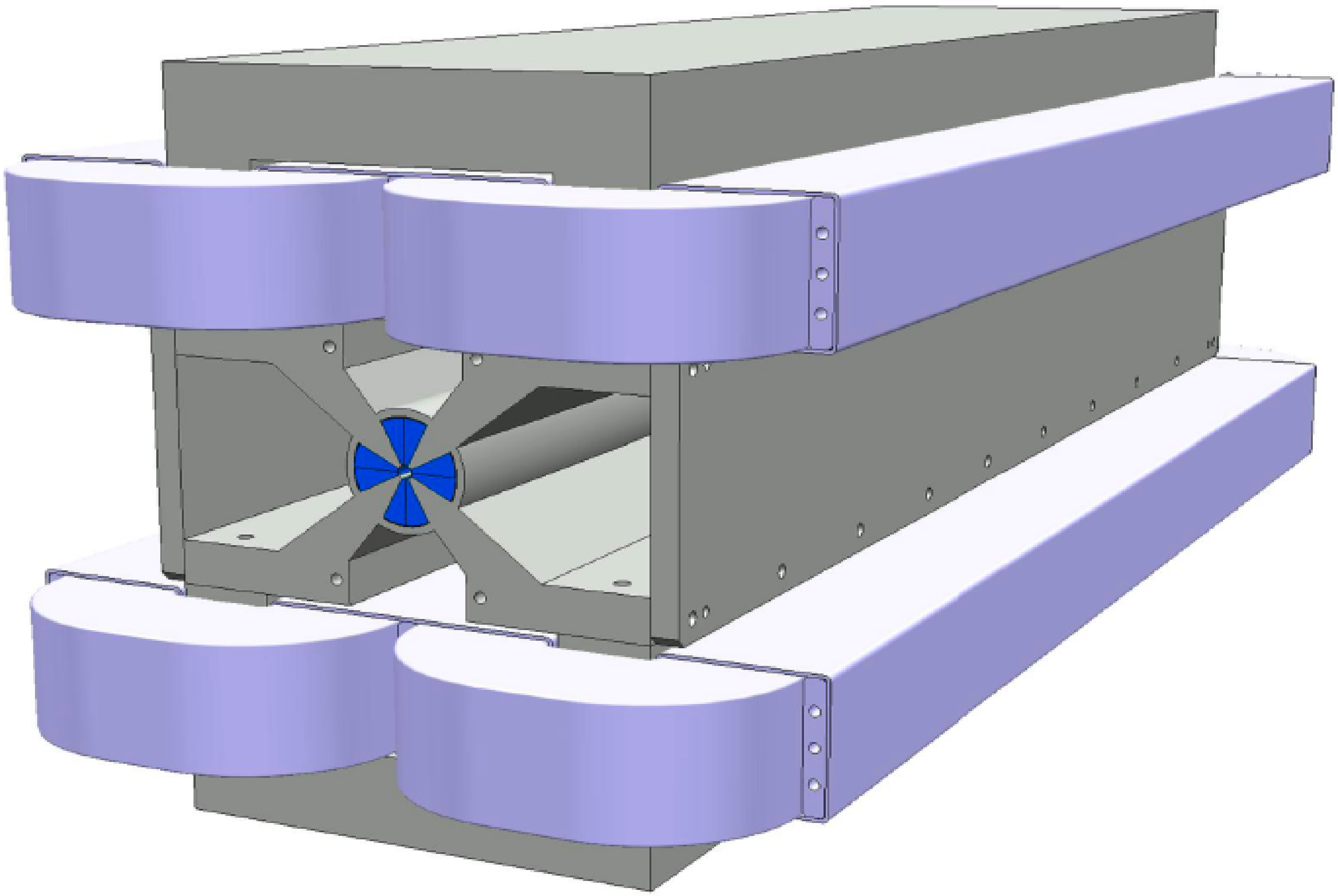
	Iw=5000 [A]
Grad [T/m] Sm_2Co_{17}	531
Grad [T/m] $Nd_2Fe_{14}B$	599

“CLIC09 Workshop” 12-16 October 2009, M. Modena

- The presence of the “ring” decrease slightly the Gradient (by 15-20 T/m) but will assure a more precise and stiff assembly

- EM Coils design will permit wide operation conditions (with or without water cooling) that can be critical for performances (ex. stabilization)

1) LAST Conceptual Design of the "full" magnet

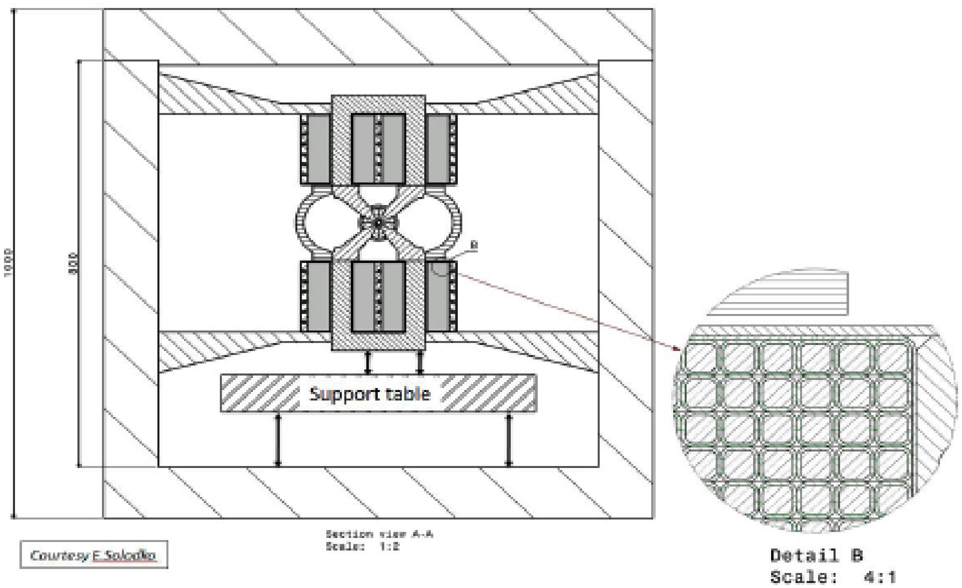


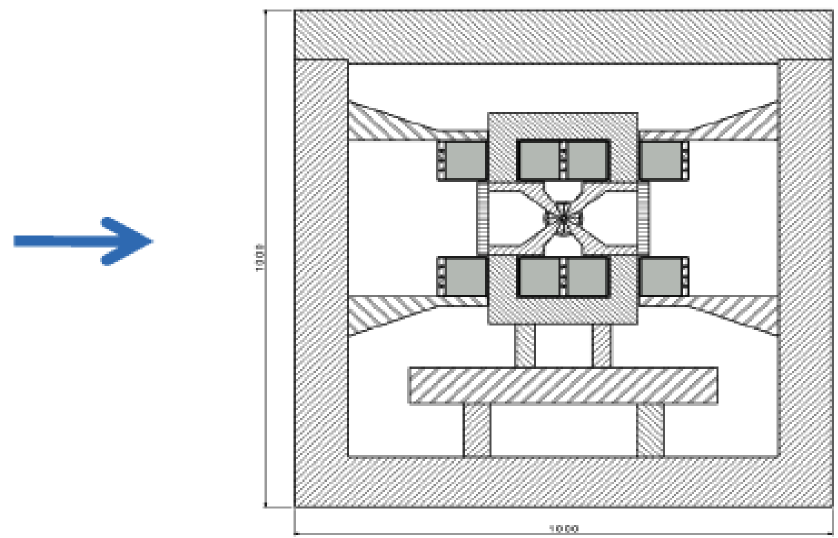
7 May 2010 , 13th CLIC MDI Meeting: "QD0 Studies & Proto Status" (M. Modena)

2

2) Design concept and evolution:

- *"Water-free" coils design (but with thermalization channel to keep temperature under control)*
- *Coils fixation independent from the quadrupole structure*
- *Mechanical details of a LONG version still to be studied*
- *Define strategy to measure field in small aperture (→L.Walckiers)*
- *Test tolerance of PM in external magnetic field*





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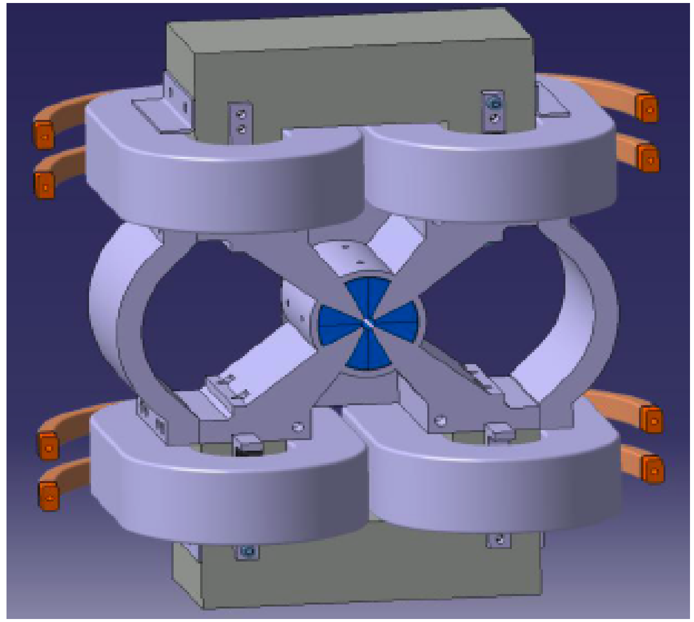
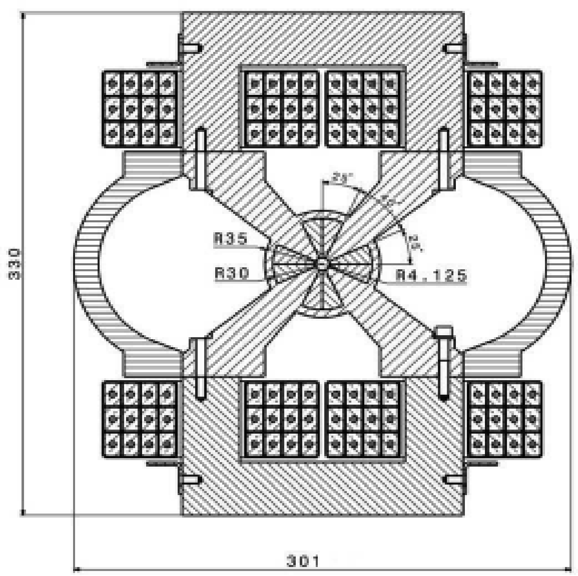
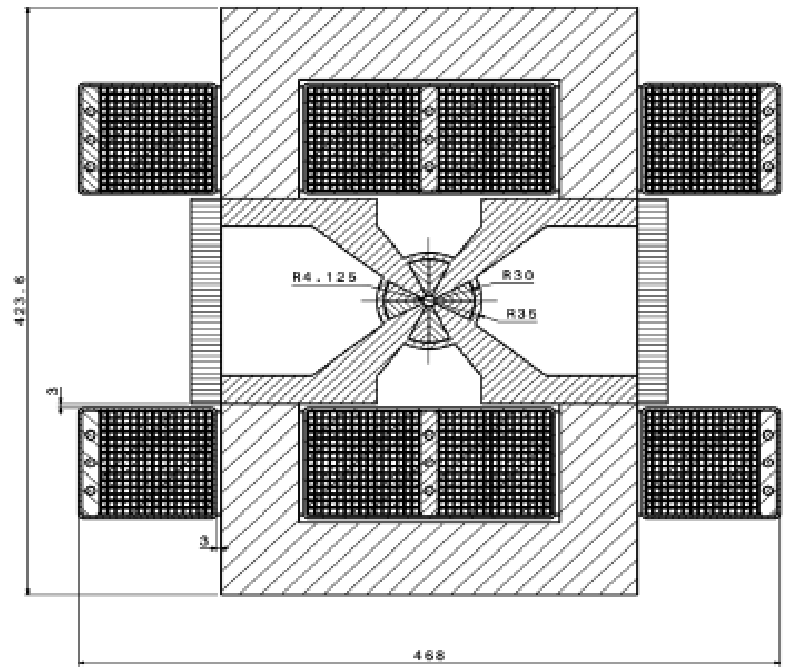
3

3) Prototype evolution

Building short prototype
Available by end 2010



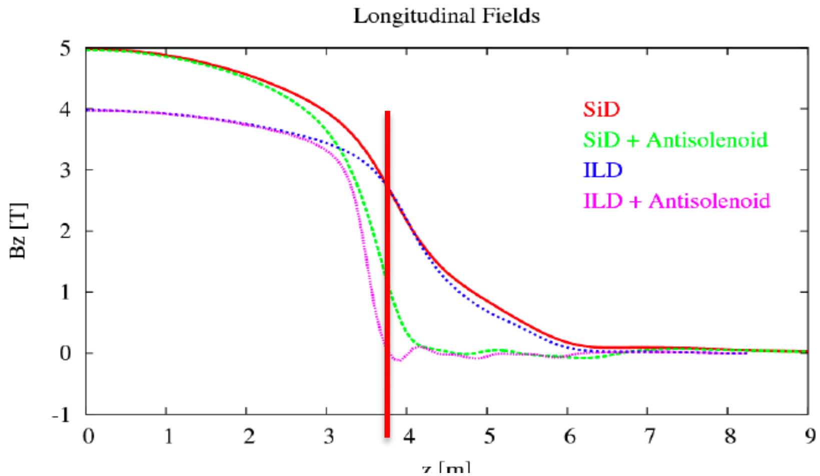




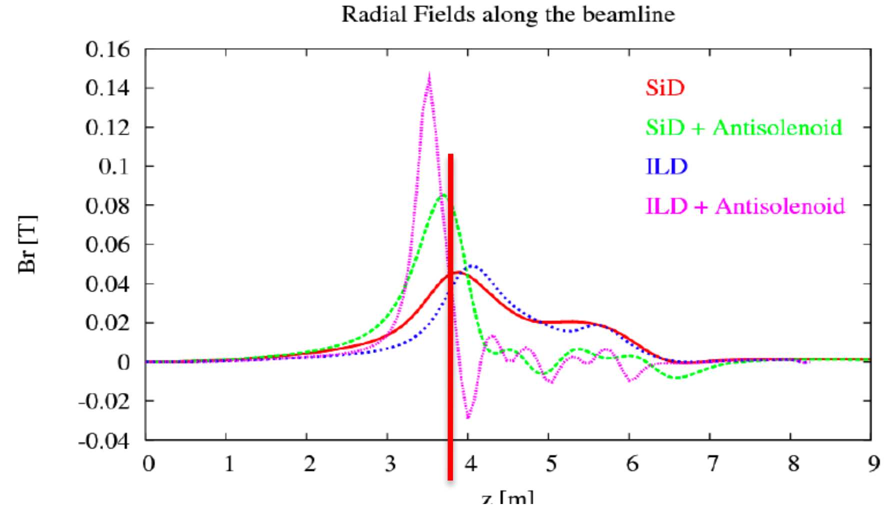
7 May 2010 , 13th CLIC MDI Meeting: "QD0 Studies & Proto Status" (M. Modena)

4

Longitudinal Field along the beamline



Radial Field along the beamline



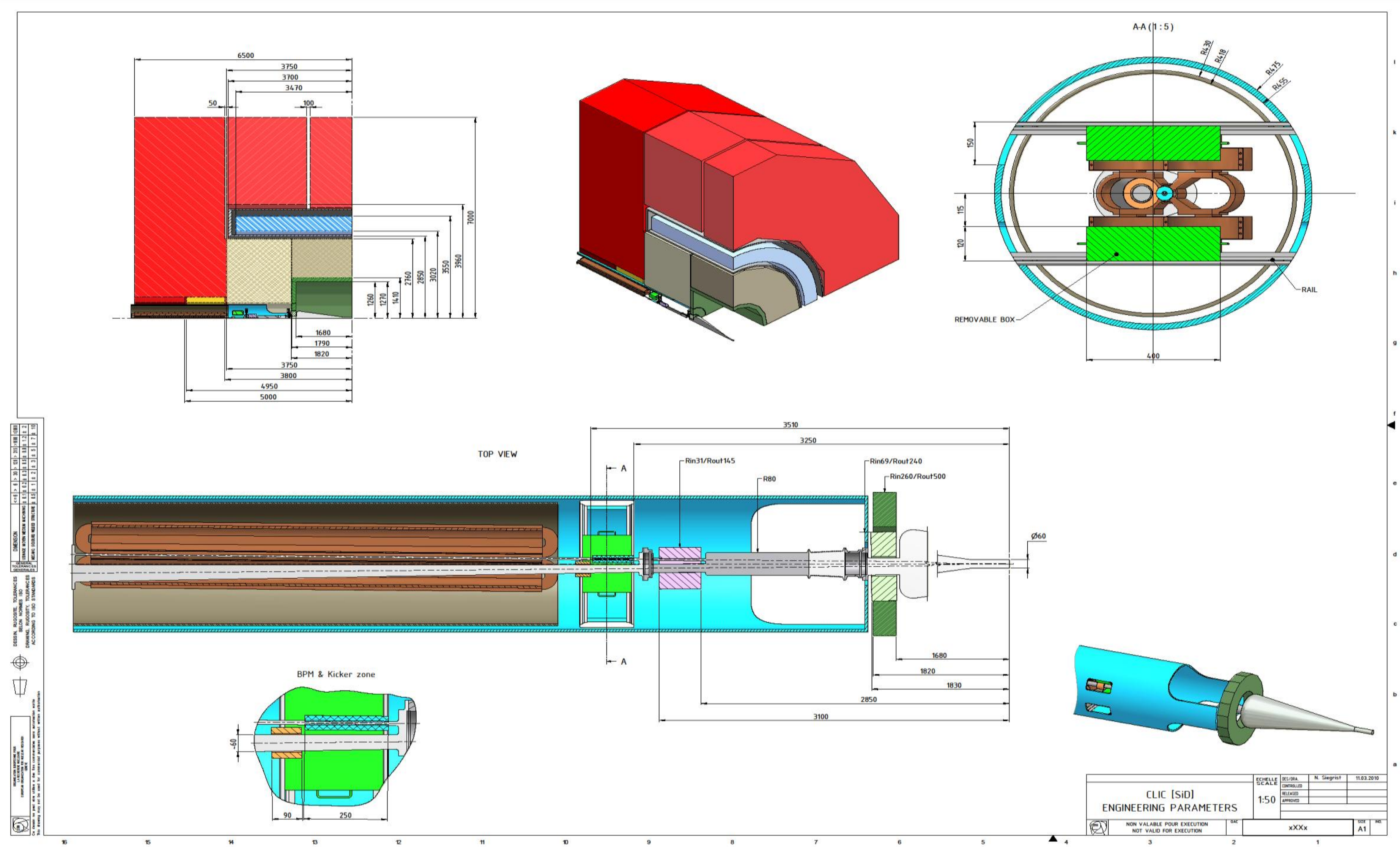
Conclusion & Outlook

- The two compensating solenoid perform in the same way from the beam optics point of view. Vertical dispersion and <x',y> coupling due to main solenoid field reduced > 90%
- Luminosity optimization for Incoherent Synchrotron Radiation might be required
- Compensating solenoid can help in reducing the dynamic tolerances due to field instability (provided the field changes scale in the same way!)

The residual vertical dispersion and <x', y> coupling must be compensated

- Optimization of the compensating solenoid
- Using the other magnets of the FFS

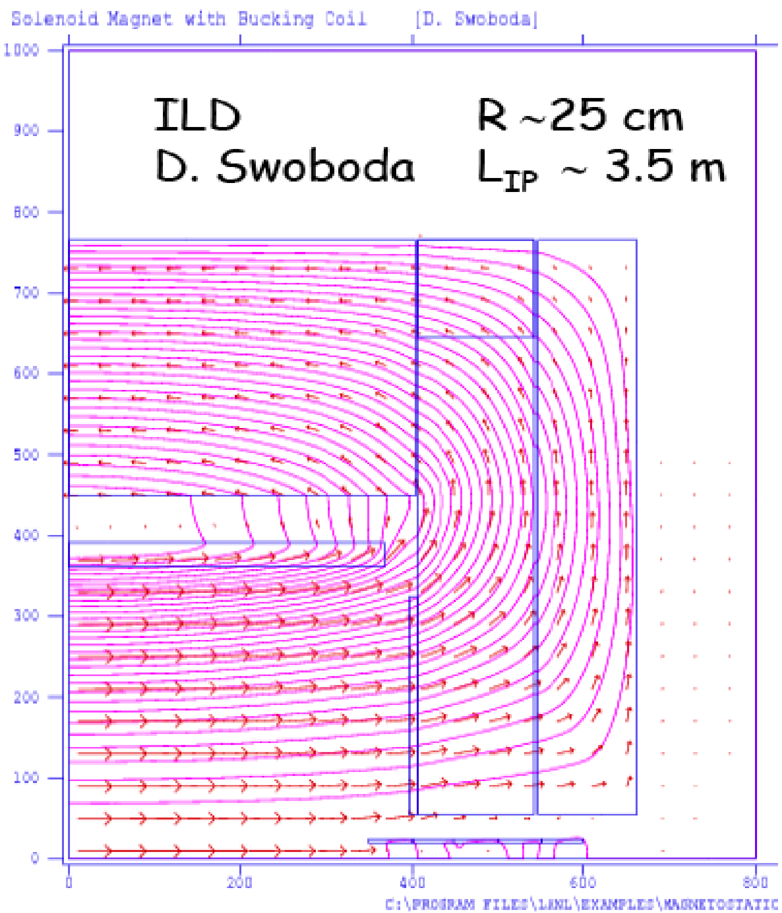
Latest CLIC-SiD detector

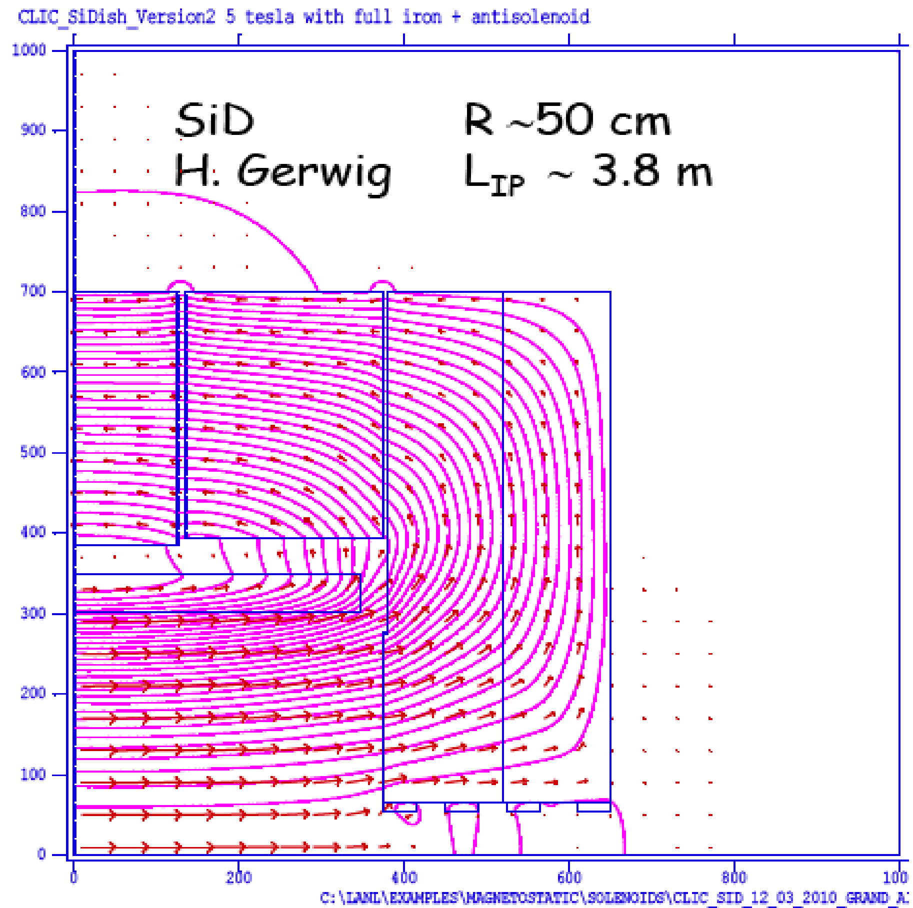


Anti-solenoid protects QD0 magnet:

B.Dalena

Field Computation

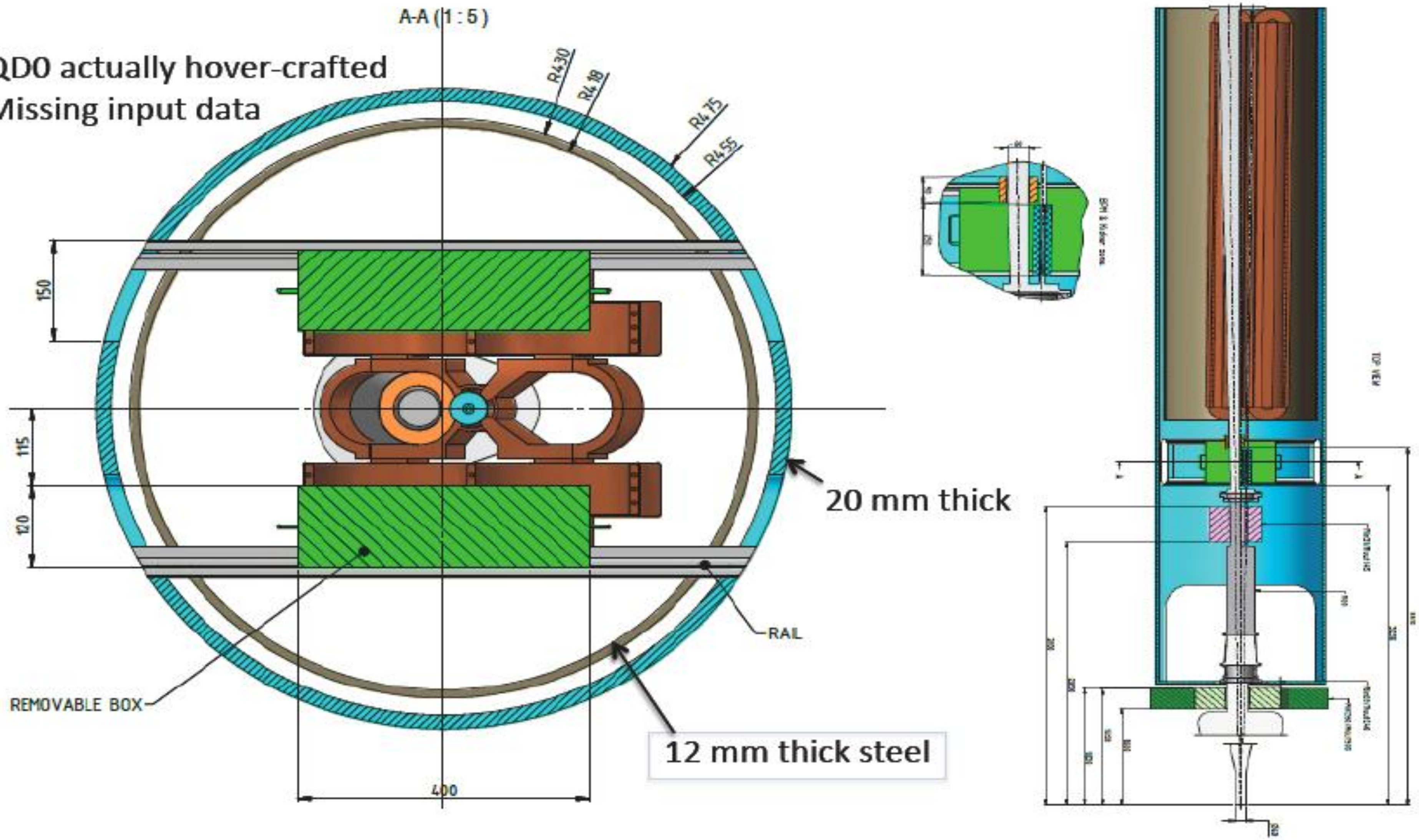




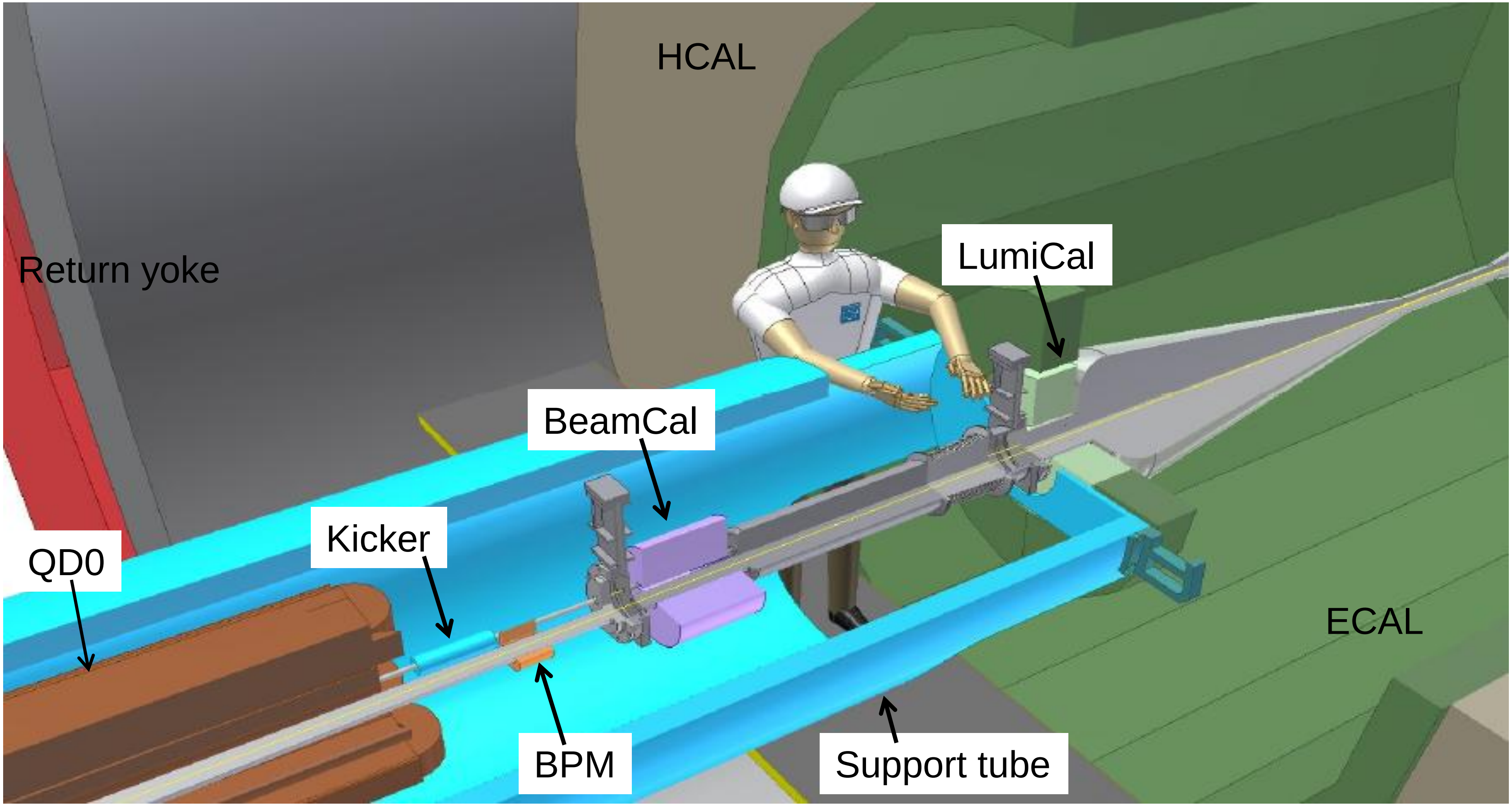
- Engineering design to be made
- Find way to protect QD0 even if one of the solenoids trips

Cross-section support tube, dimensions

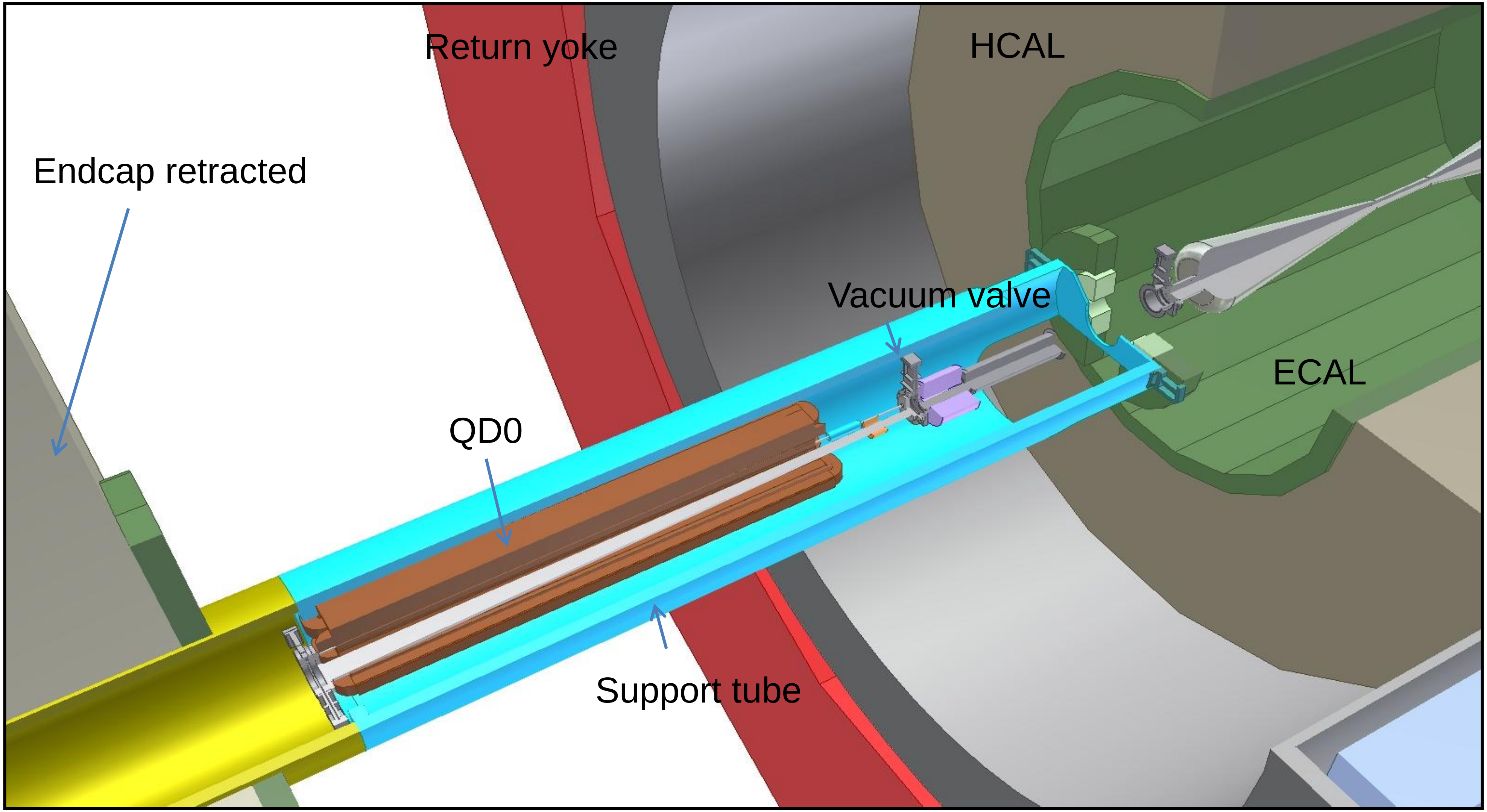
QD0 actually hover-crafted
Missing input data



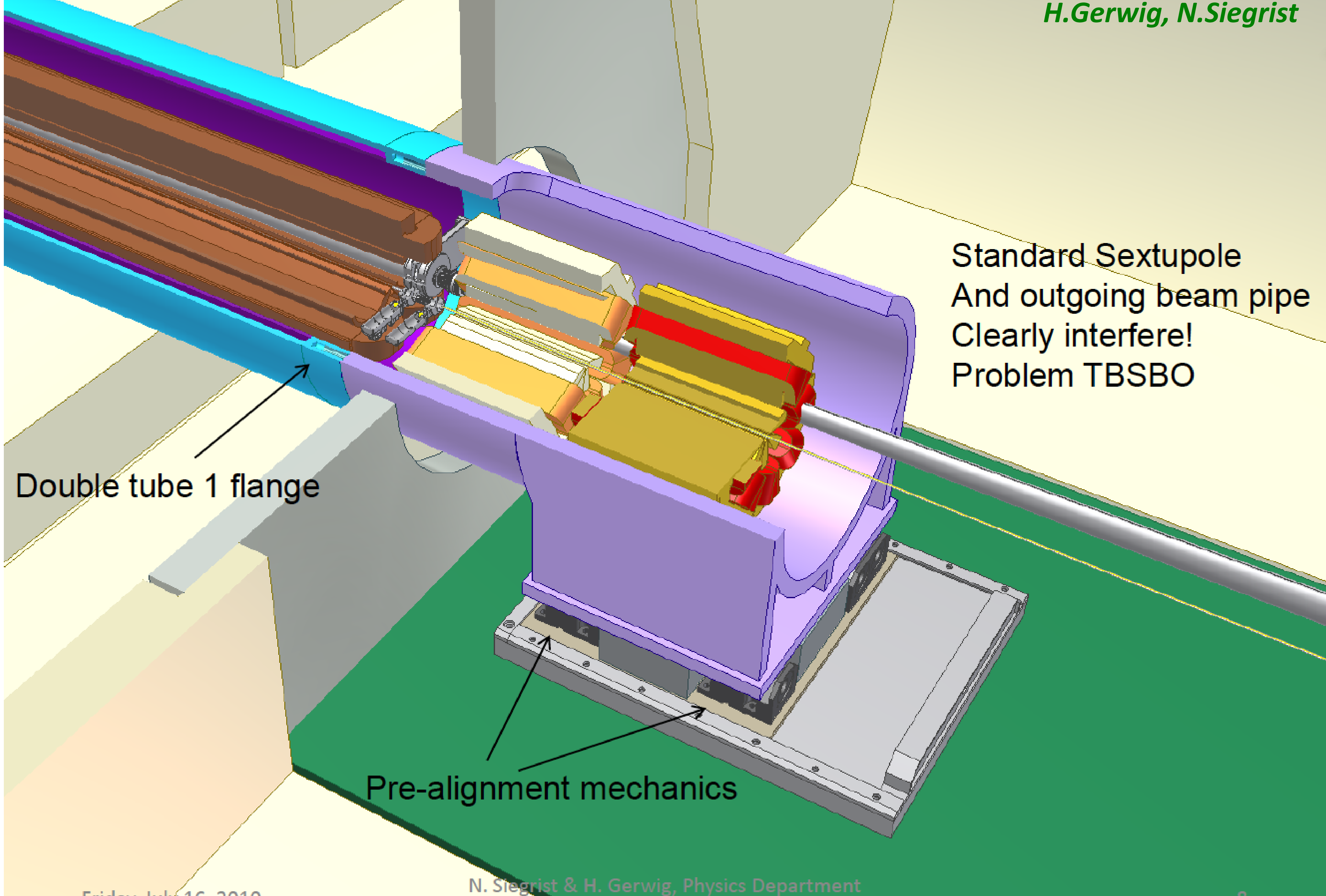
7 May 2010 H. Gerwig - 13th MDI 13

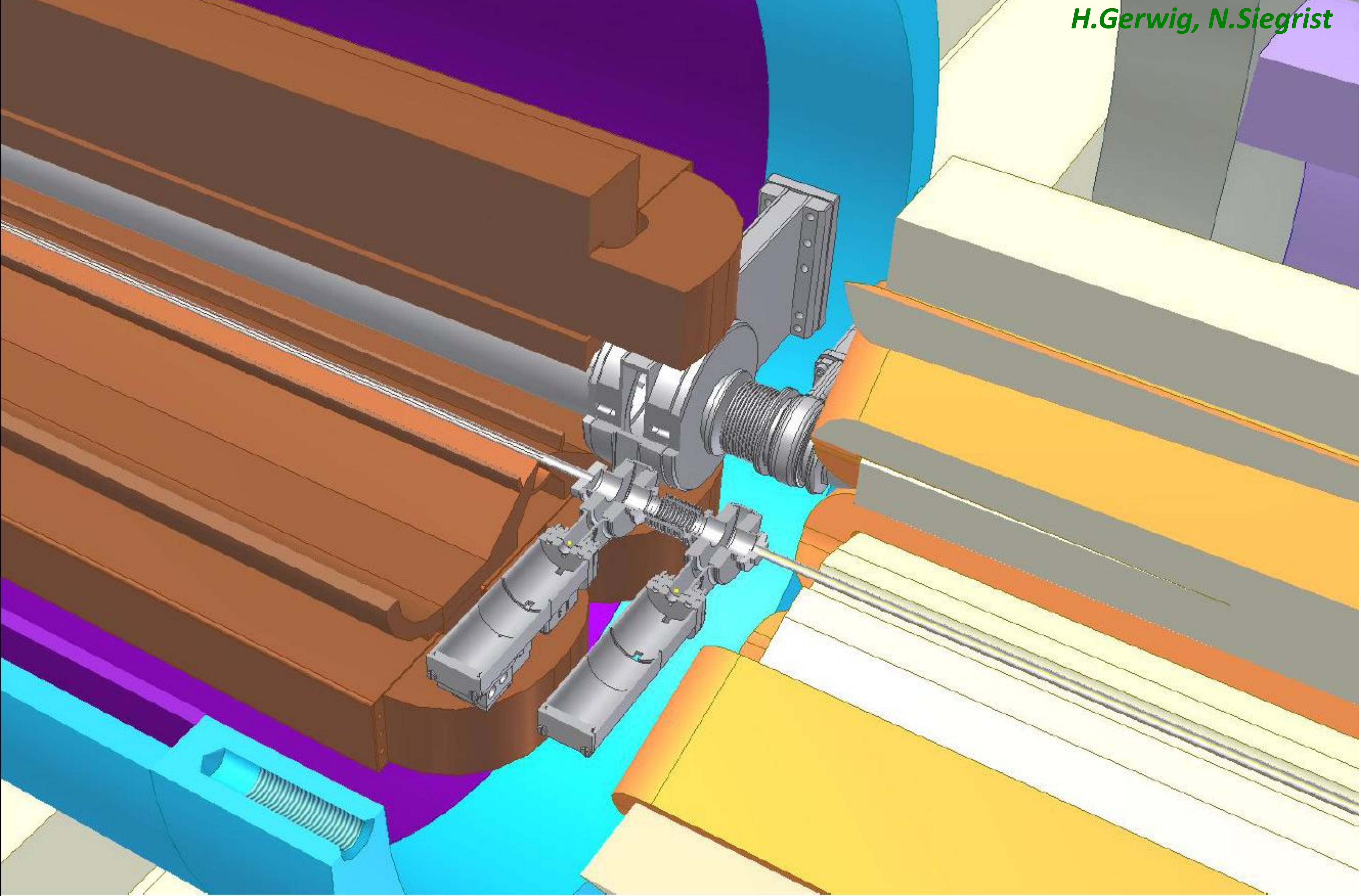

HCAL
Return yoke
LumiCal
BeamCal
Kicker
QD0
ECAL
BPM
Support tube

H.Gerwig, N.Siegrist

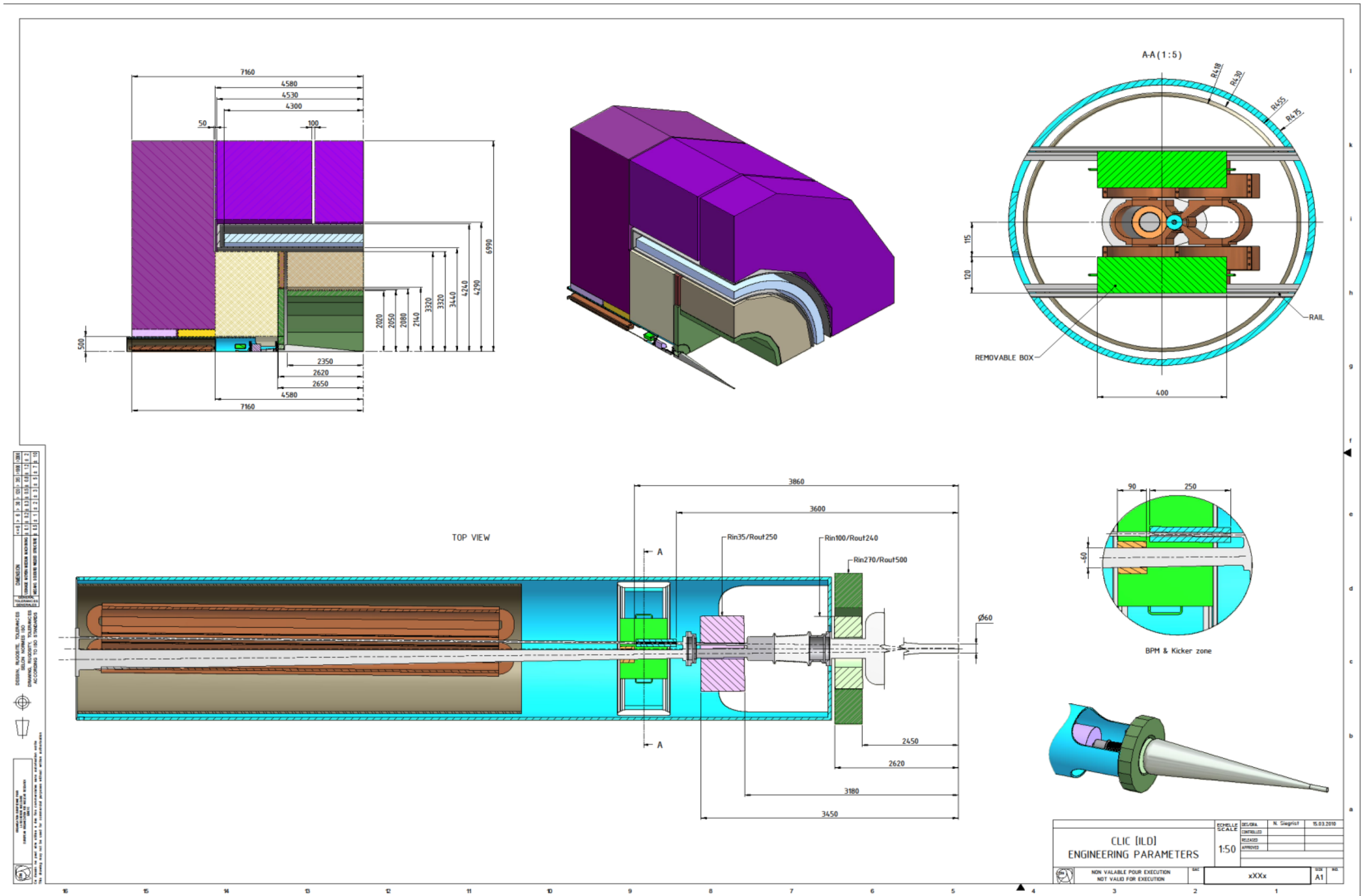


H.Gerwig, N.Siegrist

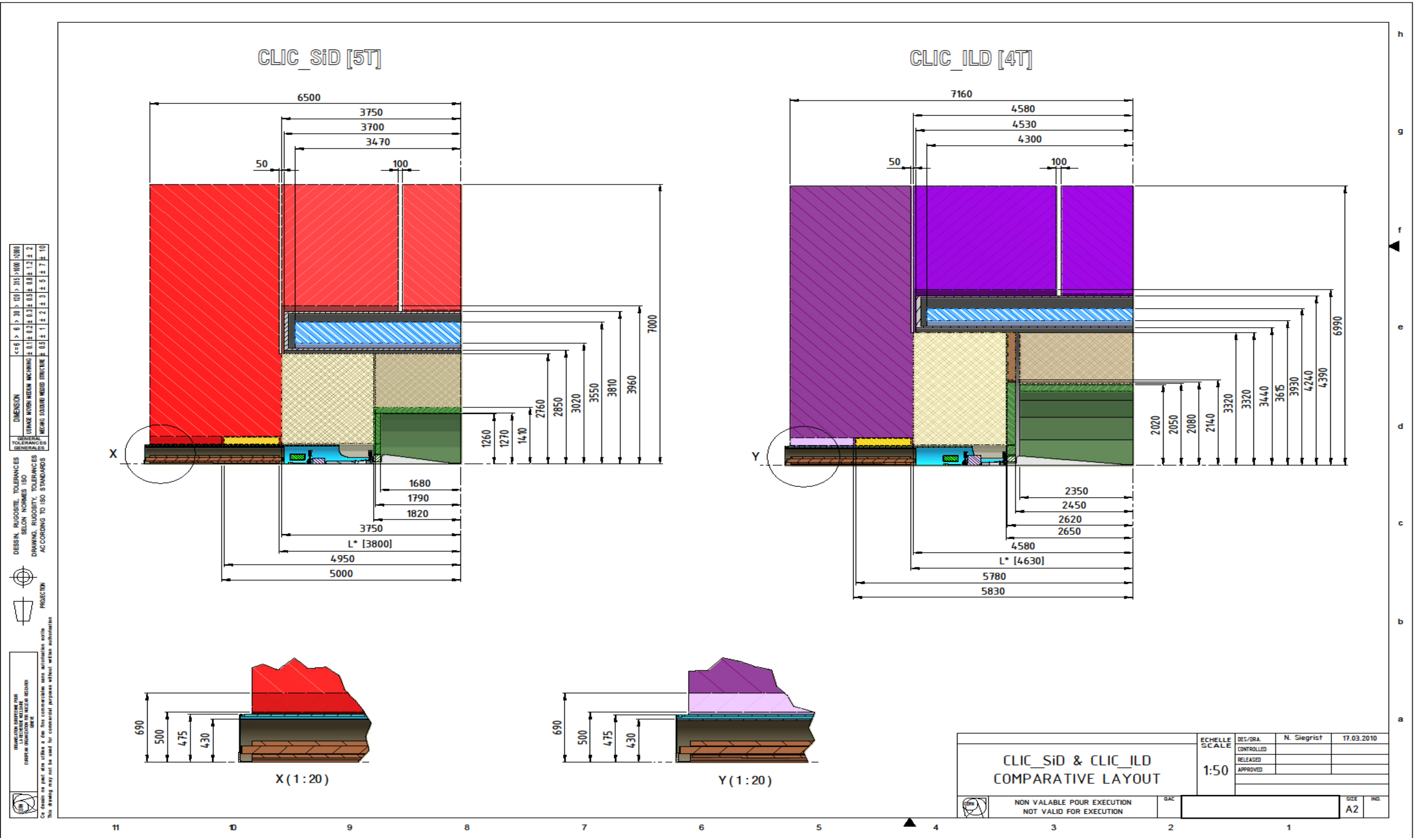



H.Gerwig, N.Siegrist

CLIC-ILD parameter drawing



Comparison between the two detectors

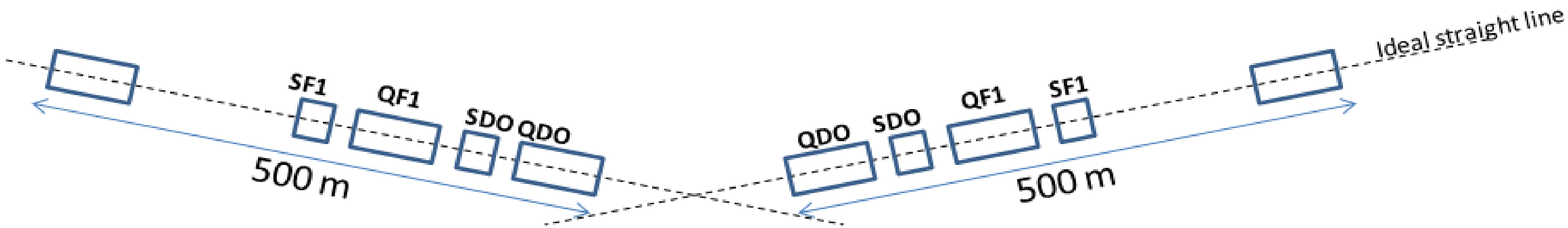


Helene Mainaud

Determination of the position of QD0 w.r.t other components of the BDS (500 last m)

- **Requirements:**

  ✓ 10 µm (for L*=3.5 m), rms value
  ✓ Position of the zero of the QD0 w.r.t to the ideal straight line of the 500 m last meters of BDS



- **Solution proposed:**

  ✓ Stretched wire + WPS sensors
  ✓ Same solution than for the main linac, except the length of wire (500 m instead of 200 m)
  ✓ 500 m wire validated in TT83 tunnel in 2008.

- **Main remaining issues:**

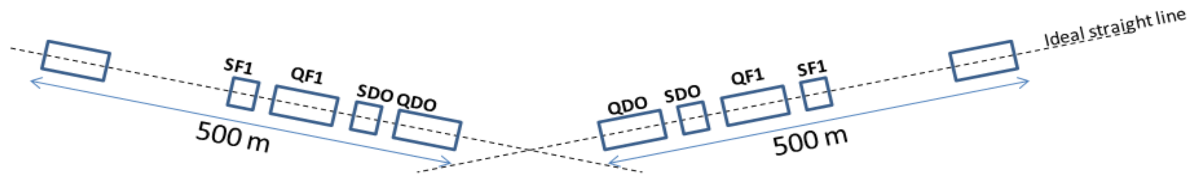
  ✓ Integration
  ✓ Fiducialisation

Helene Mainaud

Monitoring of the position of one QD0 w.r.t the other

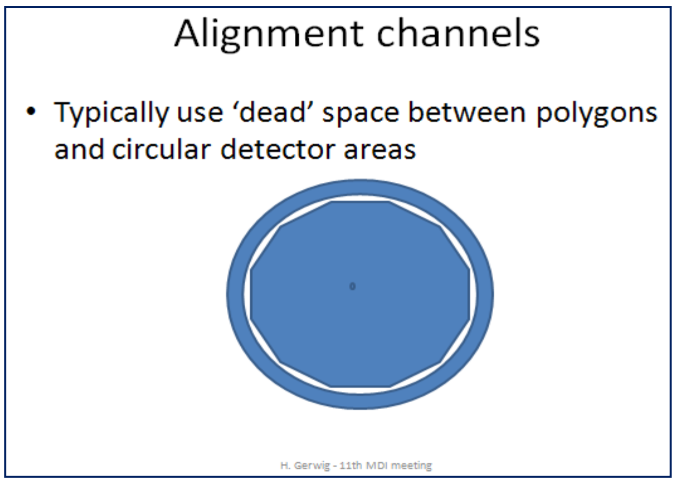
- **Requirements:**

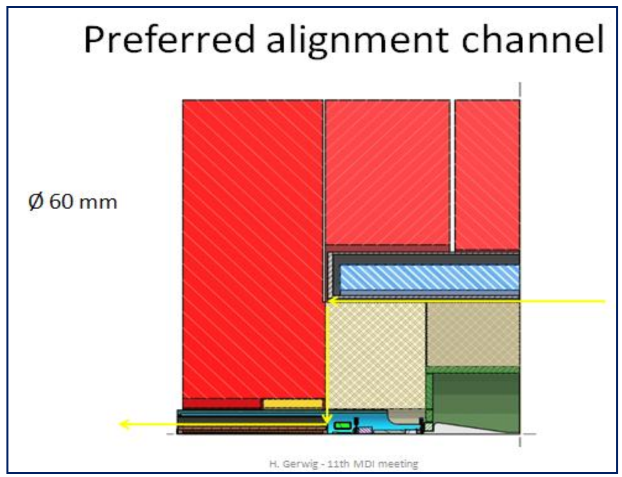
  ✓ The best we can!

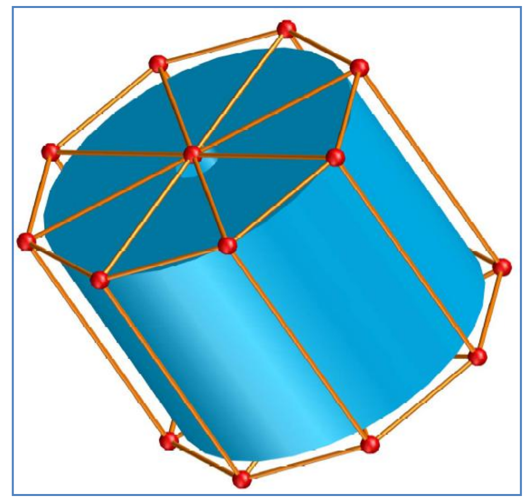


- **Solution proposed:**

  ✓ Solution based on RASNIK system, through the detectors (using dead space between detector areas)

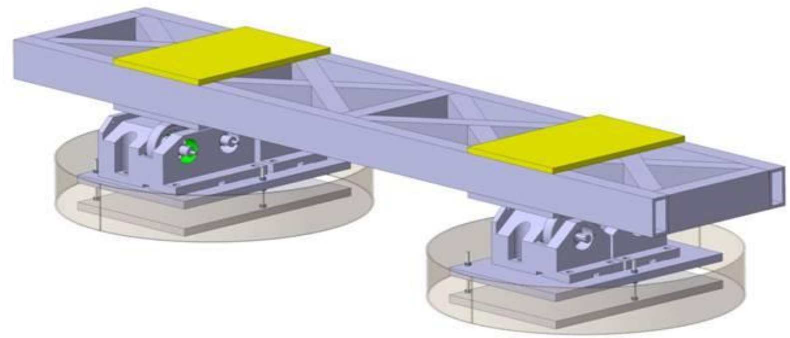






Helene Mainaud

Re-adjustment solution: cam movers for 5 DOF



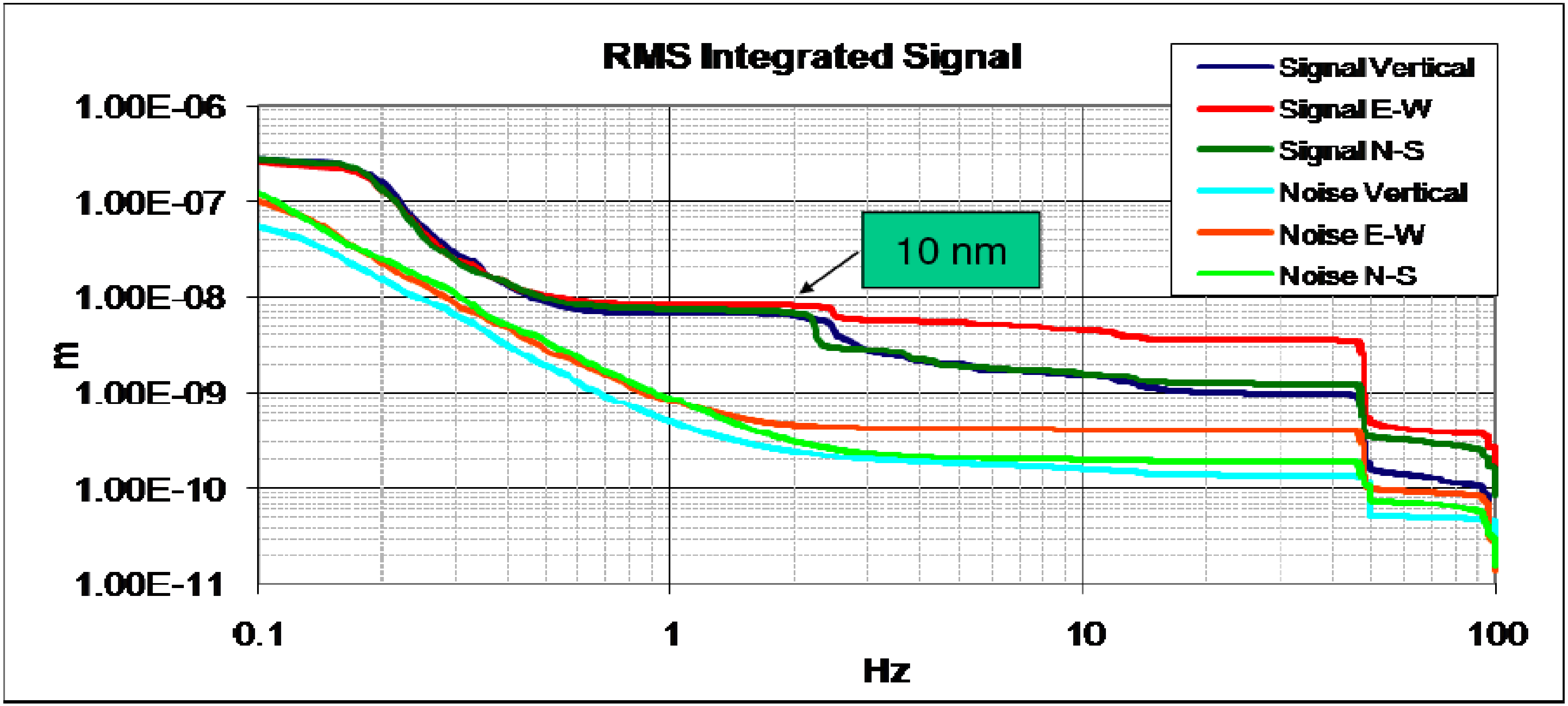
- **Requirements:**
  - ✓ Sub-micrometric displacements
  - ✓ Compatible with stabilization requirements

- **Solution proposed:**
  - ✓ Cam based system : same than for the MB quad of the linac

- **Remaining issues:**
  - ✓ Integration!

Ground motion measurement in CMS

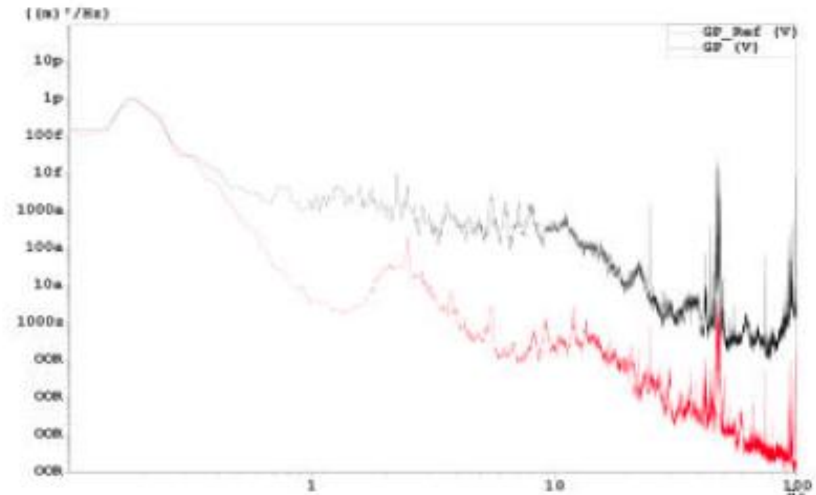
- To measure the ground vibration, two geophones were placed close together on the floor under YB0.
- The measurements were provided while the **cooling systems were off.**

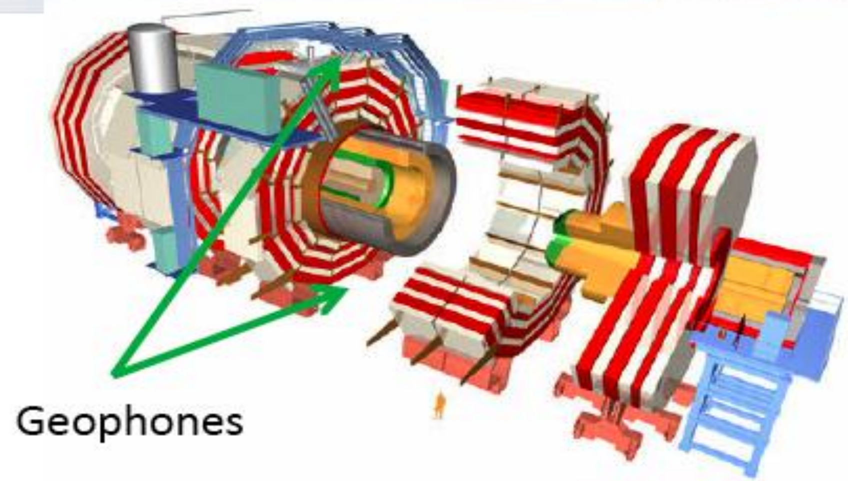


M.Guinchard and A.Kuzmin

CMS top of Yoke measurement

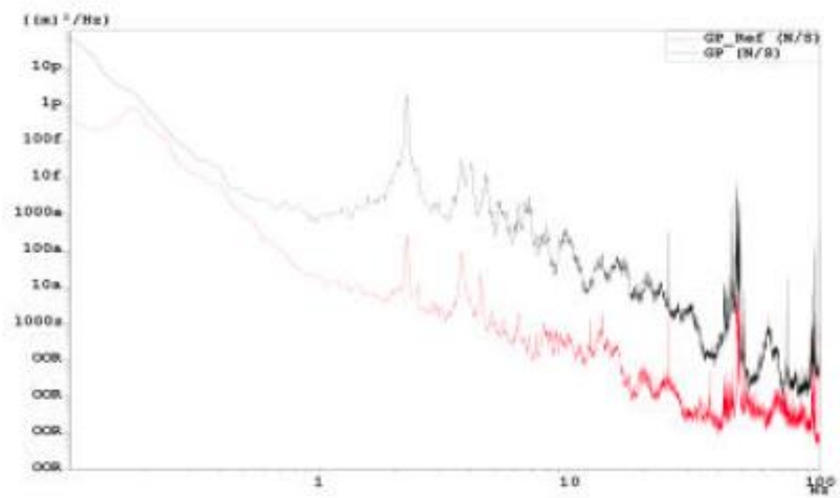
PSD of the signals Vertical direction

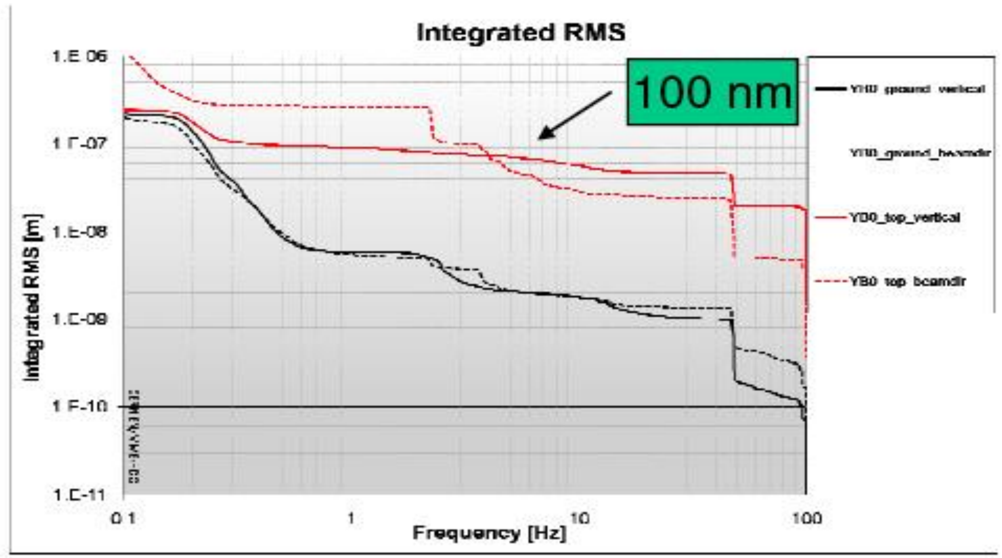




Cooling system OFF

PSD of the signals Beam direction





M.Guinchard and A.Kuzmin

Things needed to be studied for nm stabilisation

- Instrumentation:
  - nm , low frequency, compact, rad hard, insensitive to magnetic field
- Mechanics=> design and dynamic calculations
  - Maximise rigidity, Minimise weight, Minimise beam height, Optimise support positions
- Stabilization strategy
  - automatics, active or passive isolation, feedback etc…

Specification: 0.15 nm for f > 4 Hz in vertical plane

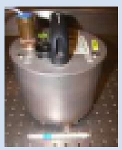
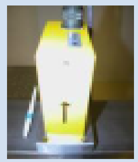
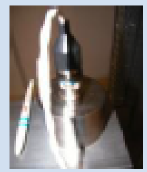
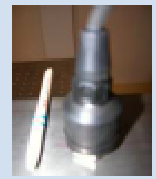
A.Jeremie, C.collette, K.Artoos

Sensors that can measure nanometres

Absolute velocity/acceleration studied at LAPP:

Type of sensors	Electromagnetic geophone	Electrochemical geophone	Piezoelectric accelerometers		
Model	GURALP CMG-40T	SP500-B	ENDEVCO 86	393B12	4507B3
Company	Geosig	PMD Scientific	Brüel & Kjaer	PCB Piezotronics	Brüel & Kjaer
Sensibility	1600V/m/s	2000V/m/s	10V/g	10V/g	98mV/g
Frequency range	[0.033; 50] Hz	[0.0167; 75] Hz	[0.01; 100] Hz	[0.05; 4000] Hz	[0.3; 6000] Hz
Measured noise (f > 5Hz)	0.05nm	0.05nm	0.25nm >50Hz: 0.02nm	11.19nm >300Hz: 4.8pm	100nm

Sub-nanometre measurements

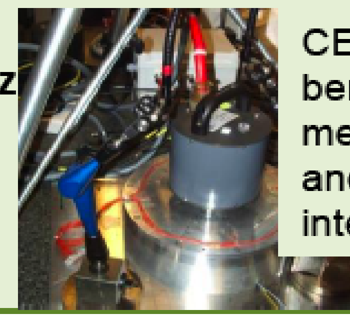

Relative displacement/velocity:

Capacitive gauges :Best resolution **10 pm (PI) , 0 Hz to several kHz**

Linear encoders best resolution 1 nm (Heidenhain)

Vibrometers (Polytec) ~1nm at 15 Hz

Interferometers (SIOS, Renishaw, Attocube) **<1 nm at 1 Hz**

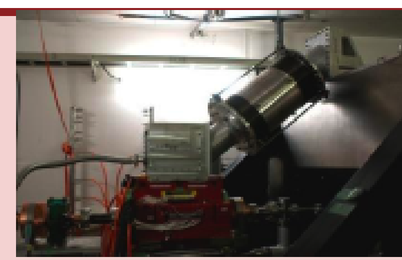


CERN test bench : membrane and interferometer

<u>OXFORD MONALISA (laser interferometry)</u>

Optical distance meters

Compact Straightness Monitors (target 1 nm at 1 Hz)



ATF2 vibration and vacuum test
⇒Validation
⇒Next: optical test

Actuators

A.Jeremie, C.collette, K.Artoos

Selection actuator type: comparative study in literature

First selection parameter: Sub nanometre resolution and precision

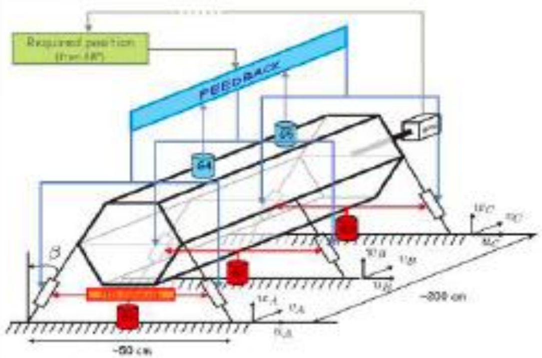
This excludes actuator mechanisms with moving parts and friction, we need **solid state mechanics**

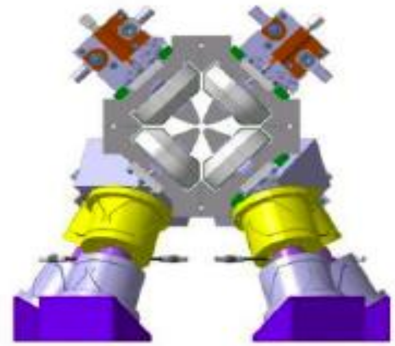
Actuator type	Property	Comments
Piezo electric materials	High rigidity	+ Well established - Fragile (no tensile or shear forces), depolarisation
Magneto Strictive materials	High rigidity	-Rare product, magnetic field, stiffness < piezo, - force density < piezo + No depolarisation, symmetric push-pull
Electrostatic plates	No rigidity, ideal for soft supports	Risk of break through, best results with µm gaps, small force density, complicated for multi d.o.f. not commercial
Electro magnetic (voice coils)	No rigidity, ideal for soft supports	Heat generation, influence from stray magnetic fields for nm resolution
~~Shape Memory alloys~~		Slow, very non linear and high hysteresis, low rigidity, only traction
~~Electro active polymers~~		Slow, not commercial

Option CERN: Rigid support and active vibration control

Approach: PARALLEL structure with inclined actuator legs with integrated length measurement (<1nm resolution) and flexural joints

Rigid: less sensitive to external forces but less broadband damping

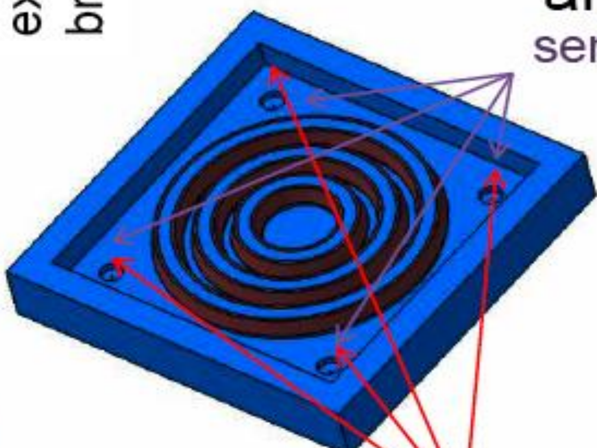




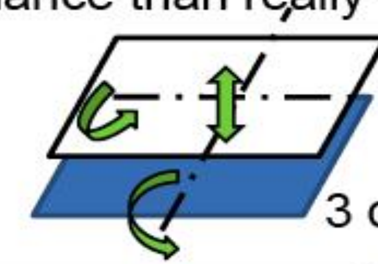
Concept drawing

Up to 6 d.o.f.

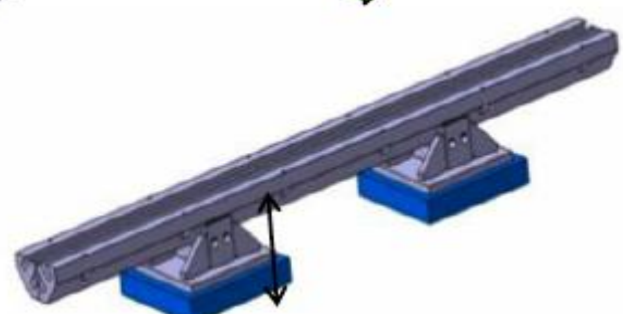
Option LAPP: Soft support (joint more for guidance than really « soft ») and active vibration control



Soft elastomere joint in between

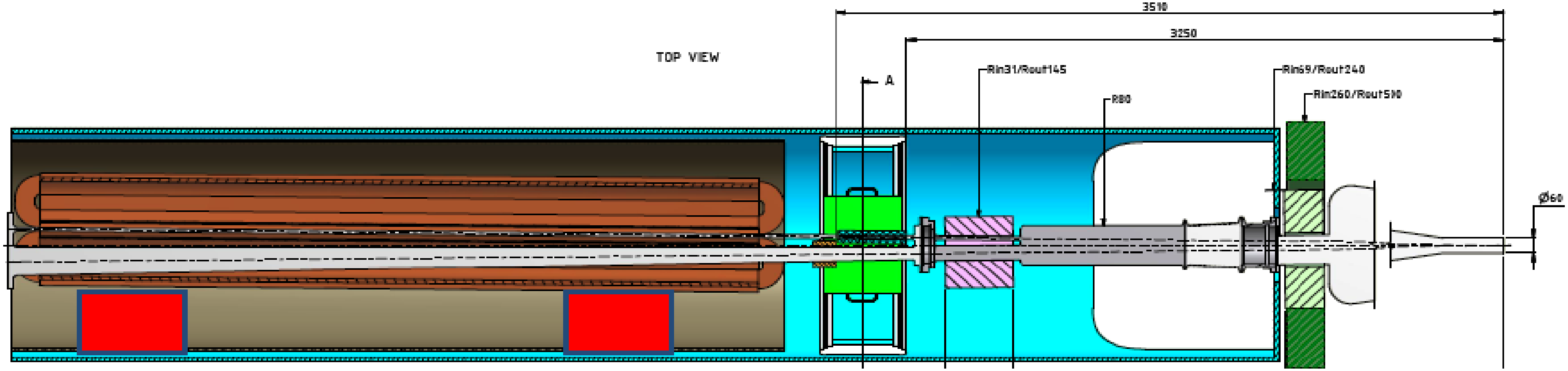


3 d.o.f. :

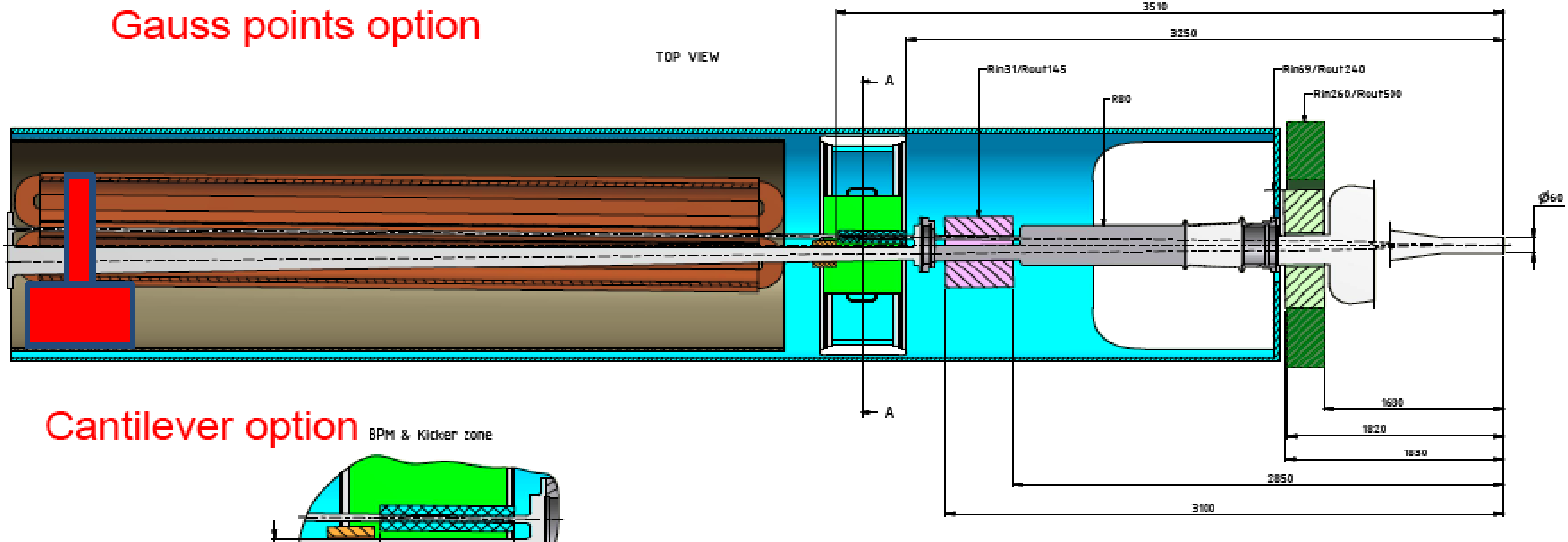


7

How to integrate with the rest (cantilever or Gauss points)



Gauss points option



Cantilever option

BPM & Kicker zone

Test program at LAPP:

Currently: tests on a sensor borrowed from micro-epsilon (CS601-0.05) on a dedicated test set-up.
Have to give back end of this week
⇒Preliminary results show that a nanometre movement can be measured by the sensor

Bought a sensor from PI (D-015): will receive beginning June, complete (not quick and dirty like currently on borrowed sensor) for about a month. Then if OK, we will buy 3 more: receive around end August. Then tests on isolation device can start.

Study elastomere : shape (recent tests are difficult to interpret, need a better study) and fabrication process: unique piece vs separate rings)

If time, then work can be done on FF magnet.

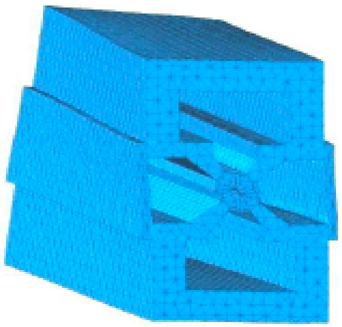
10

L.Pacquet, G. Deleglise

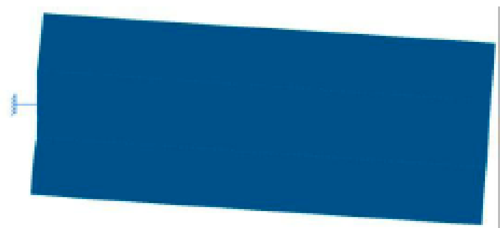
Preliminary FF calculations

just preliminary tests to get a feeling of what is going on…the numbers are not optimized, the tendency of the frequency of first mode to go up or down is correct!

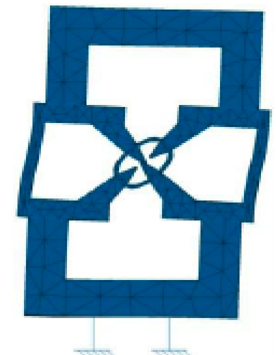
Solid block without coils :
991Hz



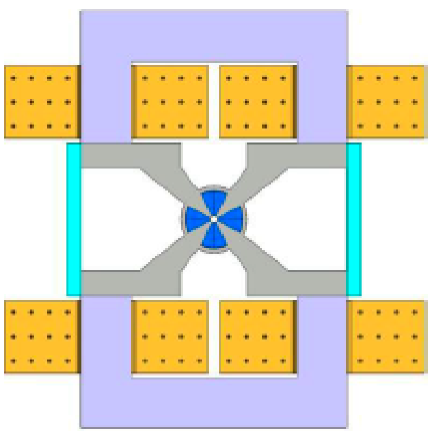
Cantilever :
125Hz



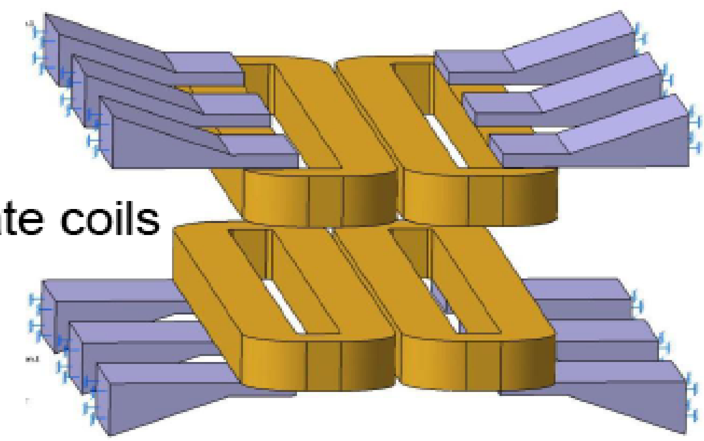
2 supports under magnet :
249Hz



Solid block with mass of coils :
557Hz



Work started with separate coils



19

Pre-isolator – How does it work?

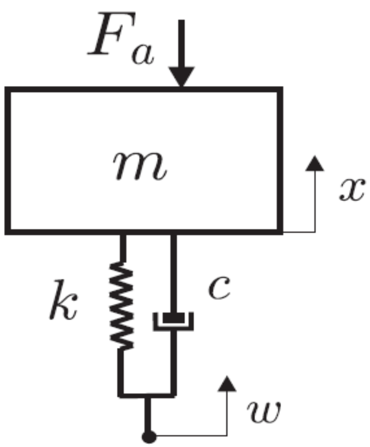
Low dynamic stiffness mount **+** Large mass

natural frequency around 1 Hz

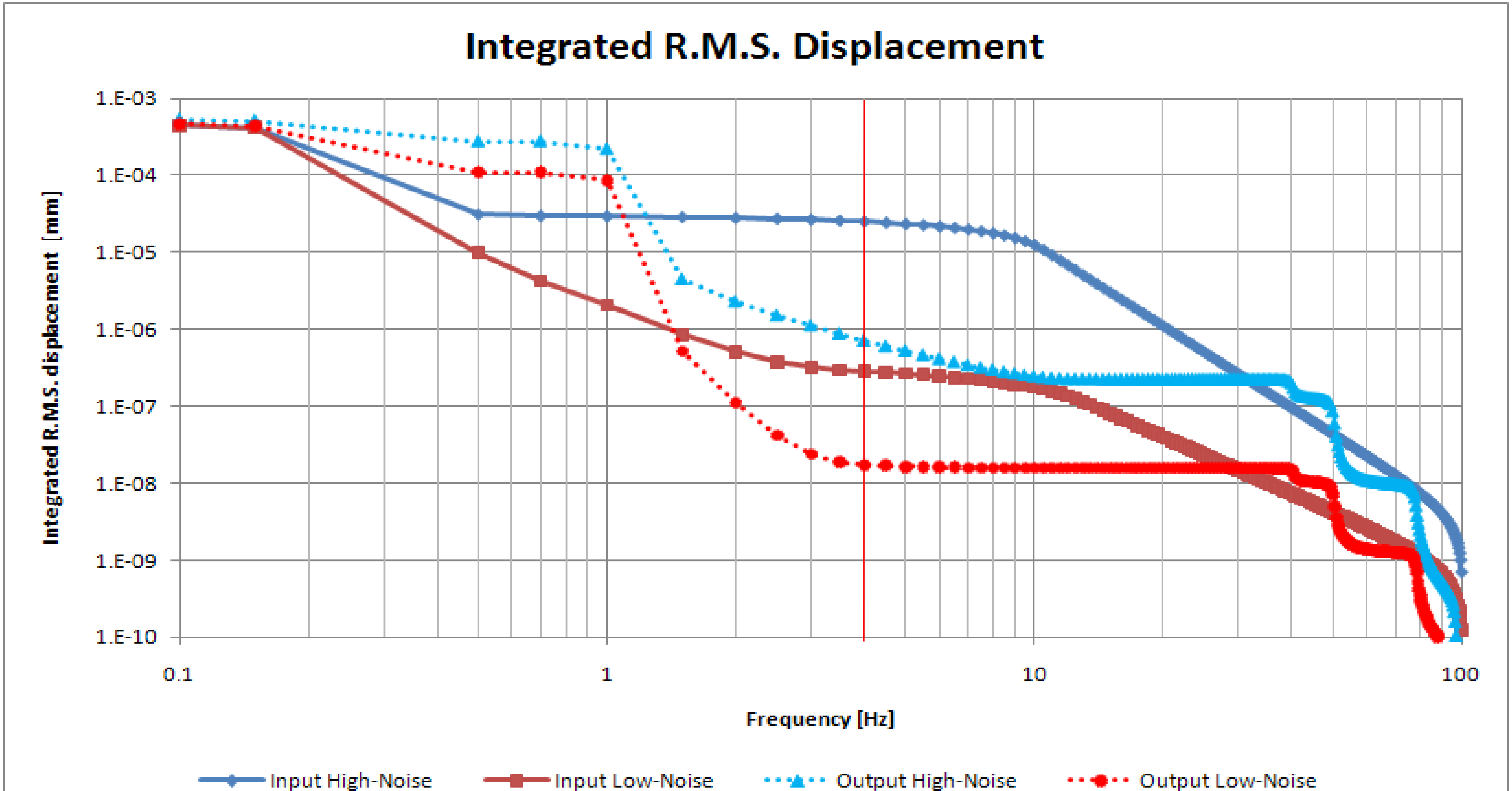
50 to 200 tons

Acts as a low-pass filter for the ground motion (w)

Provides the inertia necessary to withstand the external disturbances (F_a), such as air flow, acoustic pressure, etc.)



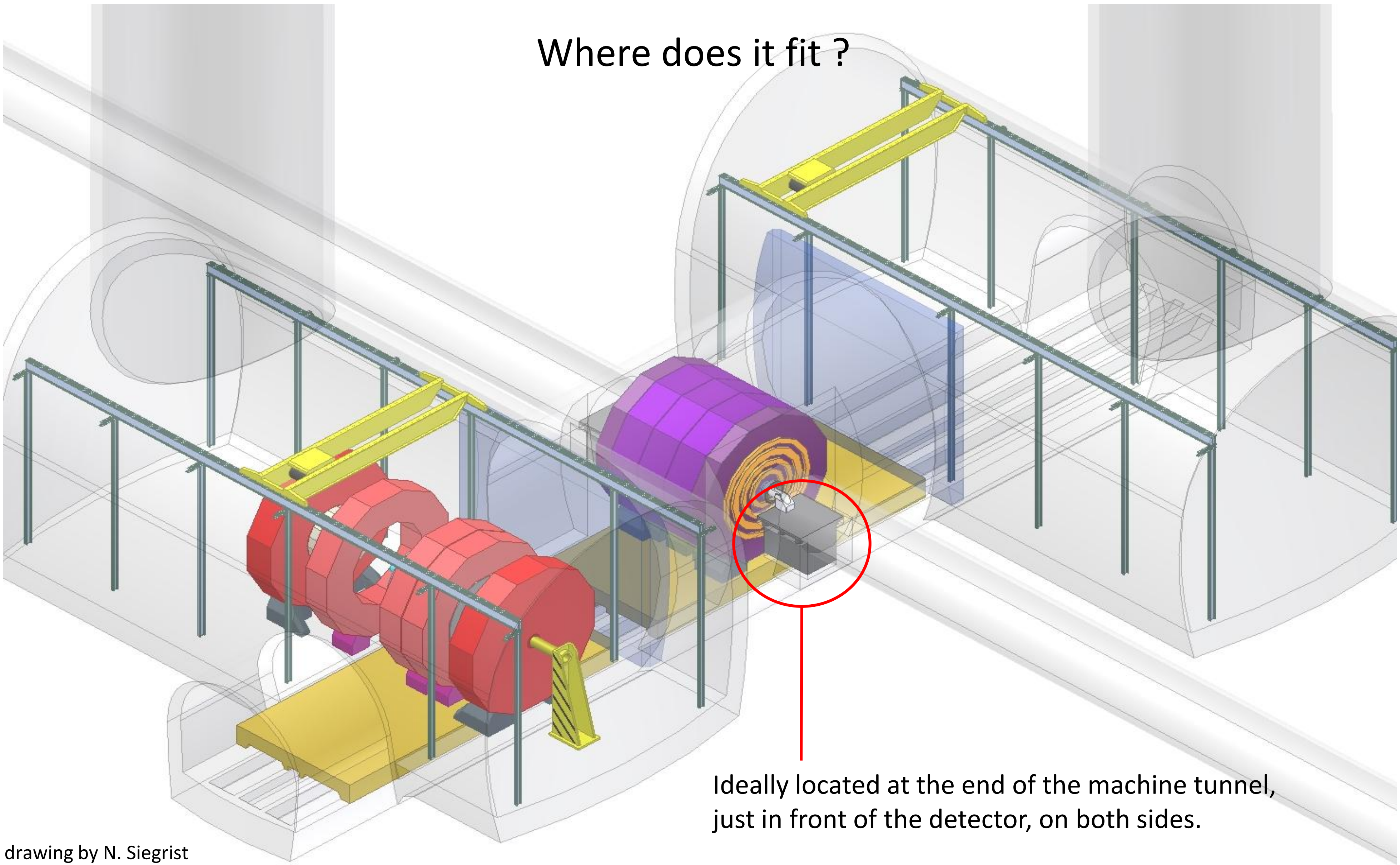
RMS vertical displacement reduced by a factor >10 from 4 Hz.



plots by F. Ramos

H.Gerwig,A.Gaddi, N.Siegrist

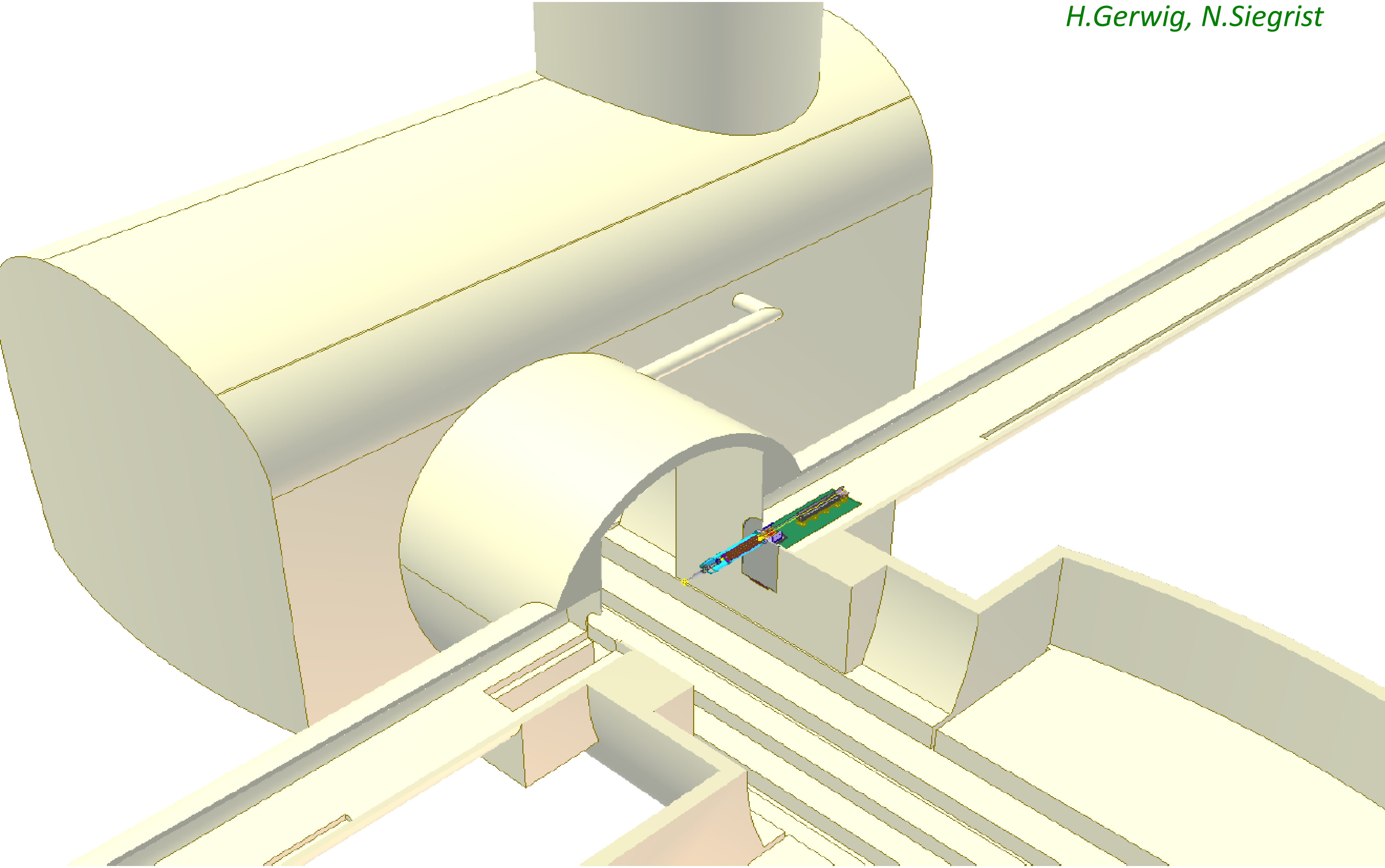
Where does it fit ?



Ideally located at the end of the machine tunnel, just in front of the detector, on both sides.

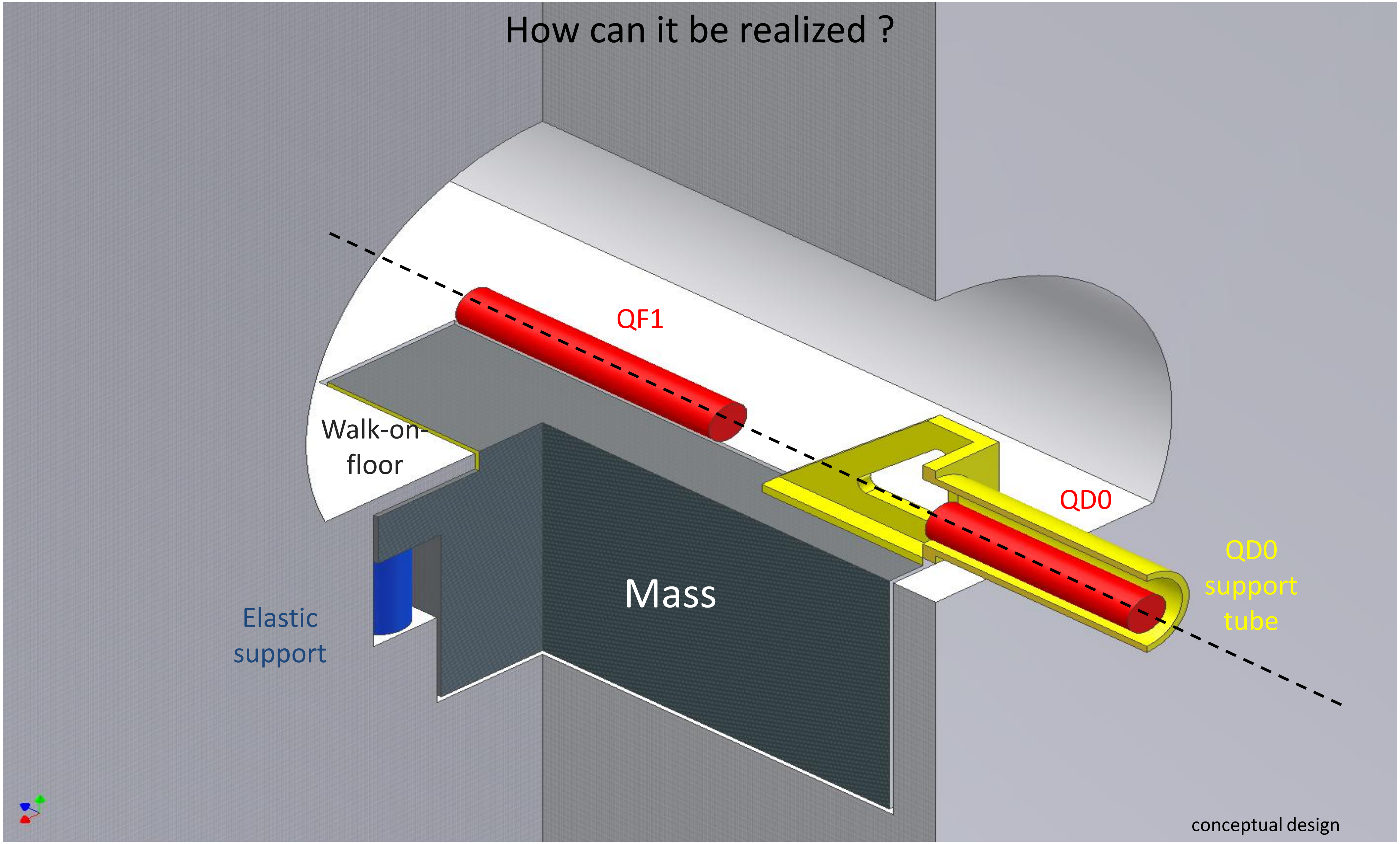
drawing by N. Siegrist

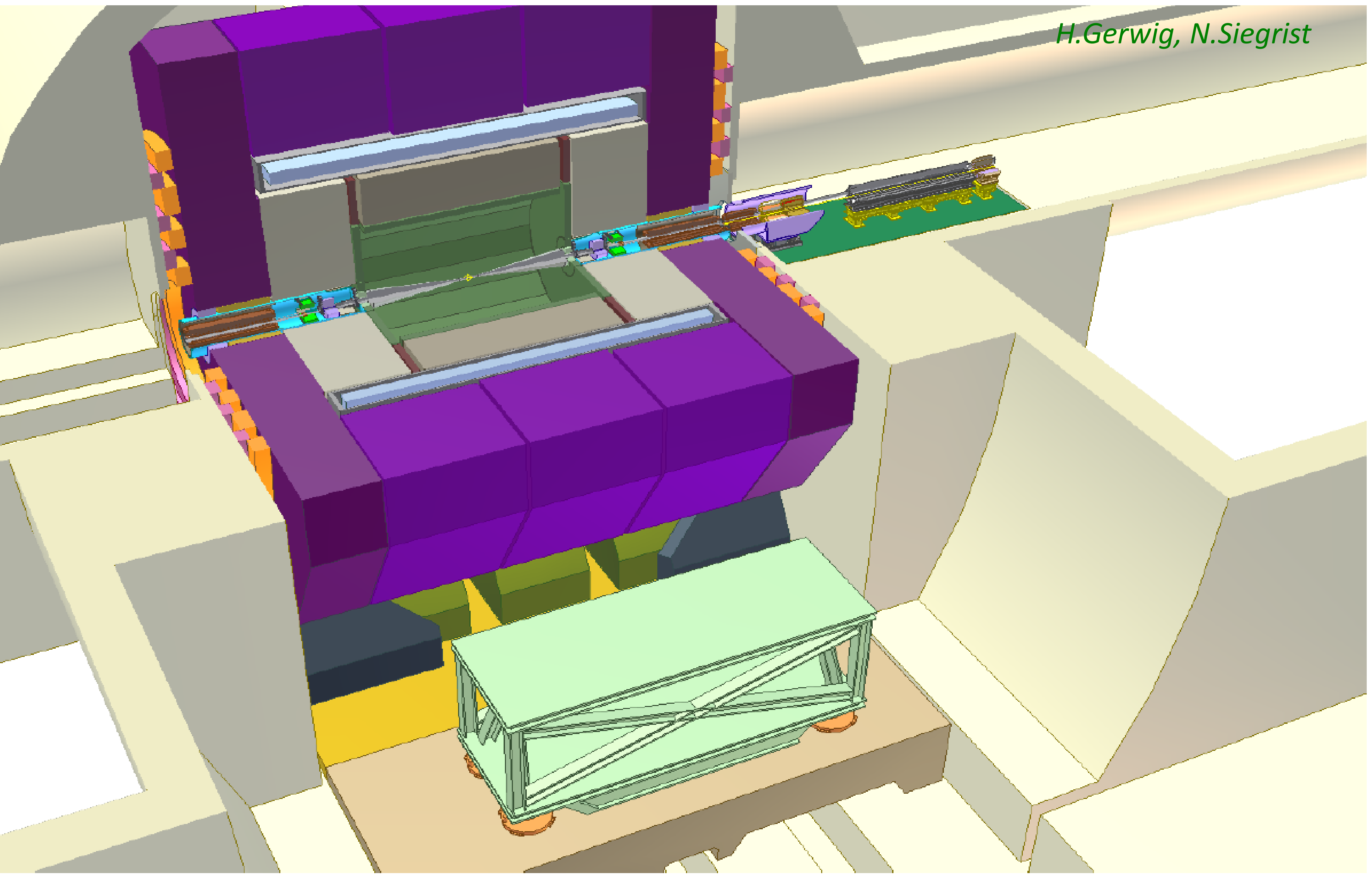
H.Gerwig, N.Siegrist

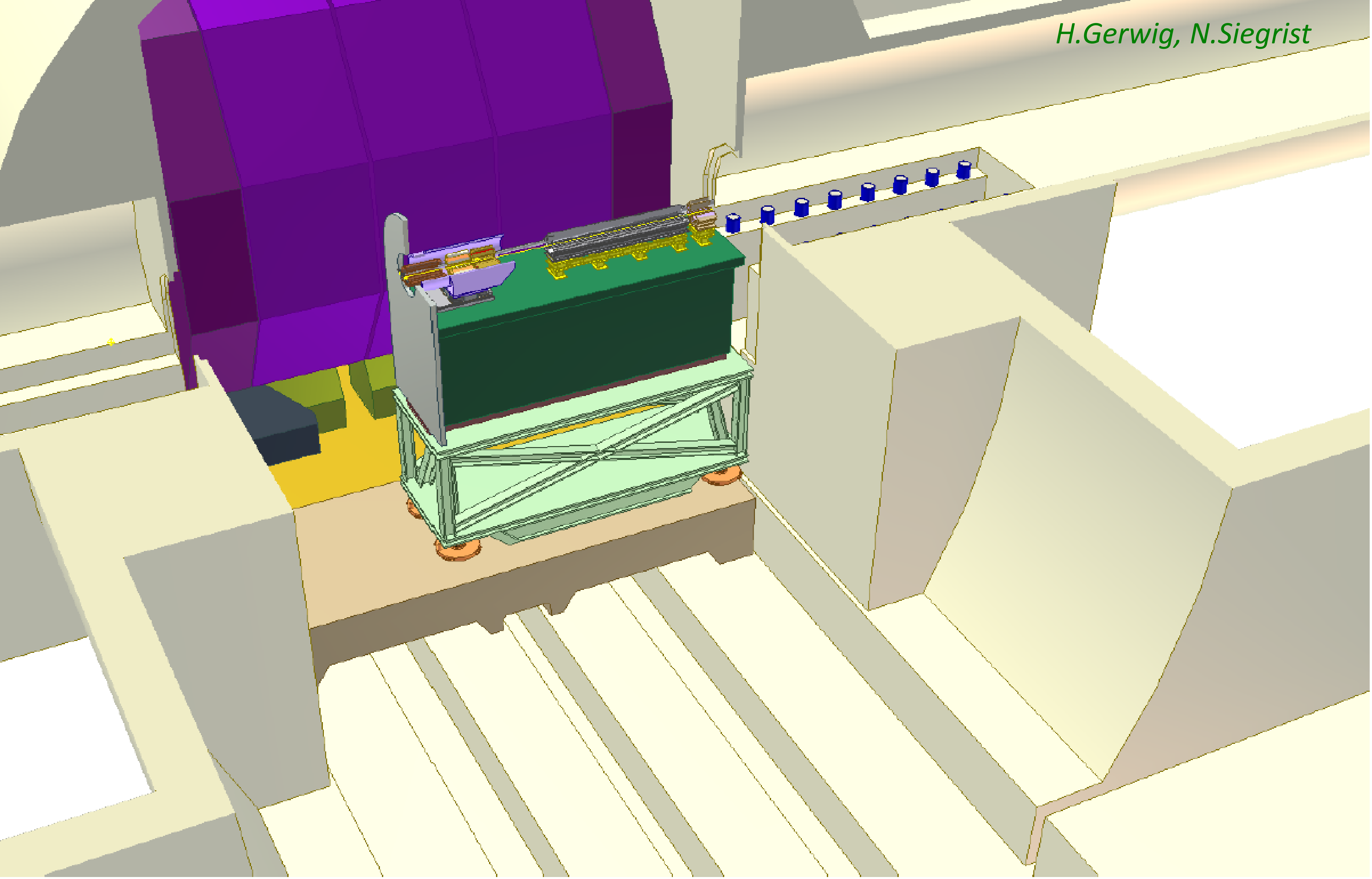


A.Gaddi

How can it be realized ?

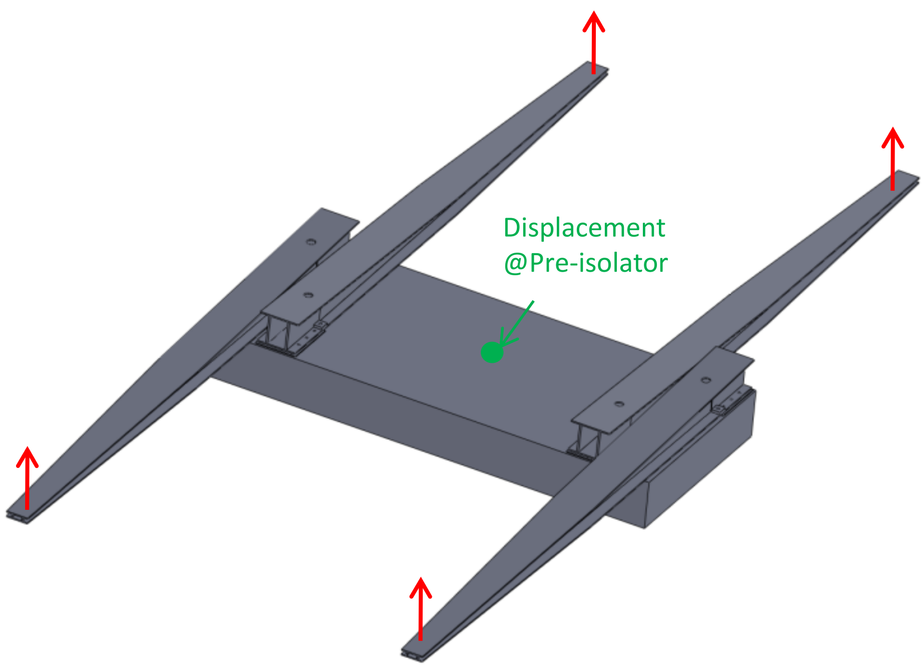



H.Gerwig, N.Siegrist


H.Gerwig, N.Siegrist

Small scale prototype test proposed:

Experimental set-up – How ?



The prototype needs to be:

Simple to design/build/assemble
Easy to “debug” & tune
Cheap

Proposal:
40 ton mass supported by
4 structural beams acting as flexural springs

Only if unsuccessful: consider larger L*

In the past some studies were made for L* = 8 m, however not fully optimised

If L* = 8 m: QD0 would be in the tunnel, i.e. have a much more stable support (in principle)
But some heavy prices to pay (Luminosity, prealignment, …)

Would prefer intermediate value (e.g. 6 m)?

Parameters	L* = 3.5 m	L* = 8 m
Luminosity	L_o	$0.72\ L_o$
QD0 support	Detector	Ground
QD0 gradient	575 T/m	323 T/m
QD0 grad tolerances	$5\ 10^{-6}$	$3\ 10^{-6}$
Final focus length	400 m	800 m
QD0 length	2.73 m	4.2 m
QD0 aperture radius	3.8 mm	6 mm
QD0 jitter	0.15 nm	0.18 nm
Prealignment	10 µm	**2 µm**

From Rogelio Tomas

Total and peak luminosities

L* m	total lumi $10^{34}cm^{-2}s^{-1}$	peak lumi $10^{34}cm^{-2}s^{-1}$
3.5	6.9	2.5
4.3	6.4	2.4
6	5.0	2.1
8	4.0	1.7

Some specifications

L*	m	3.5	4.3	6.0	8.0
QD0 grad	T/m	575	382	200	211
" aperture	mm	3.5	6.7	8	8.5
" jitter	nm	0.15	0.15	0.2	0.18
" support		det.	det.	ground	ground
" grad tol.	10^{-6}	5	5	-	3
Prealign.	μm	10	10	8	2
" Long.	μm	25	-	40	-
Dipole b_3	10^{-4}	6	-	22	-

Lengths of QD0, what if split into 2 or more magnets?

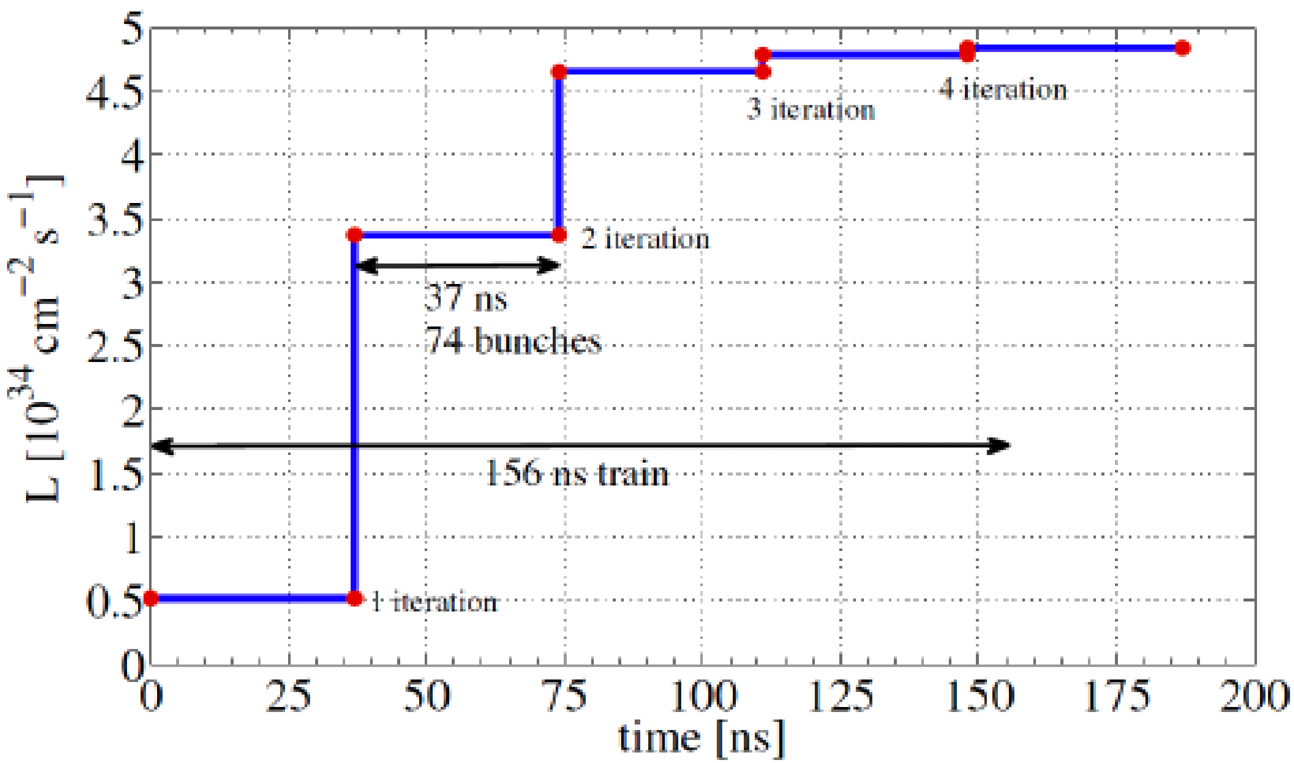
Present choice of L*

- For the CDR we concentrate of the SiD-like detector with L*=3.8 m
  - most of the work so far has been done on L*=3.5 m (close to 3.8 m) BDS, QD0, ...
  - L* = 3.8 m gives the higher luminosity (compared to 4.6 or even 6, resp 8 m)
- The L*=4.6 m for the ILD like detector is not discarded, however.
- An alternative solution with QD0 installed in the tunnel will be considered as well.
  The expected L* will be **around L* = 6 m**, assuming we shorten the end-caps.
  This will ease the stabilisation, but has an impact on the luminosity and
  on the pre-alignment tolerance.
- Latest studies have lead to a situation where the negative impact, in paticular
  on the pre-alignment has been reduced significantly

→ **L* = 6 m has become a plausible fallback solution**

Luminosity performance with IP intra-train FB

Simulation time structure:
Example applying a single random seed of GM C



- For the simulations we have considered a total feedback latency of 37 ns. The systems performs approximately a correction every 74 bunches (4 iterations per train)

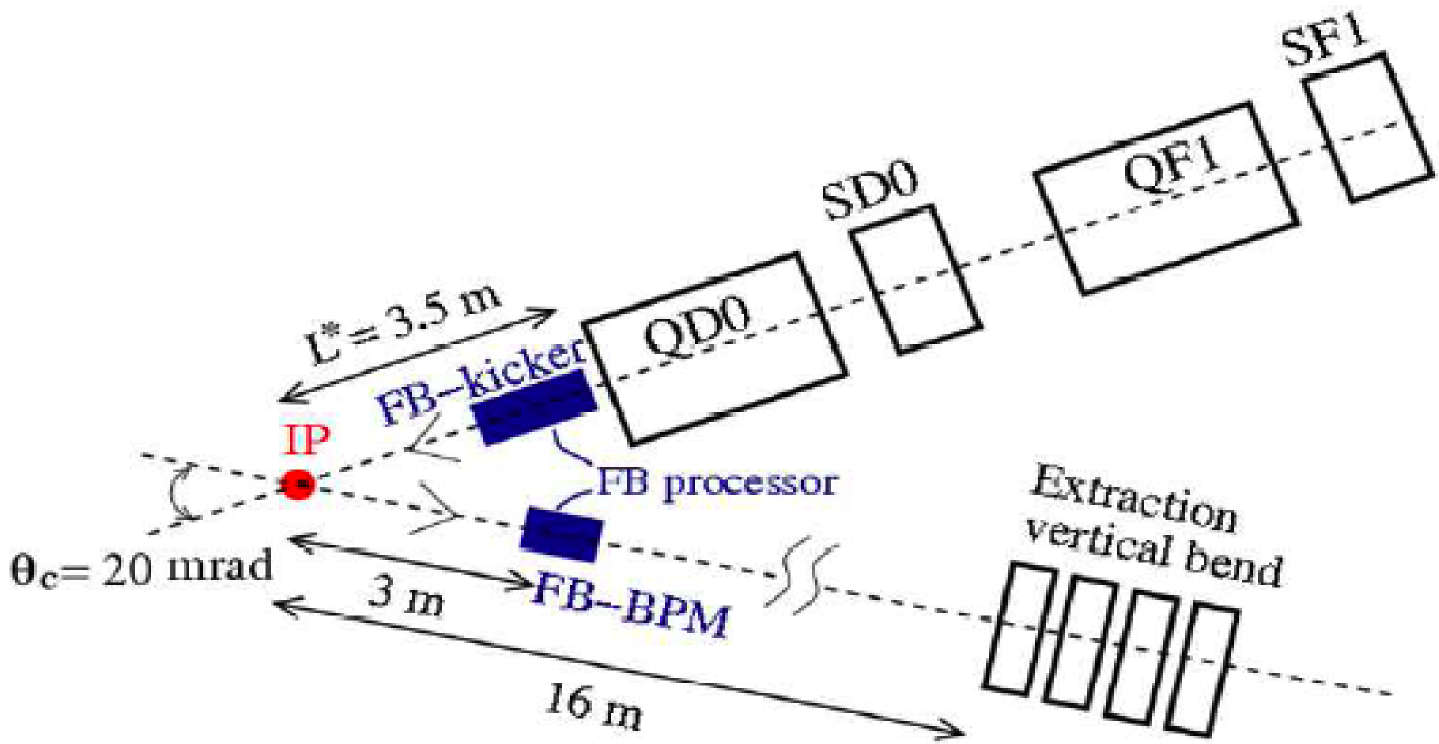
CLIC IR

IP-FB BPM and kicker positions

PRELIMINARY

The choice of the position of the IP-FB elements is a compromise between:

- Reduction of latency
- Avoiding possible degradation of the BPM response due to particle background/backsplash and possible damage of electronics components



If FONT elements 3 m apart from IP, then beam time-of-flight = 10 ns

CLIC IP-FB system latency issues

PRELIMINARY

- Irreducible latency:
  - Time-of-flight from IP to BPM: t_{pf}
  - Time-of-flight from kicker to IP: t_{kf}
- Reducible latency:
  - BPM signal processing: t_p
  - Response time of the kicker: t_k
  - Transport time of the signal BPM-kicker: t_s

Study and test of an analogue FB system for ‘warm’ linear colliders: FONT3:

P. Burrows et al. “PERFORMANCE OF THE FONT3 FAST ANALOGUE INTRA-TRAIN BEAM-BASED FEEDBACK SYSTEM AT ATF”, Proc. of PAC05.

Comparison of tentative latency times for a possible CLIC IP-FB system with the latency times of FONT3

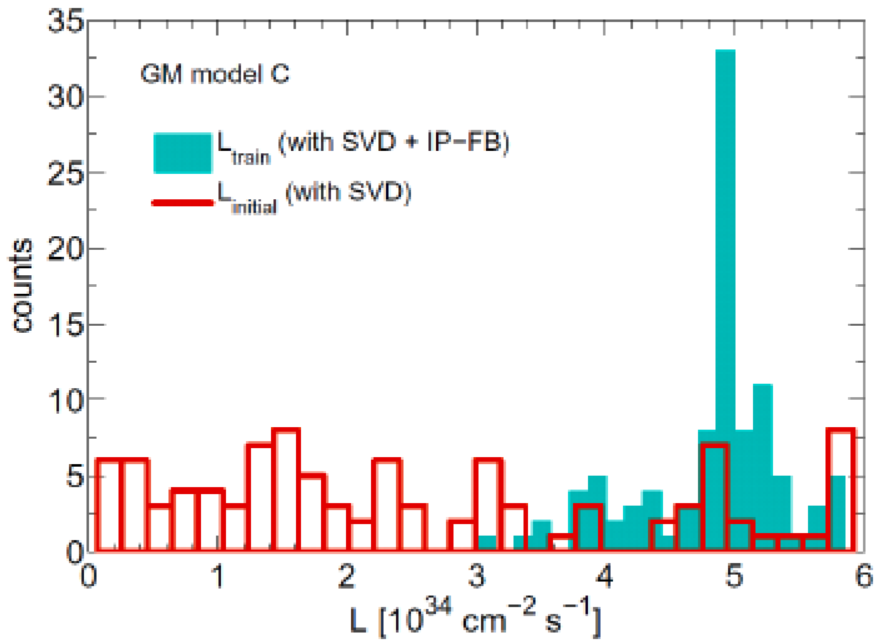
Source of delay	Latency FONT3 [ns]	Latency CLIC [ns]
$t_{pf} + t_{kf}$	4	20
t_s	6	7
t_p	5	5
t_k	5	5
Total t_{FB}	20	37

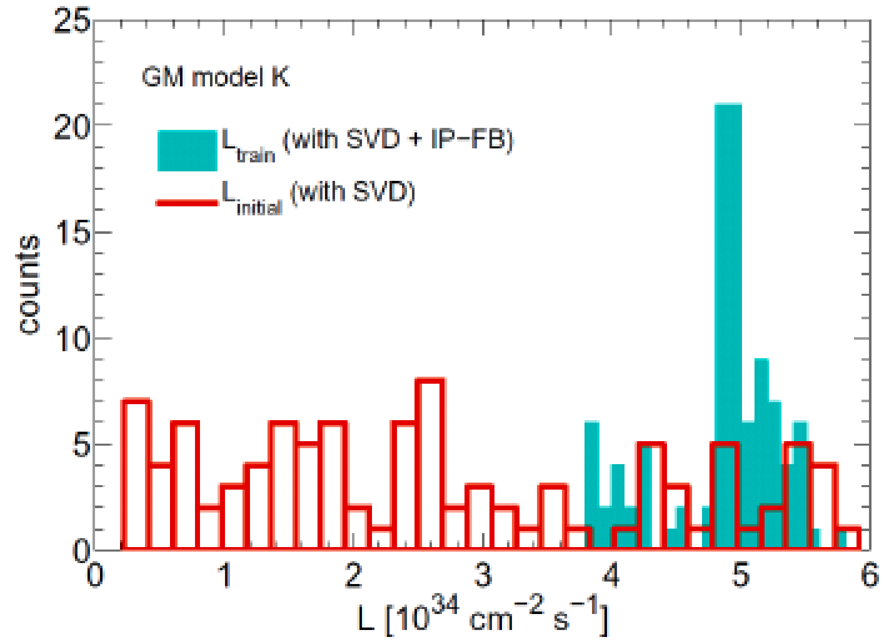
EXAMPLE:

Luminosity result with SVD orbit correction+ IP-FB

Different scenarios of ground motion

- If we consider:
  - GM (100 random seed simulation) +
  - orbit correction in the BDS (SVD) using the available BPMs (resolution 100 nm) and dipole correctors in the BDS +
  - IP-FB





Model C:

- SVD orbit correction: mean $\langle L/L_0 \rangle_{train}$=41.1%
- SVD orbit + IP-FB: mean $\langle L/L_0 \rangle_{train}$=77.51%

Model K:

- SVD orbit correction: mean $\langle L/L_0 \rangle_{train}$=42.63%
- SVD orbit + IP-FB: mean $\langle L/L_0 \rangle_{train}$=77.84%

Outstanding issues

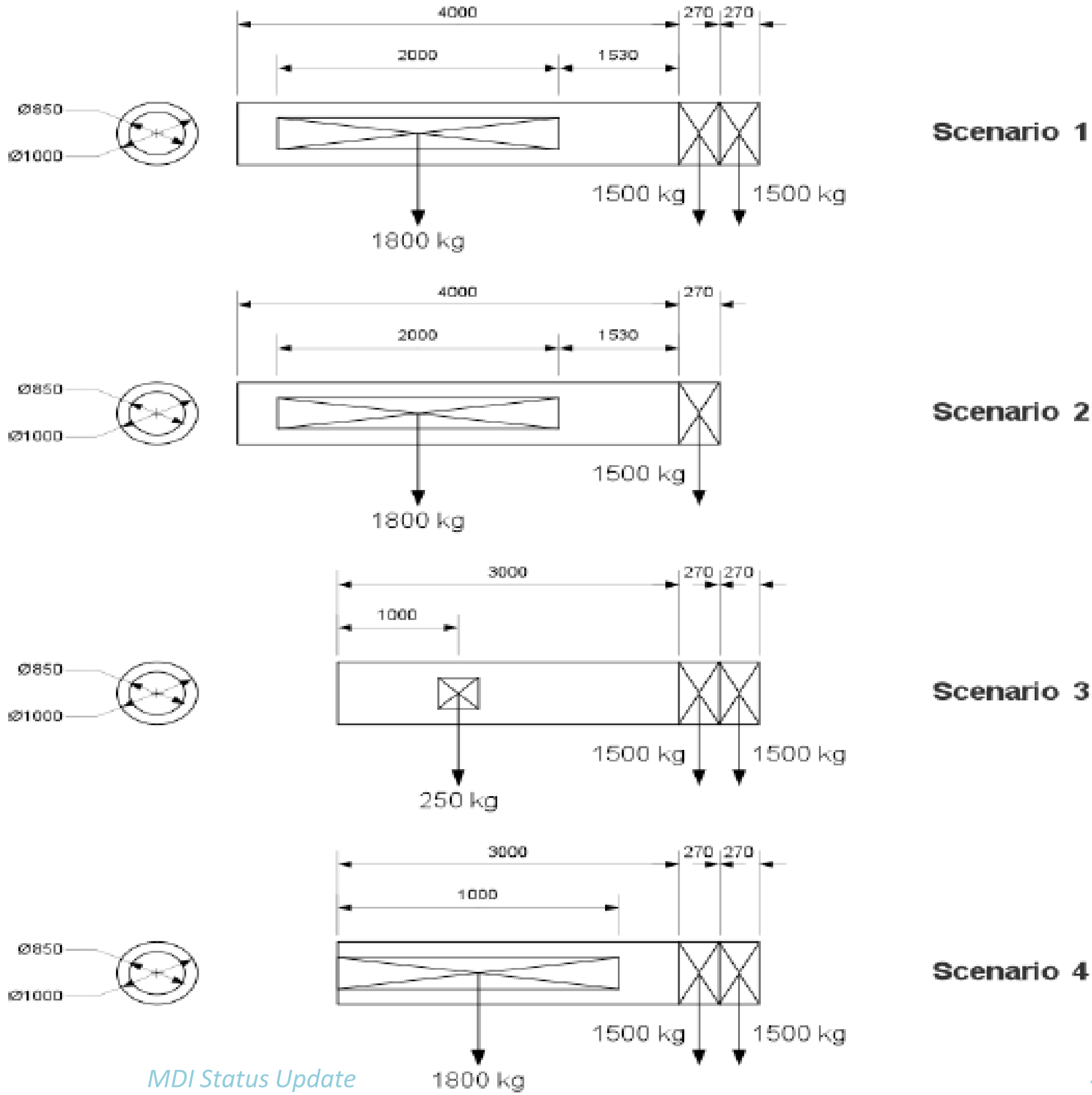
- Radiation environment for BPM electronics, feedback electronics, kicker amplifier:
  → detailed EM + neutron background simulations (Andre et al)
- Radiation tolerance, locations, shielding …
  → search for rad-hard components (and/or R&D)
- EM interference:
  Pickup on BPM or kicker
  Broadcast RF (eg. to vertex detector!)
  Ground loops

Overall integrated simulations of luminosity stability

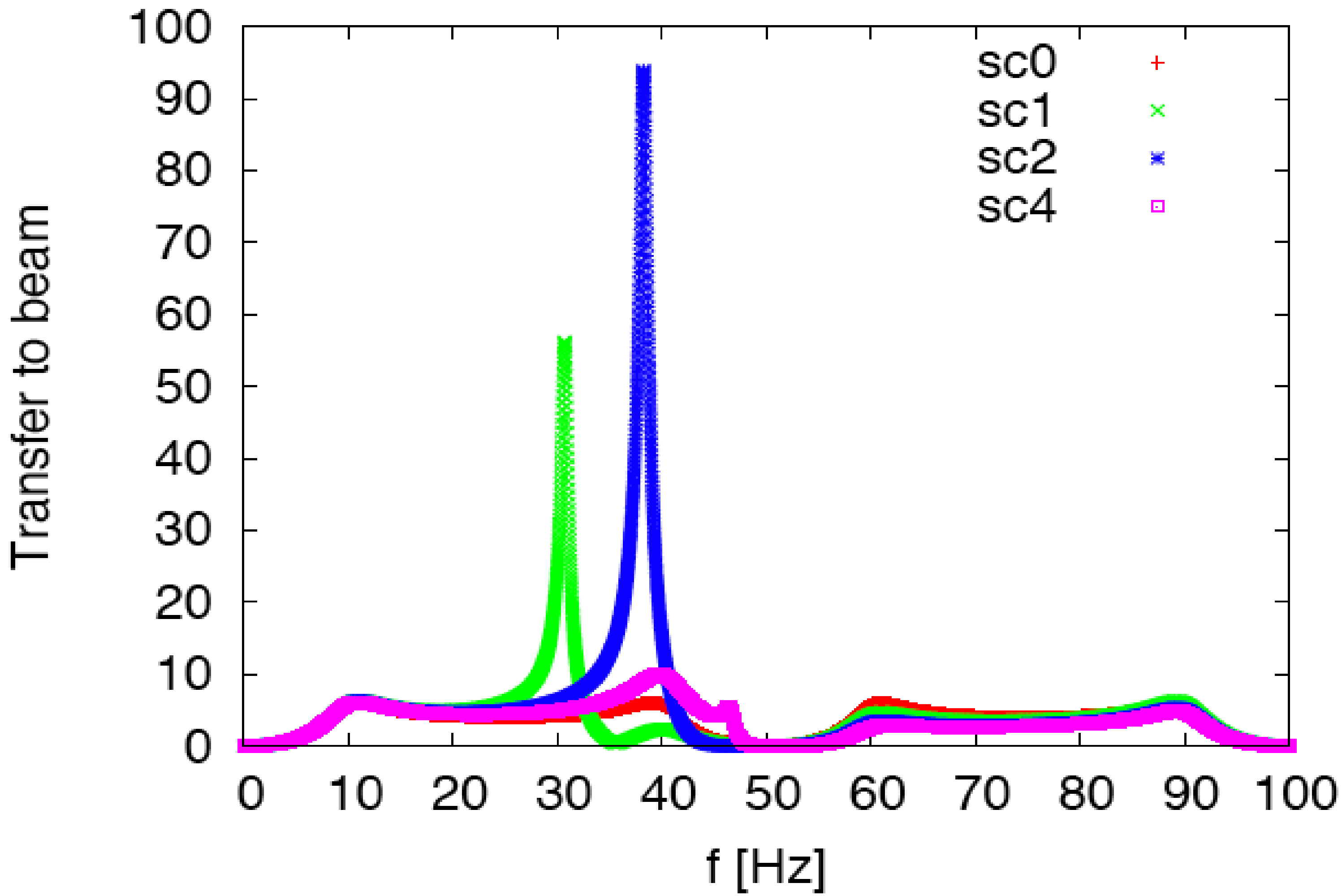
- The overall strategy of mechanical isolation and stabilisation combined with a number of beam-based feedbacks and feed-forwards, both in the linac, BDS and final focus region must be validated by an **integrated simulation.**
- This simulation is done by Daniel Schulte with in put from all parties concerned.
  The MDI input concerns the QD0 magnet vibration modes, the support structures, the pre-isolation system ,the pre-alignment system, QD0 stabilisation and IP feedback.
- Depending on the performance, the feedback controller must be programmed.
- First results of such a simulation, based on preliminary and approximate inputs, was presented by Daniel in the January MDI meeting. The results (see next slide) look promising.
- Now an effort is being organised by Hermann to get more up-to-date inputs for the simulation, hopefully in time for the CDR. MDI will try to review its inputs for this.

Contilever Designs

- Designs and transfer functions from Hubert Gerwig, Alain Herve and Fernando Duarte Ramos



Inclusion of Cantilever

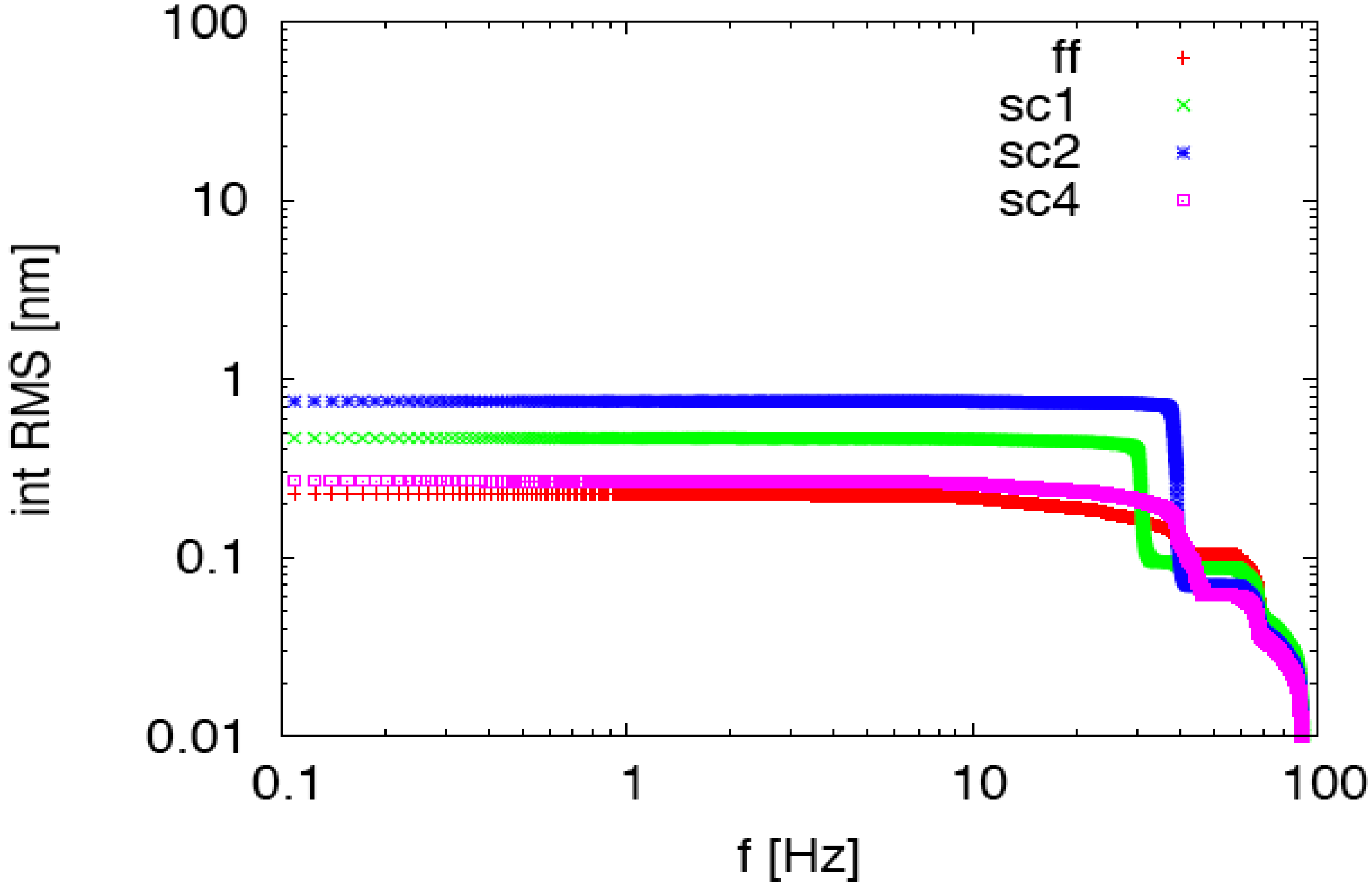


- Transfer function of single quadrupole motion in beam-beam offset, assuming beam-beam feedback and cantilever

Daniel Schulte, Jan.2010

With preliminary assumptions
Presented in January 2010

Inclusion of Cantilever



- Combination of ground motion, mechanical stabilisation, beam feed-forward (simplified), beam-beam feedback and cantilever is shown

20

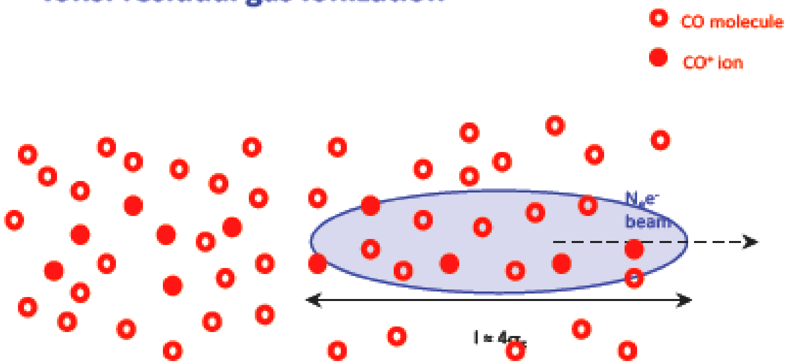
G.Rumolo, March 2010

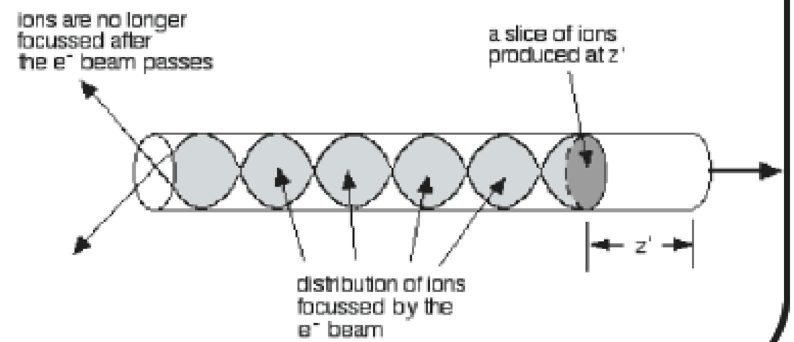
Vacuum requirements

Brief reminder on ion instabilities....

The ions produced by gas ionization can be focused by the electric field of the following bunches and they accumulate in the vicinity of the beam (trapping condition)

Ions: residual gas ionization

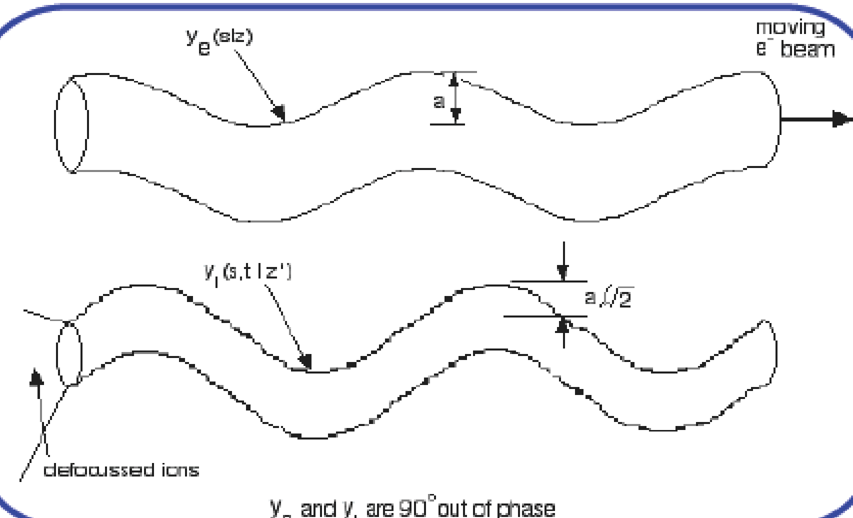




The ion cloud can affect the motion of the bunches

1) Tune shift along the bunch train
2) An unstable ion-electron coupled motion can be excited

Two-stream instability

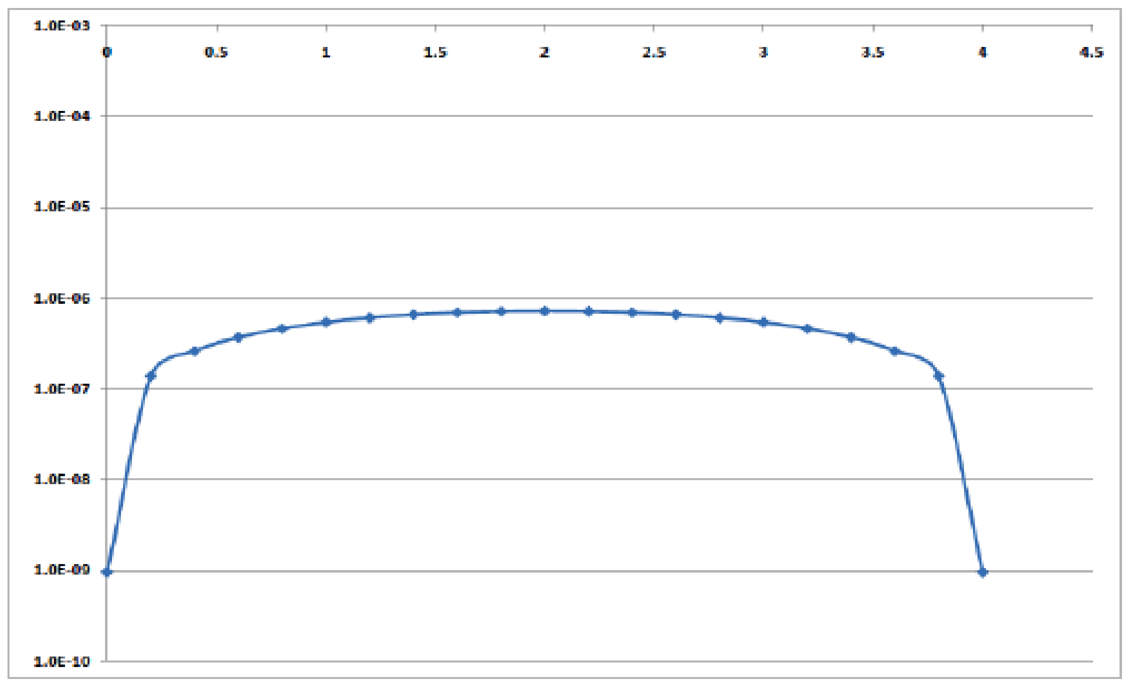


VACUUM: CONCLUSIONS AND OUTLOOK

- It has been verified with FASTION simulations that the vacuum specification of the CLIC-BDS is 10nTorr (in terms of partial pressures of H_2O and CO), as was extrapolated from the ML simulations
- Assuming 10 nTorr as base pressure along the BDS, coherent motion can appear if the pressure is degraded above 10^4 nTorr over the last 400m
- Assuming 10 nTorr as base pressure along the BDS, a pressure of 10^5 nTorr is not enough to excite a coherent instability, if only present over the last 20m of BDS
- All the above study only sets the limits above which **coherent motion** appears as an effect of the interaction beam-ions
  - ⇒ **No incoherent effects** have been carefully looked into
  - ⇒ **Emittance growth** could still be a problem for very large values of pressure, even over short distances
  - ⇒ All incoherent effects could be in principle studied via numerical simulation, but a full sensitivity study to the numerical parameters is necessary (which can require very time consuming checks)

Unbaked Pressure Profile in QD0

- Static pressures
  - Average 4.8x10^{-7} mbar [~3.6x10^{2} nTorr]
  - Peak 8.1x10^{-7} mbar [~6x10^{2} nTorr]
  - Achievable pressure is dominated by the small conductance of the tube and the outgassing rate
- Dynamic pressure components
  - Additional gas load due to surface bombardment by ions, electrons and photons will increase these static pressures
  - Some data starting to arrive from A.Sailer, but calculations are time-consuming
  - Beryllium in the experimental chamber has a high secondary electron yield and may need special coating

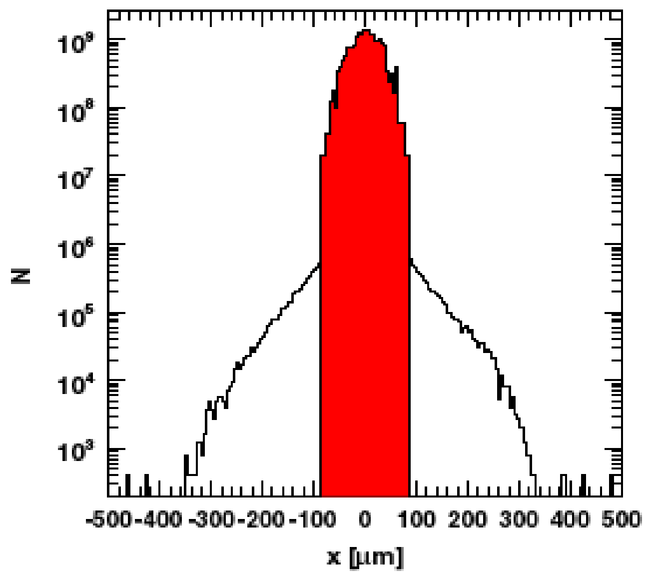


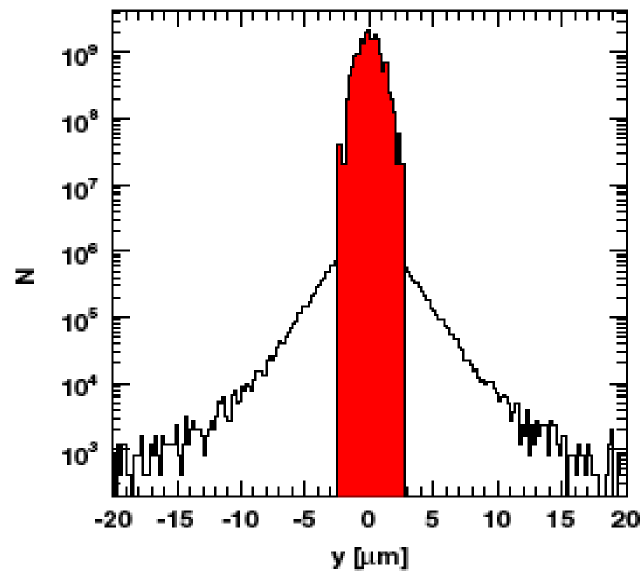
Static partial pressure of H_2O [mbar] along the QD0 beam tube [m]

A potential problem for CLIC: Muons from beam halo

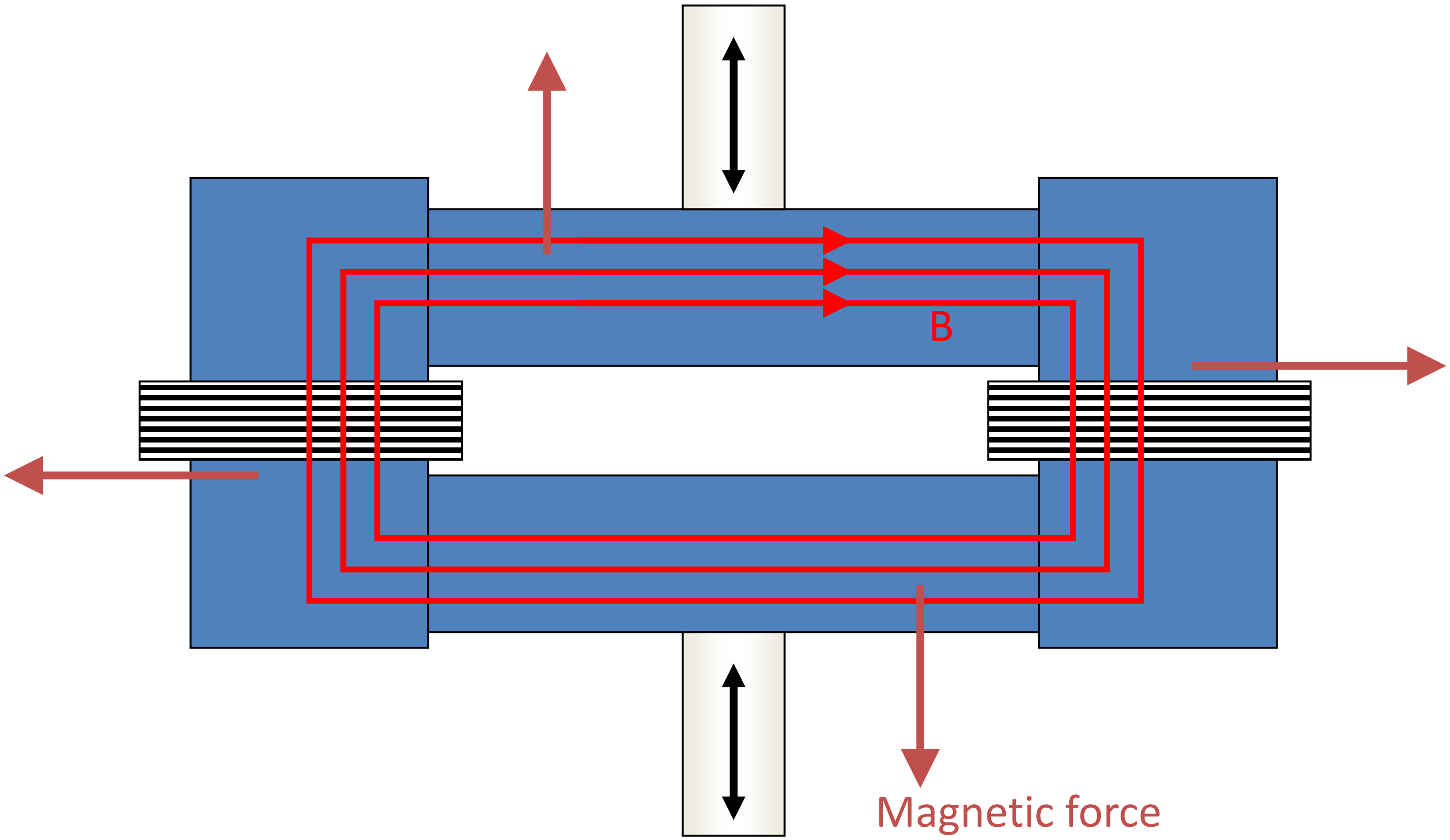
Beam tails are scraped away by a collimation system in the BDS.
Below we show simulated profiles of the beam at the BDS entrance (core of beam in red)

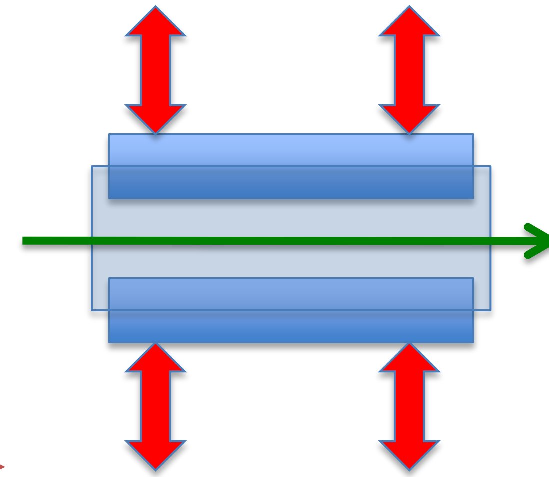
From I.Agapov et al, 2009, to be published





SCRAPERS
(Magnetic Collimators)

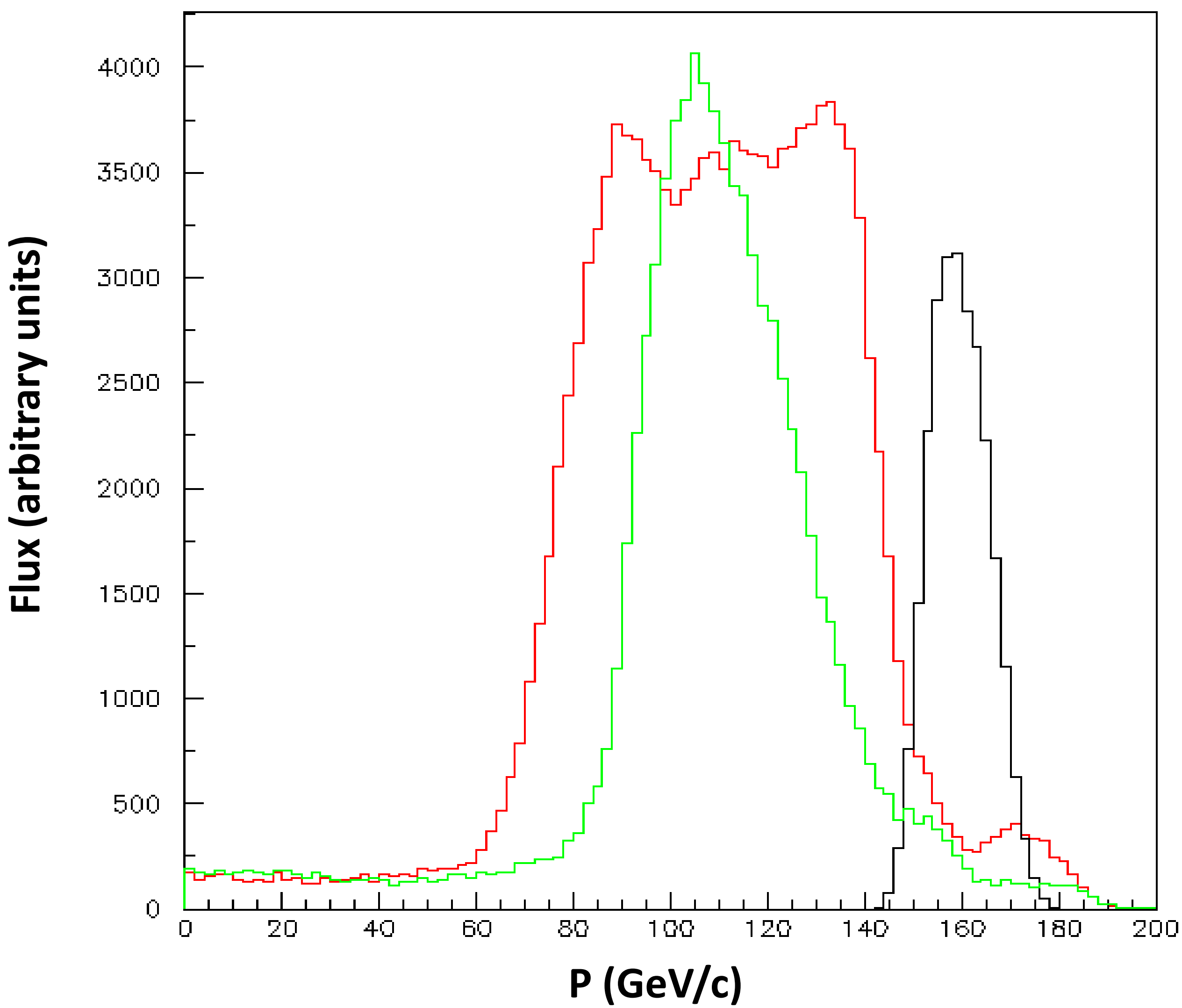




Have to get polarity right….

MIB = Magnetised Iron Block

The size of the Halo problem in M2 beam



Simulations based on the HALO program by C.Iselin (1974)

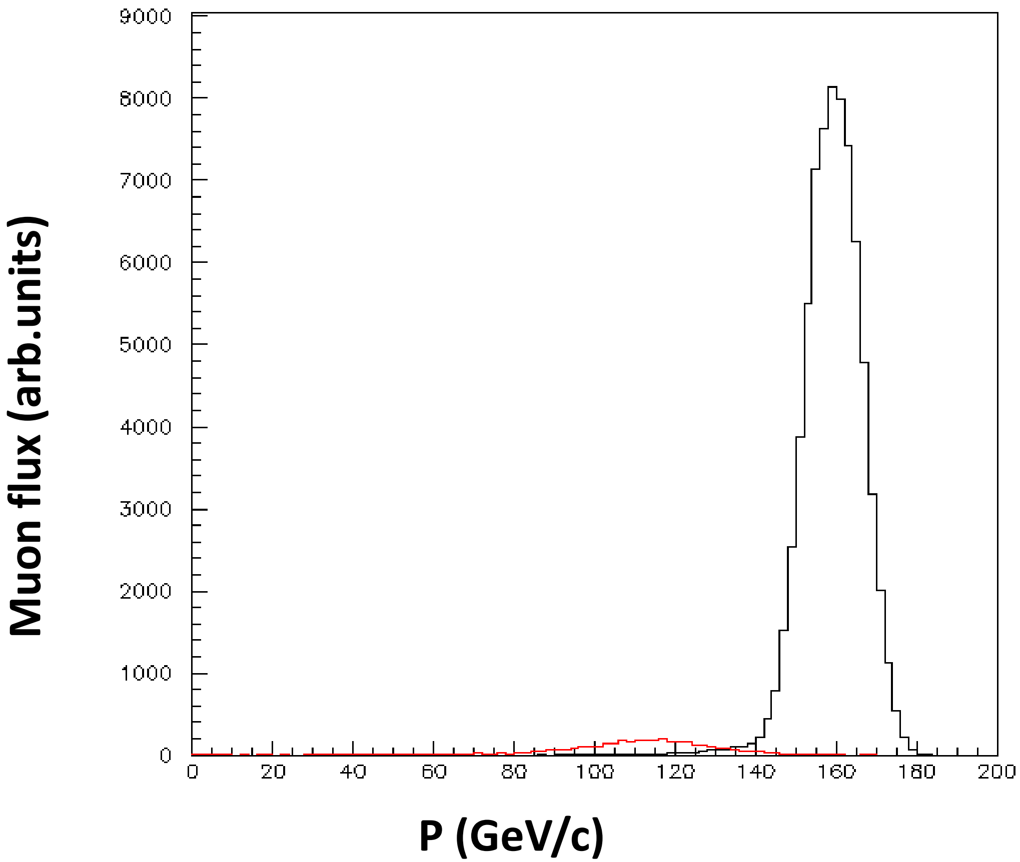
'Good' muons

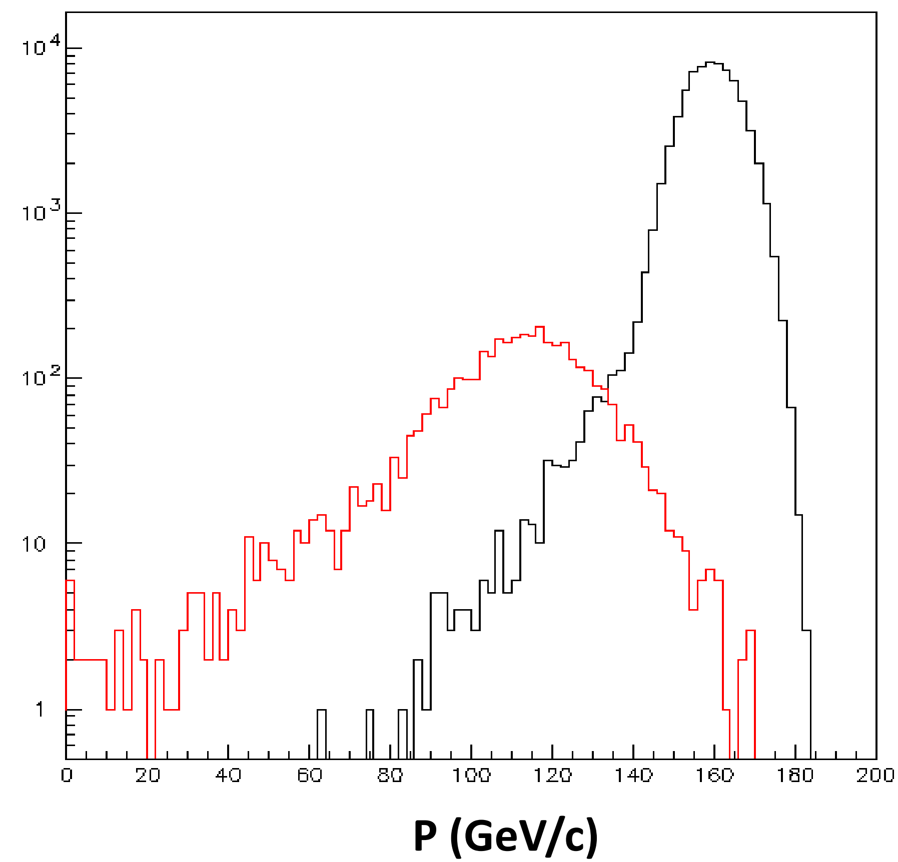
Halo after π absorber

Halo after μ momentum selection

Note: Halo / 'Good' μ ≈ 6

Muons vs Halo in M2





i.e. Halo (R=2 m) / Muons (R = 10 cm) ~ 5%,
i.e. Halo/Muons in same surface ~ 1.3 10^{-4}

Excellent agreement
With data!

Gain > factor 100

A.Gaddi, H.Gerwig, A.Hervé, N.Siegrist, F.Ramos

New ideas for cavern layout:

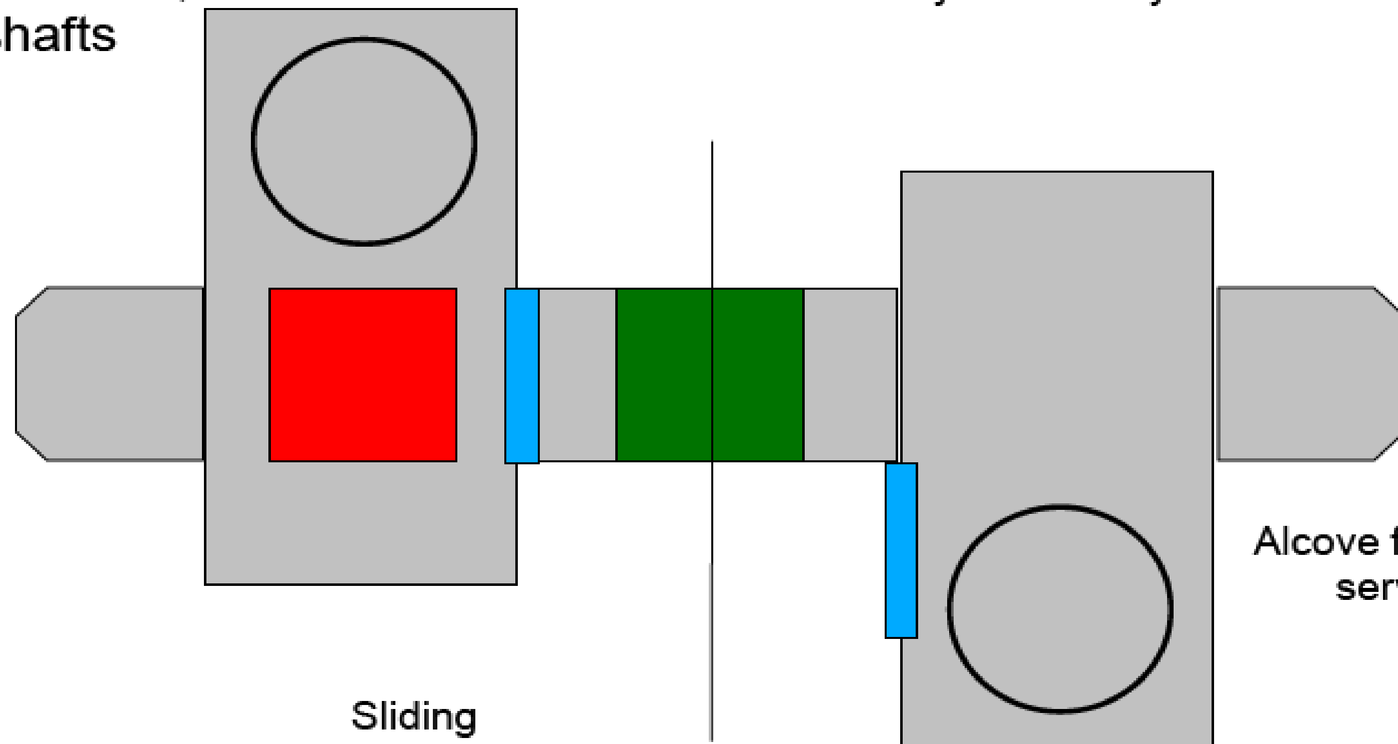
Introduction.

The push-pull scenario and the coexistence of two detectors in the same experimental area sets some specific requirements to the civil engineering and to the design of underground infrastructures.

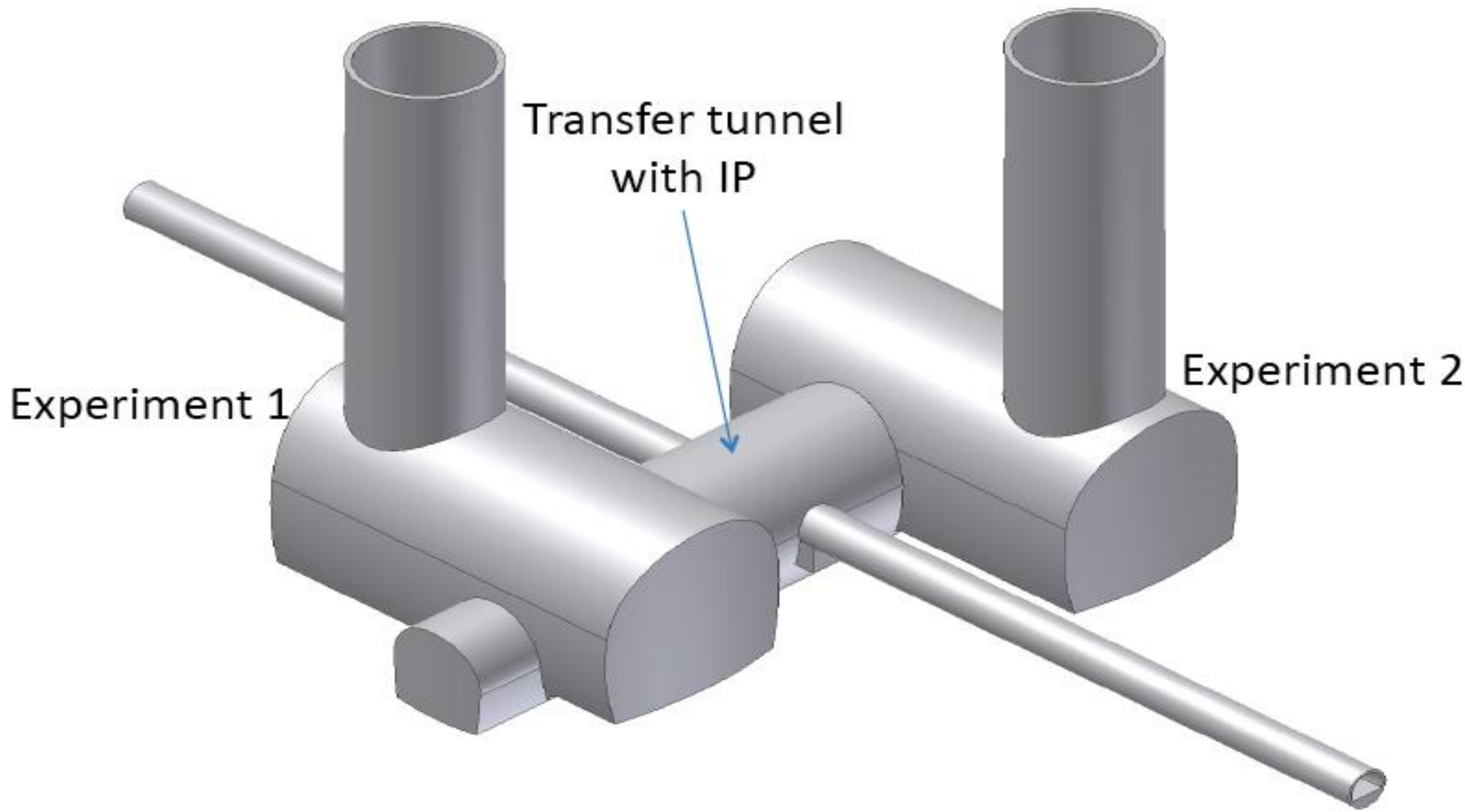
- ❑ The most basic one being a fair sharing of the underground facilities between the two detectors → symmetric layout.
- ❑ Then the possibility to move the detector form garage to beam in the fastest and safest way → detector platform, cable-chains.
- ❑ Third, to guarantee, by an appropriate design, that the personnel safety is always assured → shielding of beam-area.
- ❑ The detector assembly scenario plays a fundamental role in the design of the underground facilities → crane capacity, assembly space.
- ❑ Finally, contribute to reduce the noise injected to the machine final focus magnets → integrate a passive isolator at the interface between machine and detector.

UX Cavern optimization.

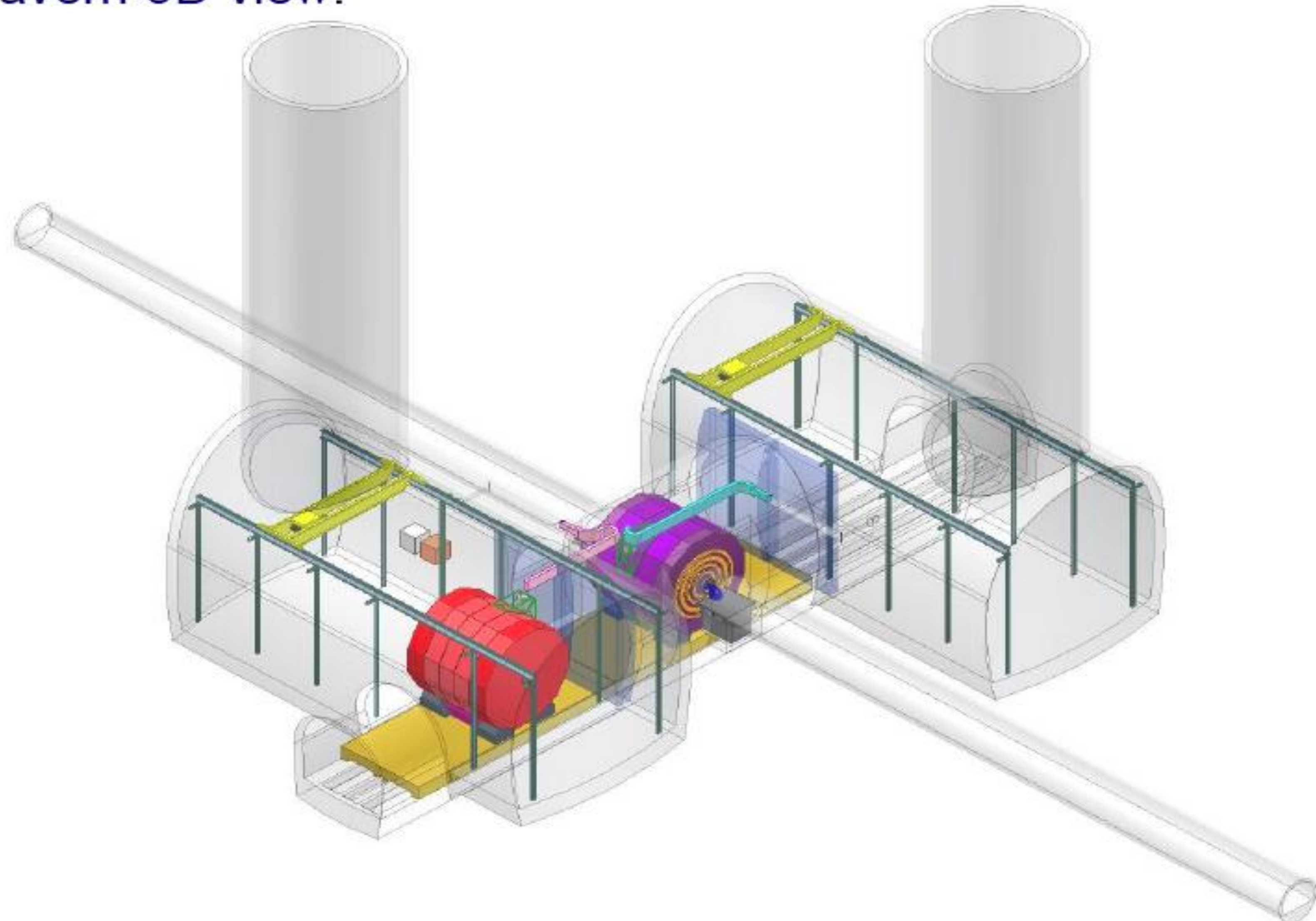
Cavern volume: 95,000 m^3
2 x Φ16m shafts



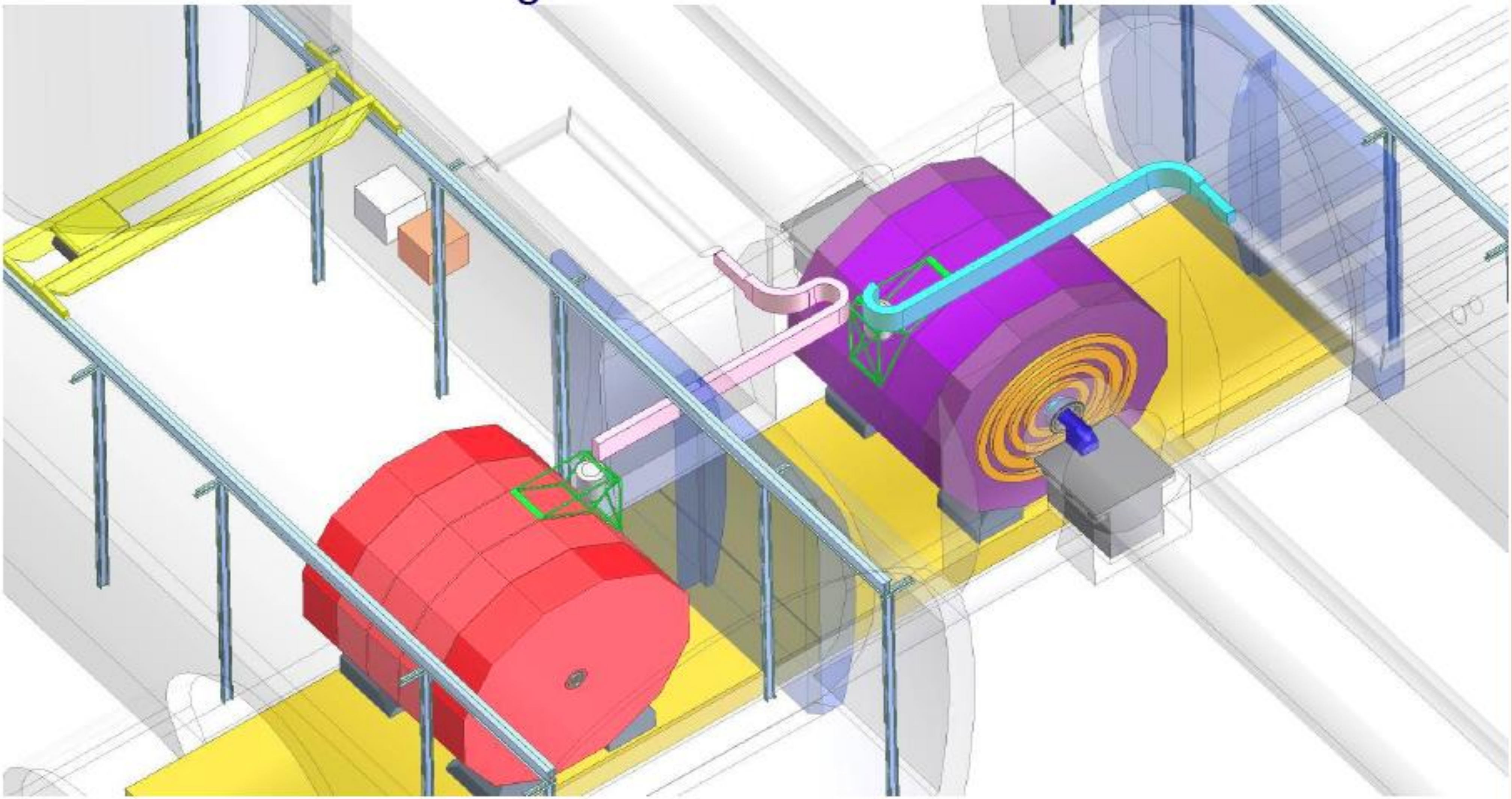
CLIC cavern



UX Cavern 3D view.



UX Cavern 3D view: magnet cable-chains & MDI pre-isolator



SUMMARY AND OUTLOOK

- Over the last year we have made significant progress in the design of the QD0 magnet and in its integration, including the infrastructure and concepts for alignment and stabilisation
- The next step is a full simulation of the expected performance of stabilisation combined with the other feedbacks, as shown but with the latest parameters
- A prototype (short) QD0 magnet will be constructed and allow tests in terms of field quality and mechanical behaviour.
  Also a small prototype of a pre-isolator will be tested soon.
- A MDI internal review has taken place on May 7th with 15 presentations.
  Slides are all available on Indico.
- Now we are preparing for writing the CDR chapter and estimating cost.
  Soon we have to start thinking about the TDR.