(Some) MDI Engineering Aspects

A. Hervé / ETH-Zürich
Together with ILC and CLIC MDI Groups

IWLC2010 – 22 Oct. 2010

Content of the talk

I will not try to cover all aspects of MDI, please refer to Wed. talks of the working group chairmen:

- Andrei Seryi (John Adams Institute) for ILC.
- Lau Gatignon (CERN) for CLIC

I will introduce:

- the main features of MDI for ILC,
- then look at CLIC, pointing out what is different and why,
- not forgetting at the end the challenges of the Push-Pull.

MDI at a LC is governed by

- A small L* (3.5 m) to maximize luminosity, and thus the last machine elements penetrate inside the detector.

- A small size of the beams (nm level), requiring extreme stability of the BDS.

- An active pre-alignment system is needed to correct for slow drifts

- A beam fast Feed Back system is also mandatory to correct movements at higher frequencies.

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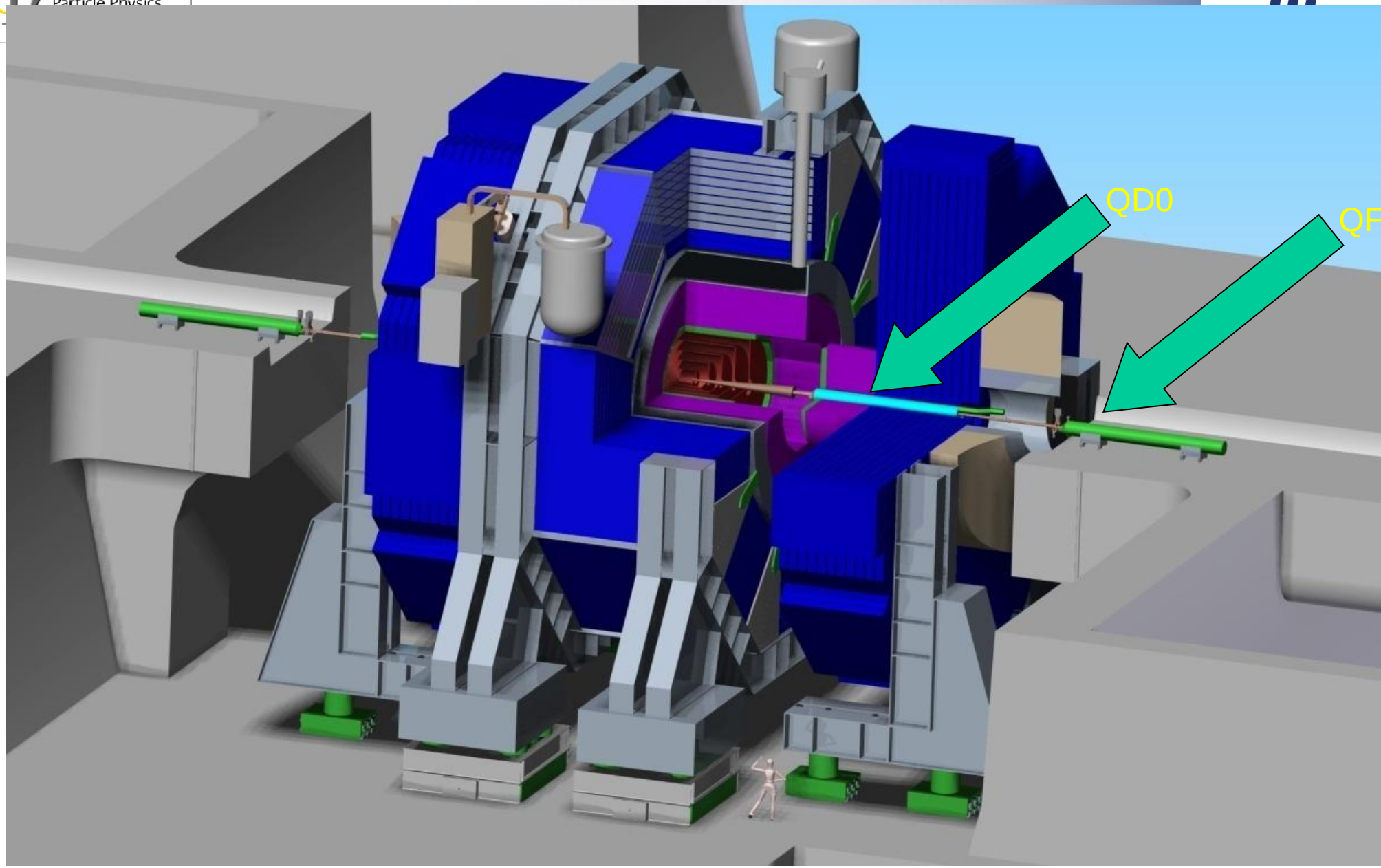
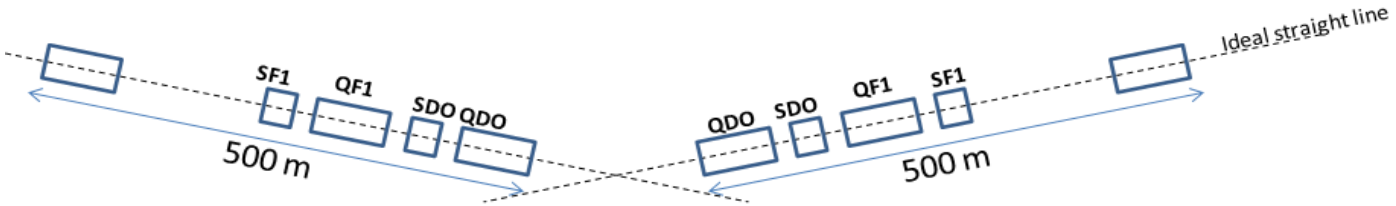
MDI @ ILC

SiD: QD0 penetrates inside the experiments



Pre-alignment system, example of CLIC
(H. Maynaud et al. /CERN)



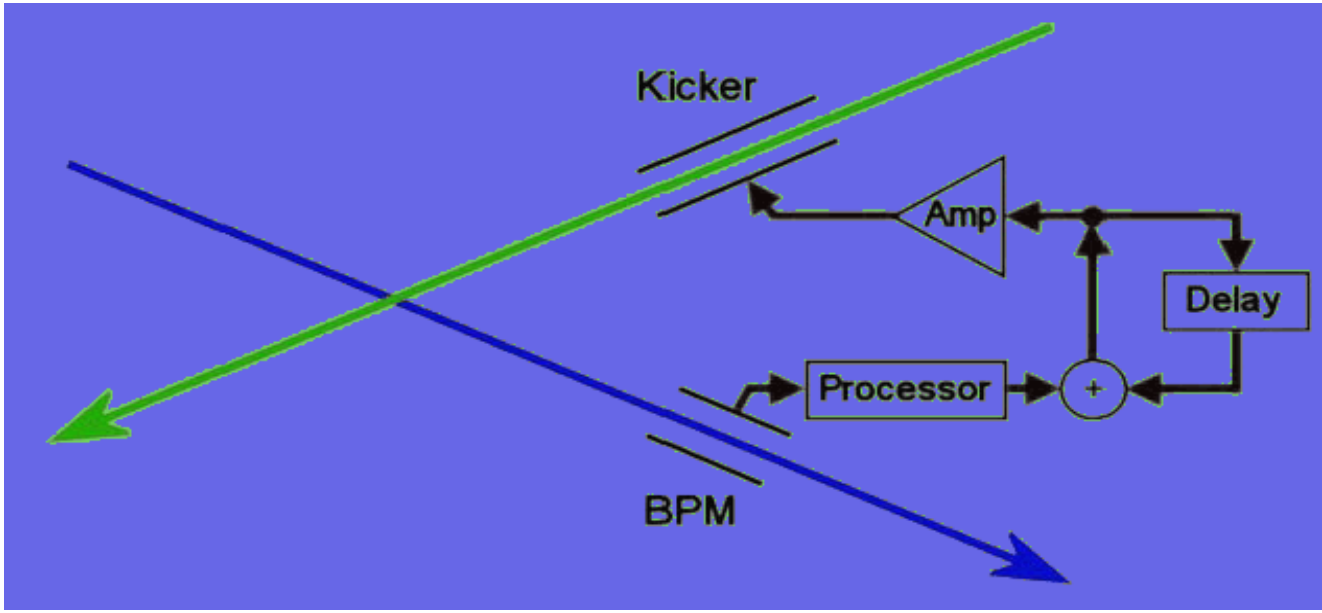
For the last 500 meters on each side of IP

- Position of the BDS elements and QD0 aligned at ± 10 μm rms w.r.t ideal straight line.

Intra-train feedback system

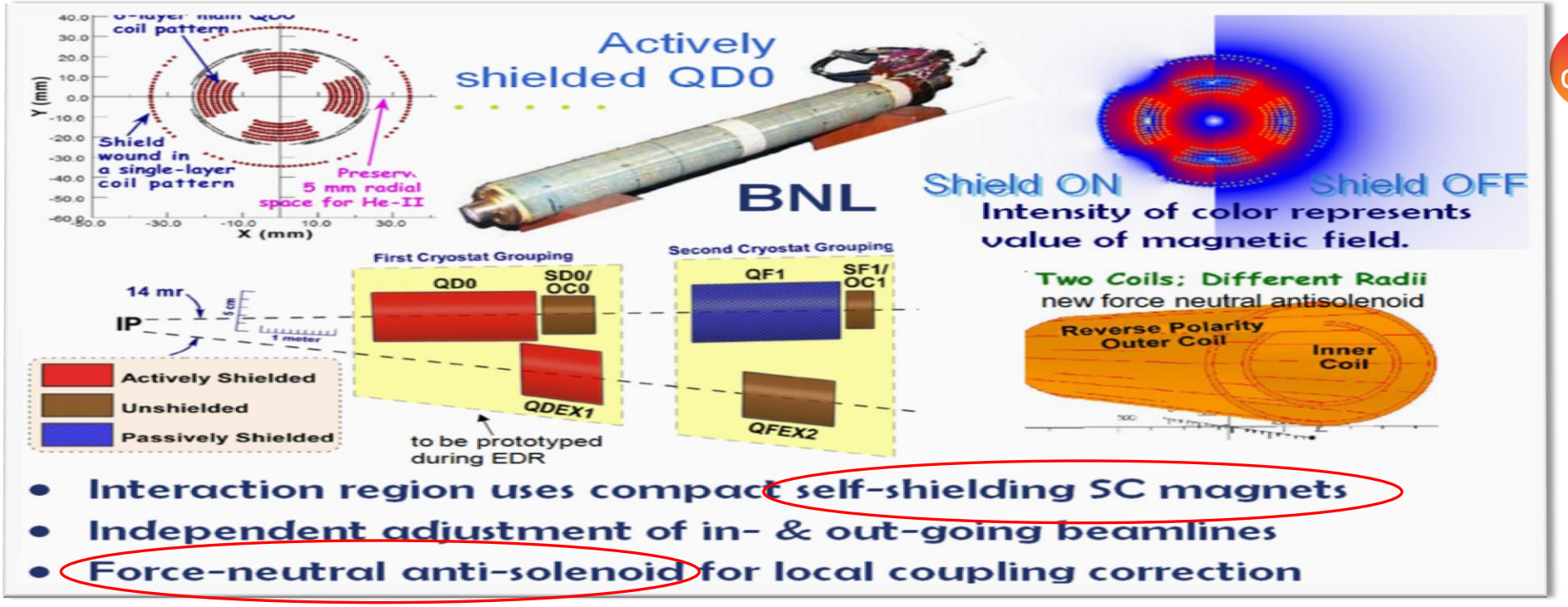
(JAI/Oxford, Valencia, CERN, DESY, KEK, SLAC)

- **Last line of defence against relative beam misalignment**
- **BPM measures vertical deviation of outgoing beam**
- **Fast kicker correct vertical position of beam incoming to IR**

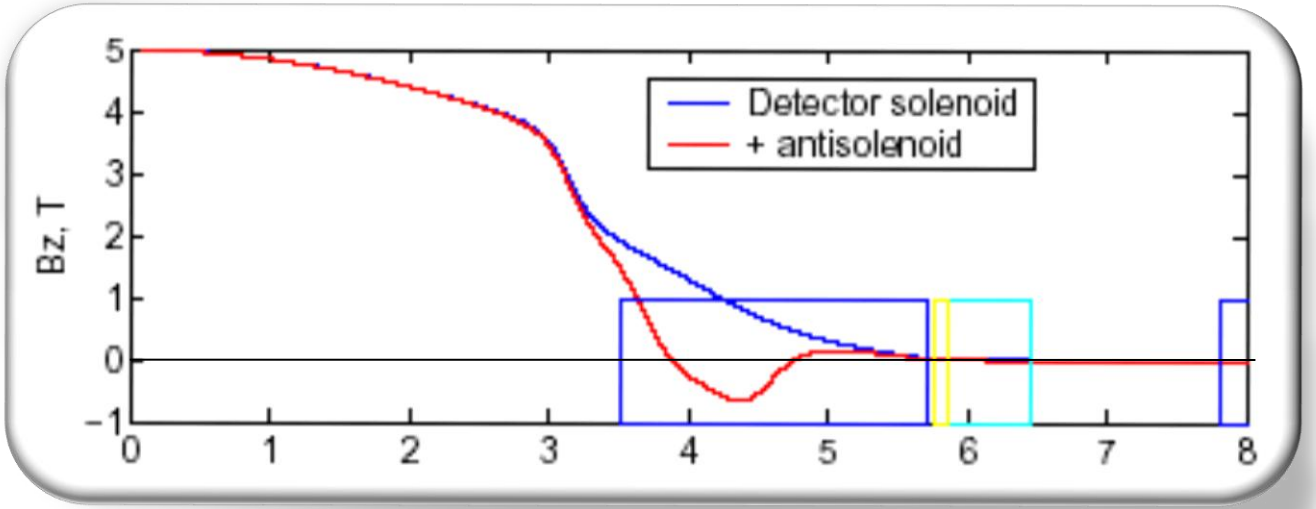


QD0 in ILC (Bret Parker / BNL)

Very involved coil package at 1.8 K

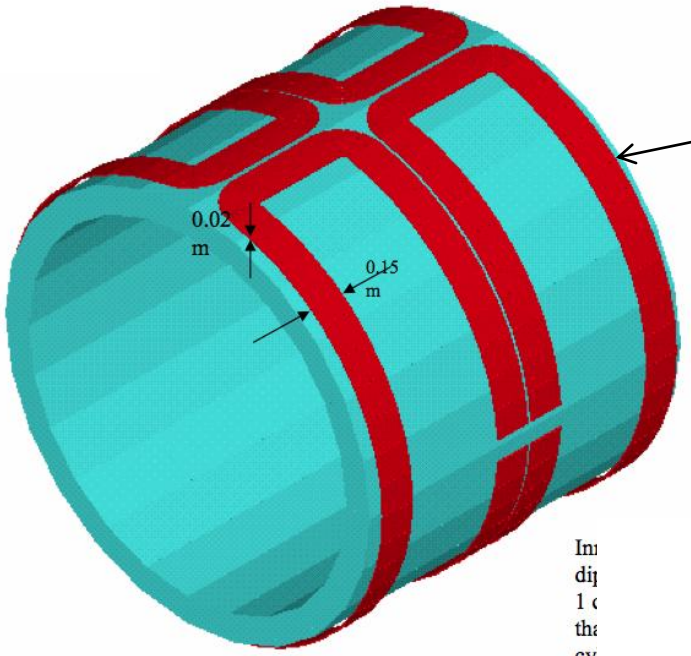


- Interaction region uses compact self-shielding SC magnets
- Independent adjustment of in- & out-going beamlines
- Force-neutral anti-solenoid for local coupling correction



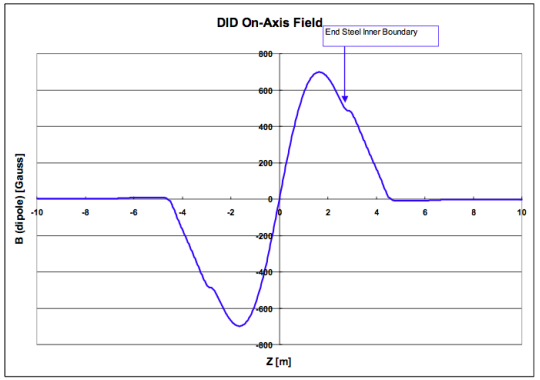
⇐ Field on axis is reduced and luminosity is recovered

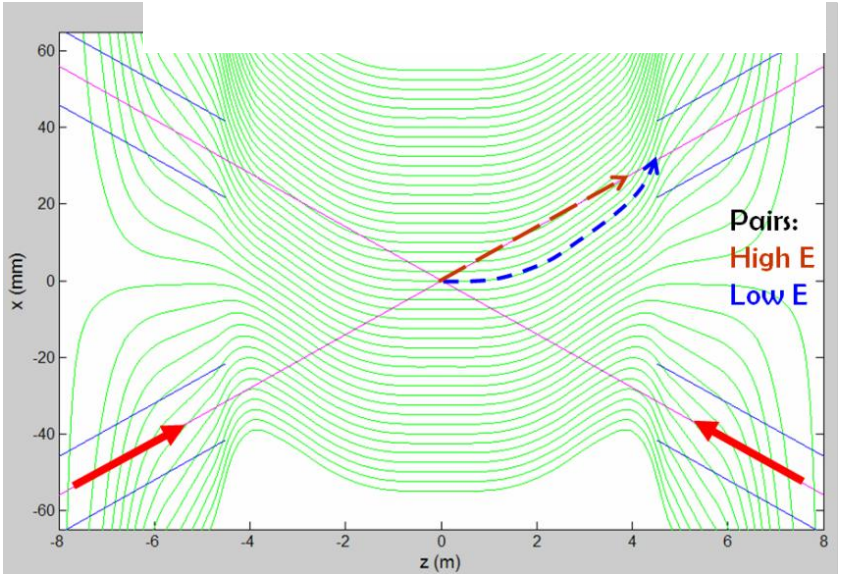
DiD and anti DiD at ILC
(Dipole Integrated Detector)
➽ not adopted at CLIC



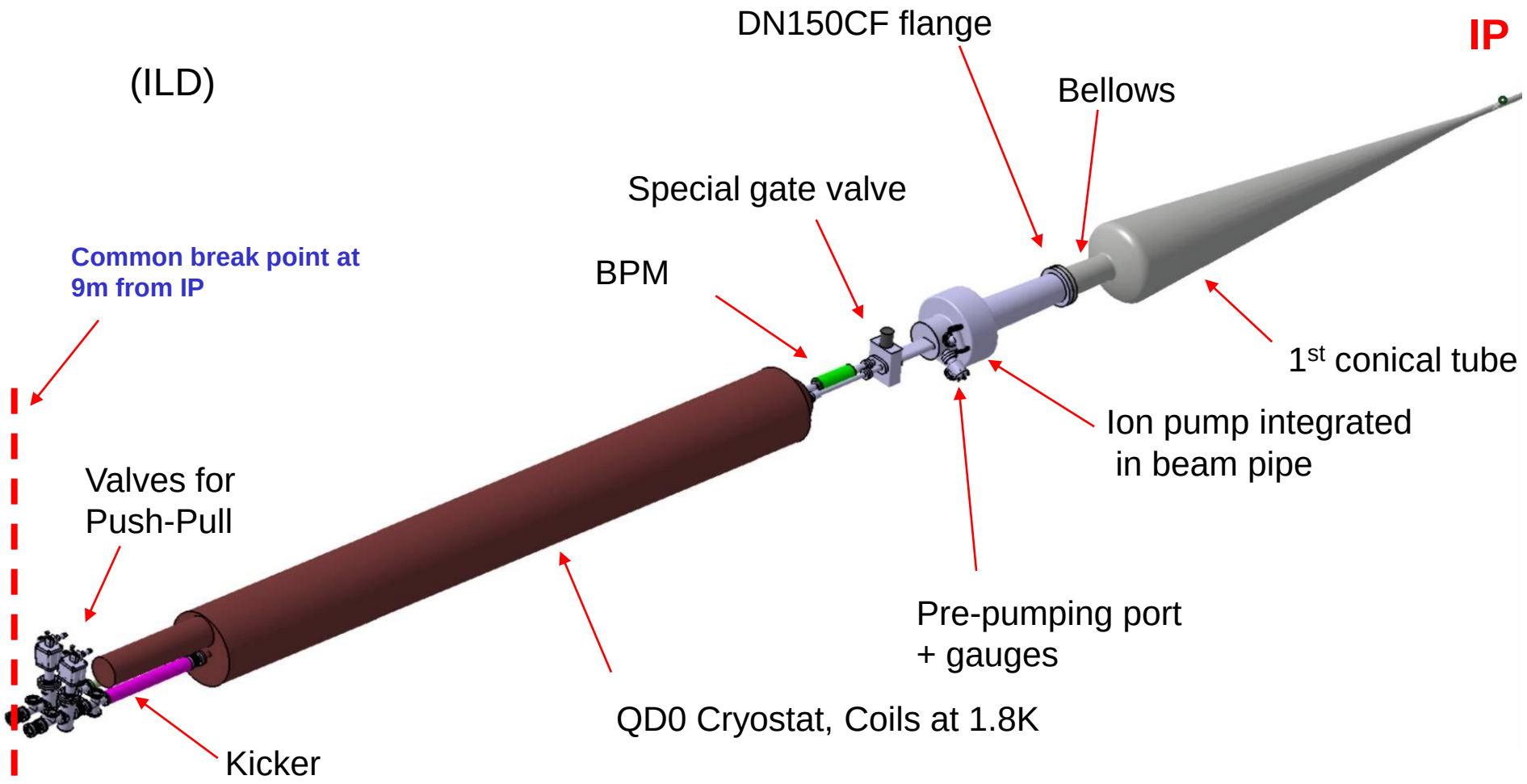
"Saddle-coil" dipole wrapped onto outer support cylinder of solenoid

DiD on-axis field

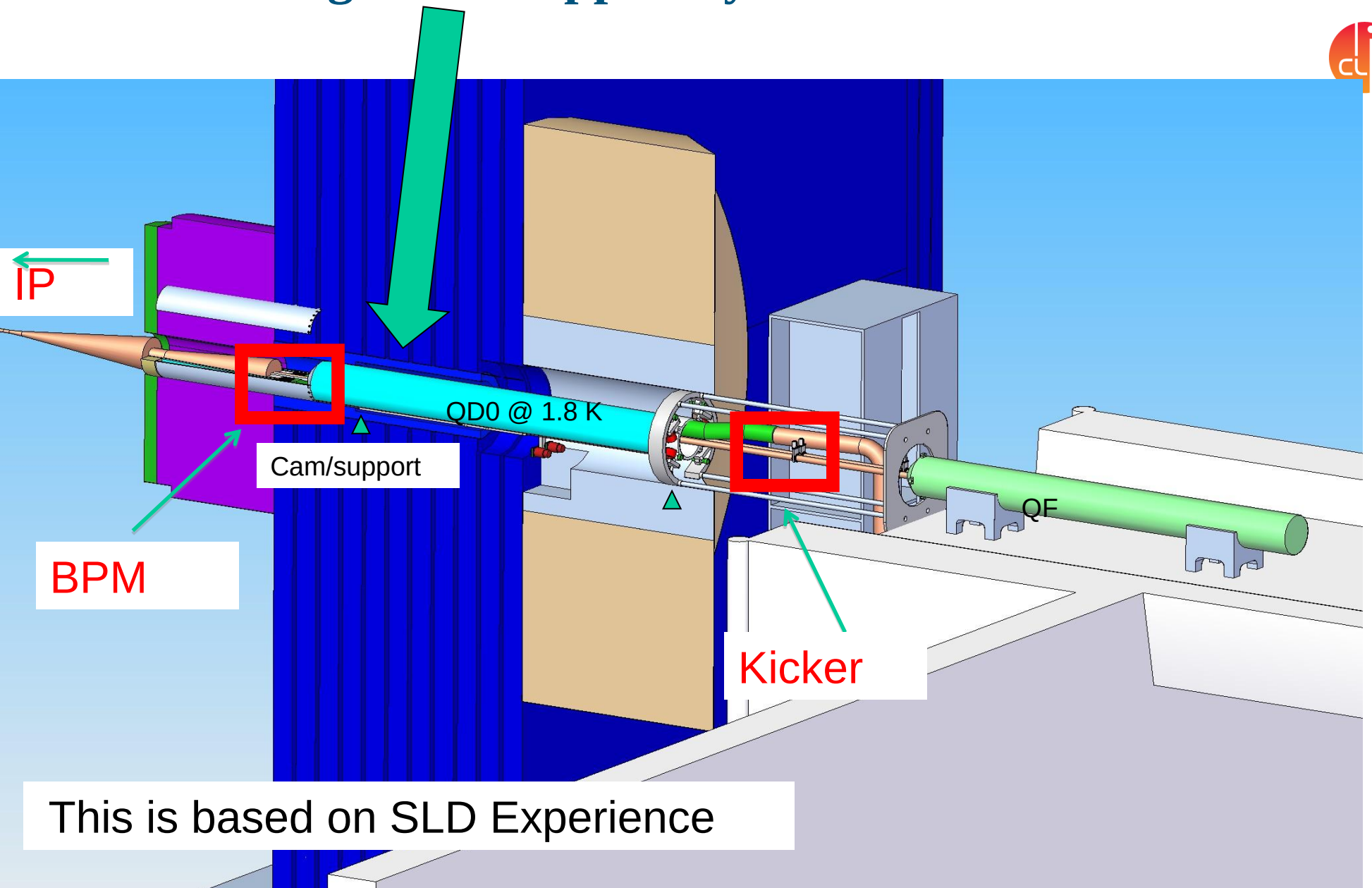




ILC typical beam line components



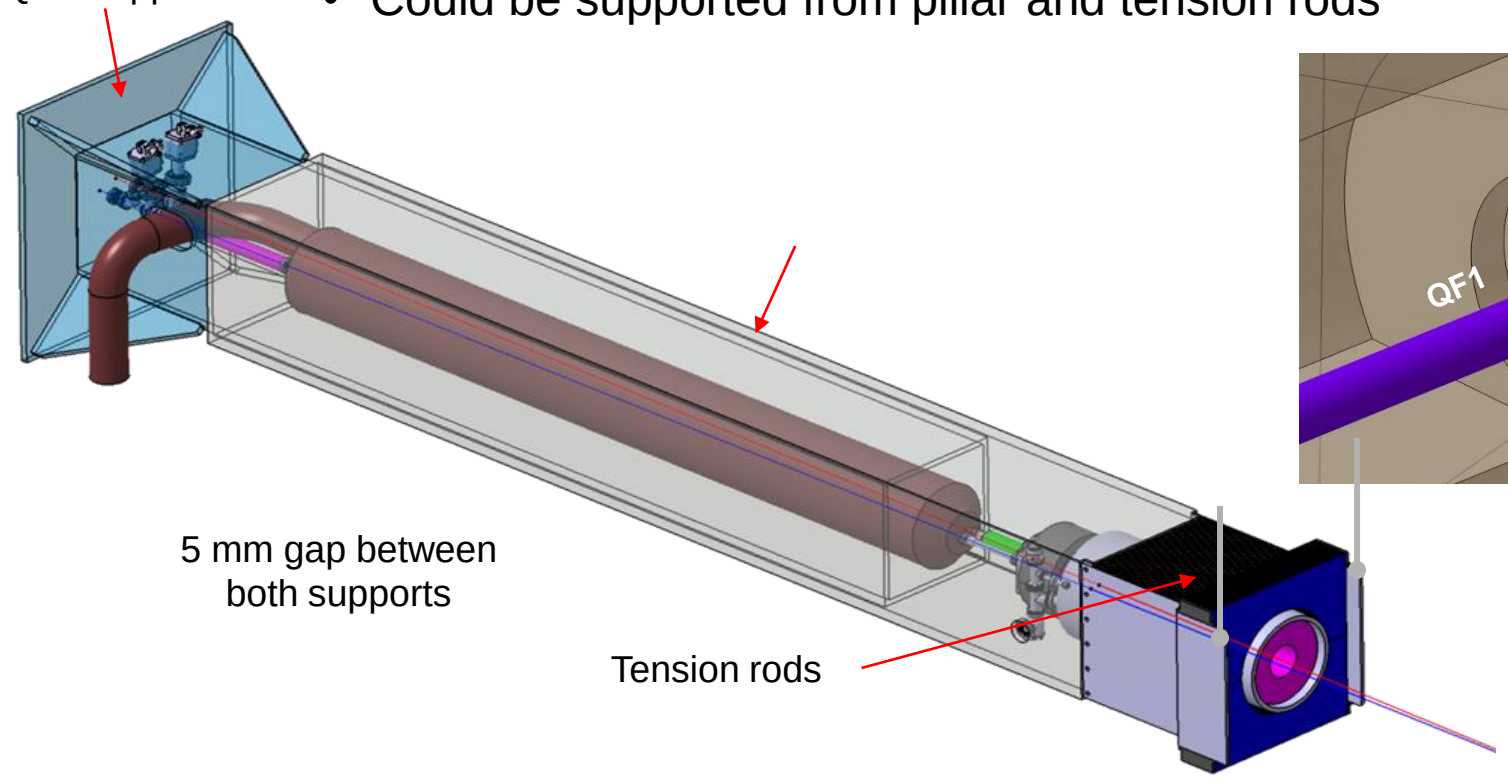
SiD supports the QD0 from the endcap door using a cam/support system

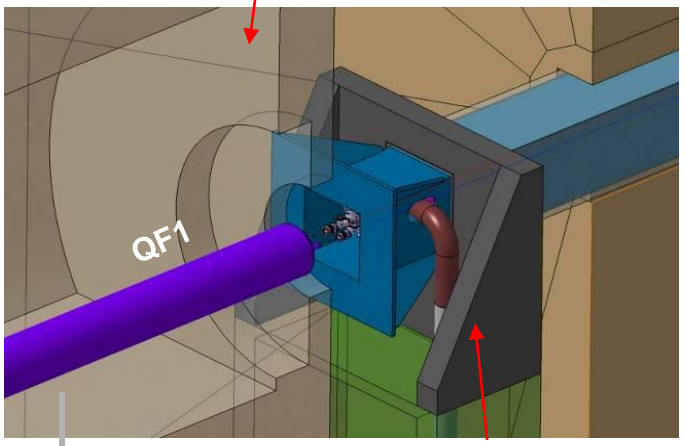


This is based on SLD Experience

ILD: QDO supported from the tunnel wall
(Matthieu Joré / LLR)

- Using 2 square tubes : (from an idea of Hiroshi Yamaoka at KEK, idea also used by CLIC detectors)
  - Internal QD0 support tube
    - Attached to machine tunnel
    - Good coherency with machine vibrations and high natural frequency
  - External FCals support tube
    - Could be supported from pillar and tension rods





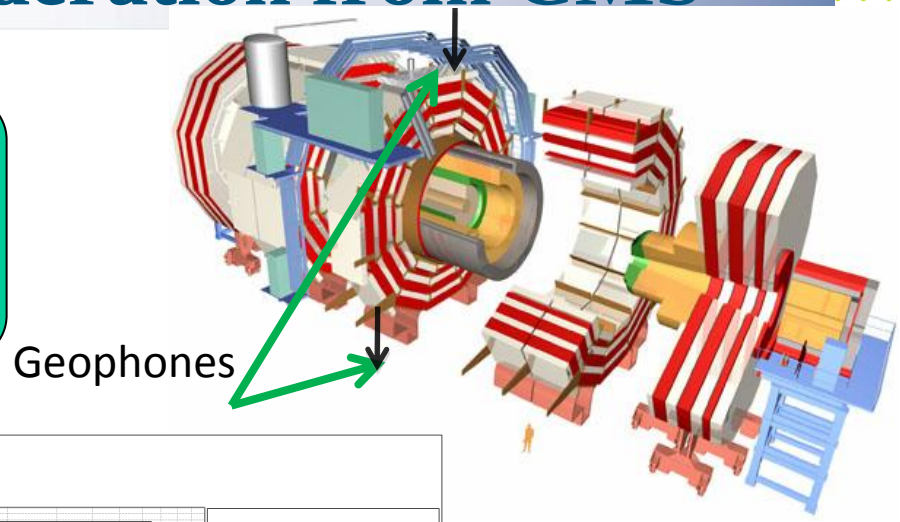
Vibration consideration for ILC and influence of beam Feed-Back system

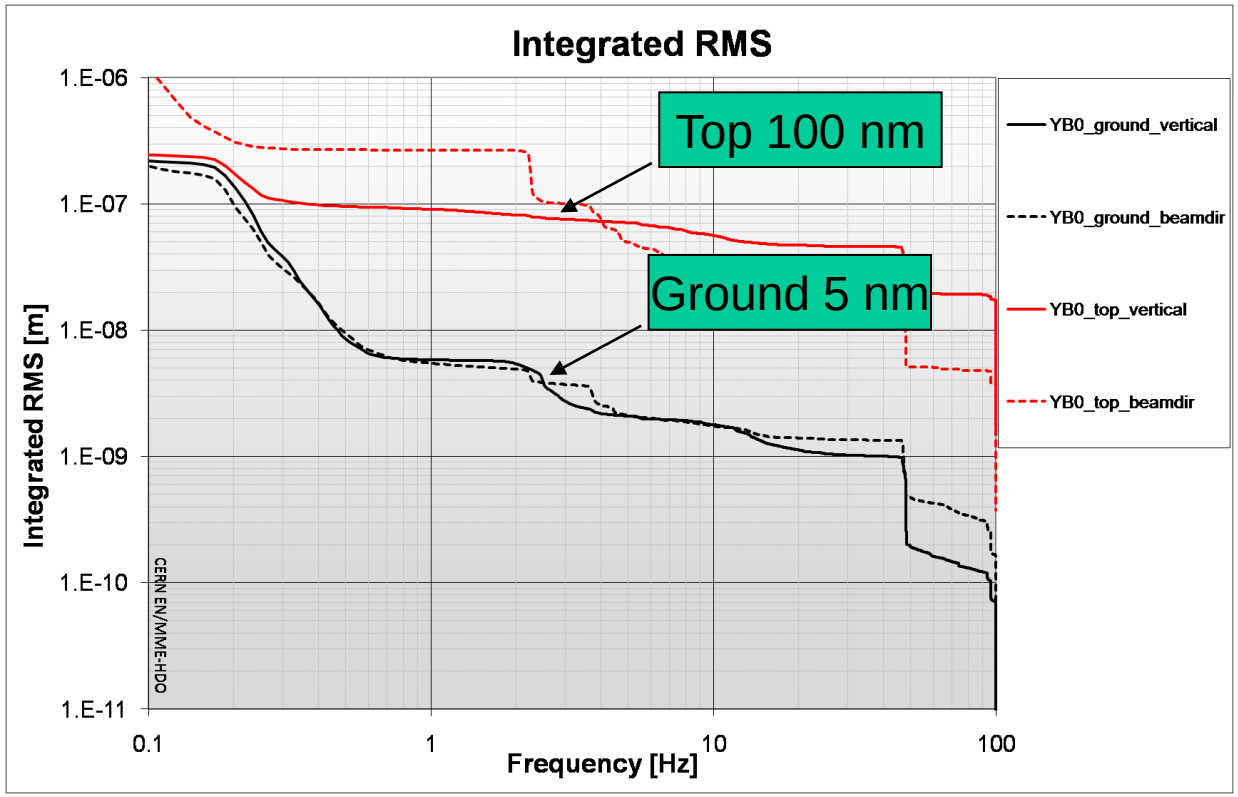
(P. Burrows et al. / JAI)

- For ILC, the fast beam Feed Back system developed at JAI is very efficient and can have a reach of 300 nm.
- Thus the needed stability of the QD0 support is around 50 nm or better.
- First vibration measurements in the CMS area have shown that this is possible.

Vibration consideration from CMS

Vibrations on ground and top of CMS central barrel YB0 in 'Quiet experimental area' end of 2009 (Artoos, Guinchard et al.)





Measurements at KEK on BELLE (Hiroshi Yamaoka) have also shown a degradation of performances when moving up along the yoke.

➨ 50 nm at beam level look reasonable.

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MDI @ CLIC

Introduction - II

• CLIC MDI studies have benefitted of a jump-start due to the studies done for ILC.

• However two parameters are really different and make the problem more difficult:

- The vertical size of the beam is smaller, typically 1 nm compared to 5 nm in ILC
- The beam time structure is unfavorable and the reach of the beam Feed-Back system is reduced.

IP-Feed-Back Systems
(Phil Burrows and J. Resta-Lopez / JAI)

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ILC (500 GeV)

- Beam time structure:
  - Train repetition rate: 5 Hz
  - Bunch separation: 369.2 ns
  - Train length: 969.15 μs
- Intra-train (allows bunch-to-bunch correction)
- Digital FB processor (allows FPGA programming)

CLIC (3 TeV)

- Beam time structure:
  - Train repetition rate: 50 Hz
  - Bunch separation: 0.5 ns
  - Train length: 0.156 μs
- Intra-train (but not bunch-to-bunch)
- All-analogue FB processor

For CLIC, intra-train FB corrections at the IP are especially challenging

- bunch separation about 740 times smaller than for the ILC
- bunch train length about 6200 times shorter than for the ILC

Stability of the QD0 mechanical support

- If we move backward in the CLIC stabilization budget:
  - Ultimate stabilization to obtained the luminosity is 0.15 nm @ 4Hz at IP.
  - Thus, before the intra-train Fast Feed-Back system, a stability of 0.5 nm is needed.
  - Thus, before the active stabilization system, 5 nm or less are needed for the stability of the mechanical support.

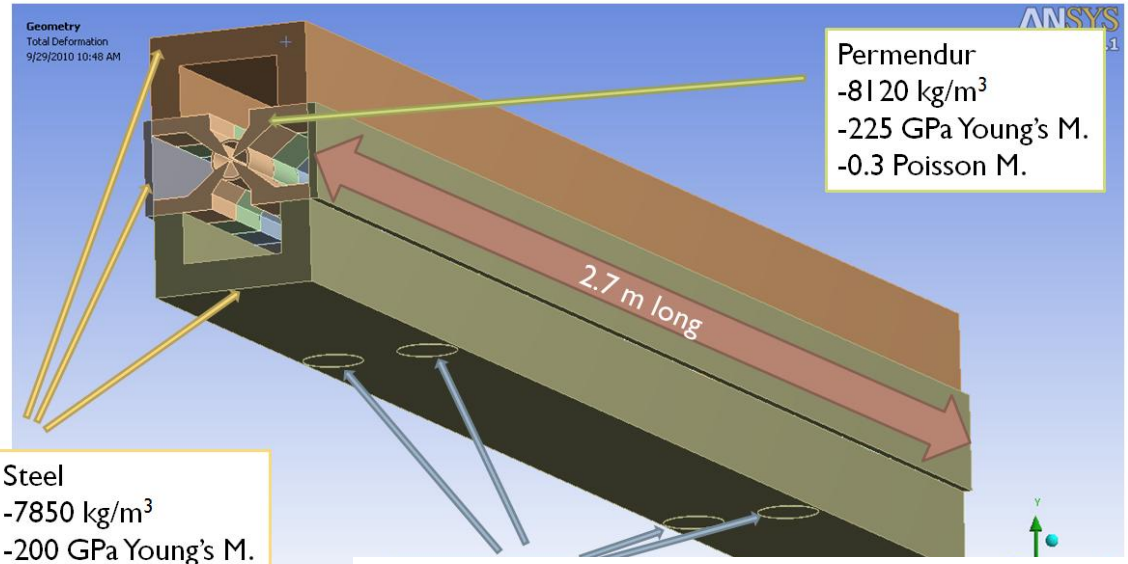
This is a factor 10 w.r.t. ILC!

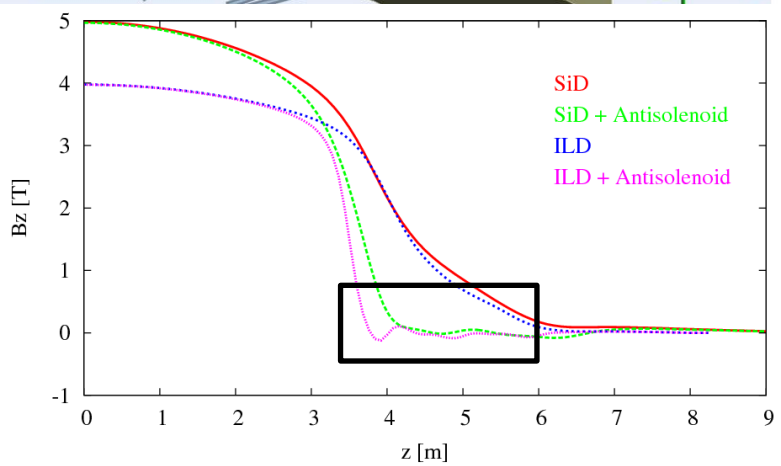
To obtain the utmost beam stability
for CLIC additional efforts are needed.

(In addition to the active pre-alignment and intra-train Fast Feed-Back systems)

1-Use a permanent magnet QD0
(Michele Modena et al. / CERN)

This is to suppress vibrations due to cooling and thin suspensions of the cold mass.





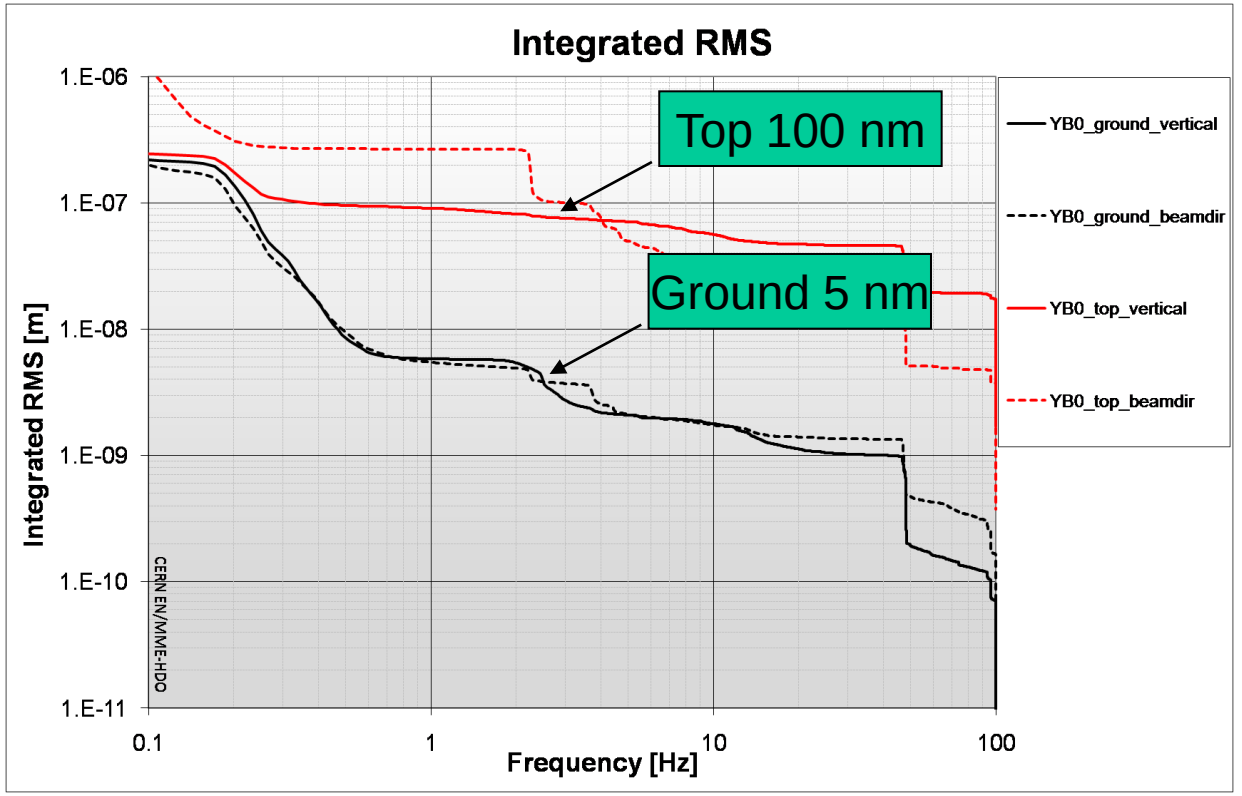
The use of Permendur imposes to have H ≈ 0.

Thus a non negligible anti-solenoid coil, fixed on the endcap, has to be foreseen outside the support tube.

This will also reduce the field seen by the beam and recover luminosity loss
⇐ (Barbara Dalena).

2-Decouple the QD0 support from the experiment

This has been shown previously: *the most stable element is the tunnel floor and not the yoke* of the experiment.

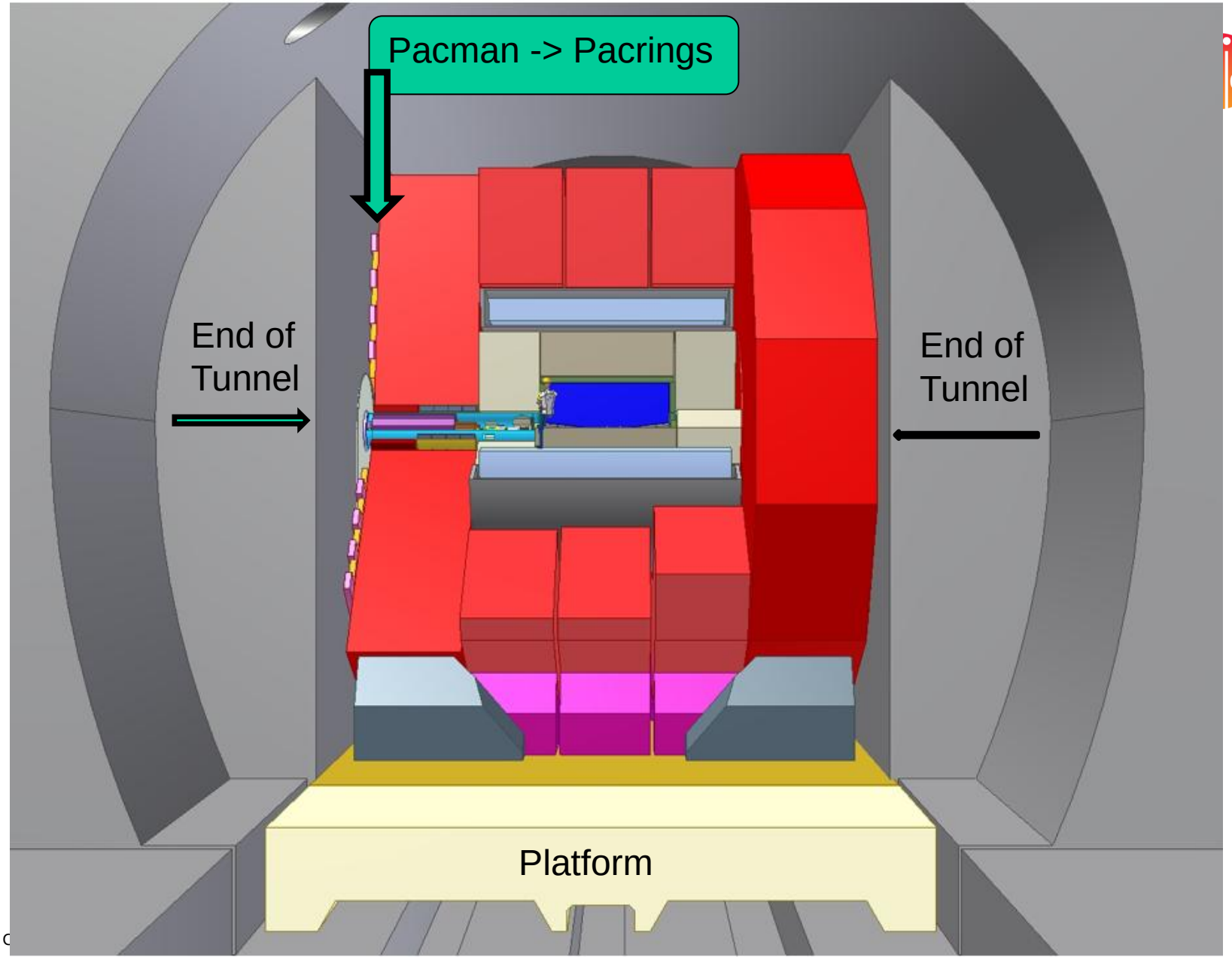


⇐
Measurements in CMS area end of 2009.

3-Minimize the length of the support tube

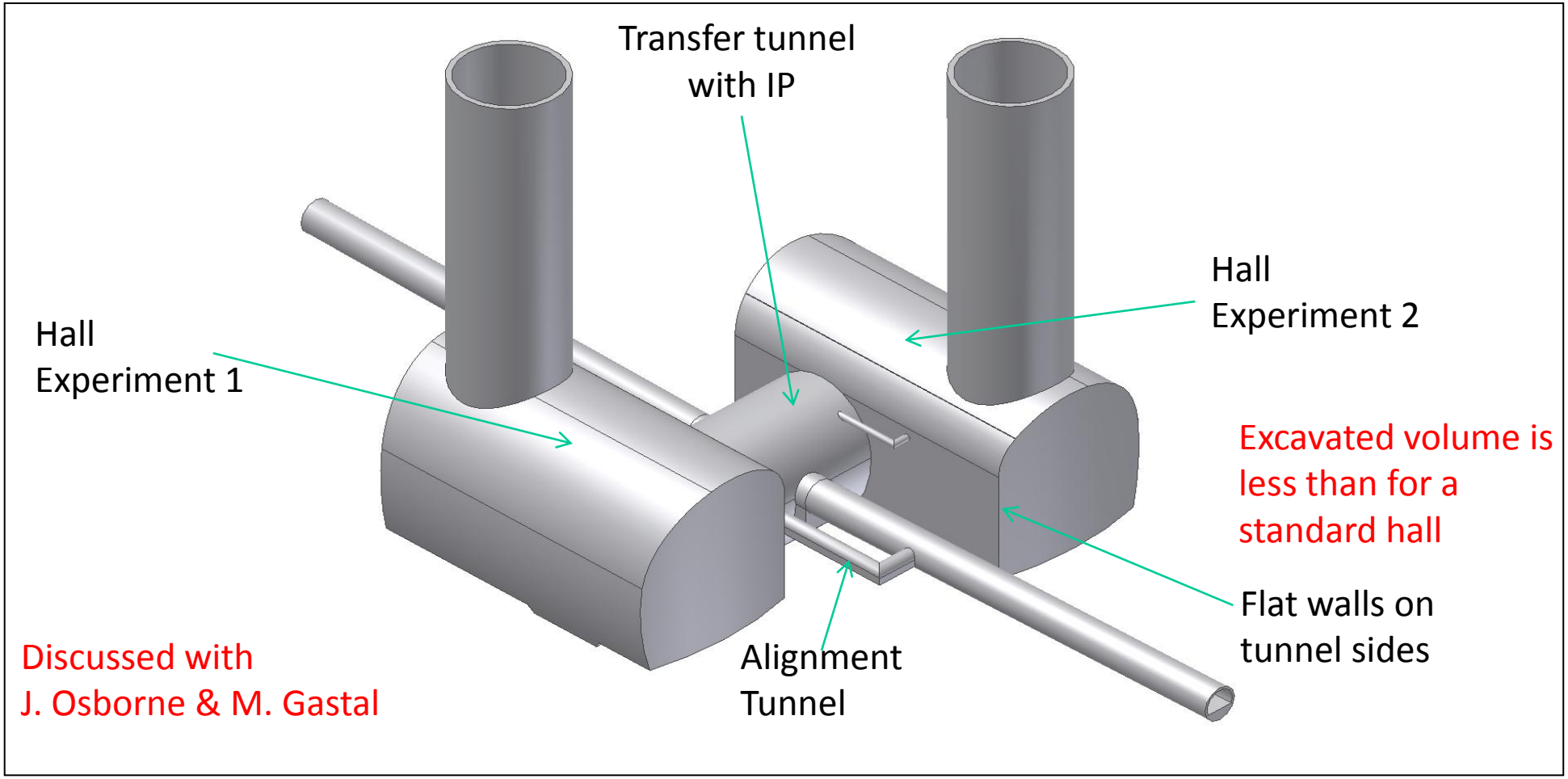
- It is clear that the length of the support tube must be minimized as flexion is involved.
- This can be obtained by abandoning the opening on IP.
- Anyway not much maintenance can be done on IP, and if the Push-Pull operation is working well, *it is more efficient to repair in the garage area*.

Minimize the length of the support tube



This governs the proposal for CLIC Experimental Area

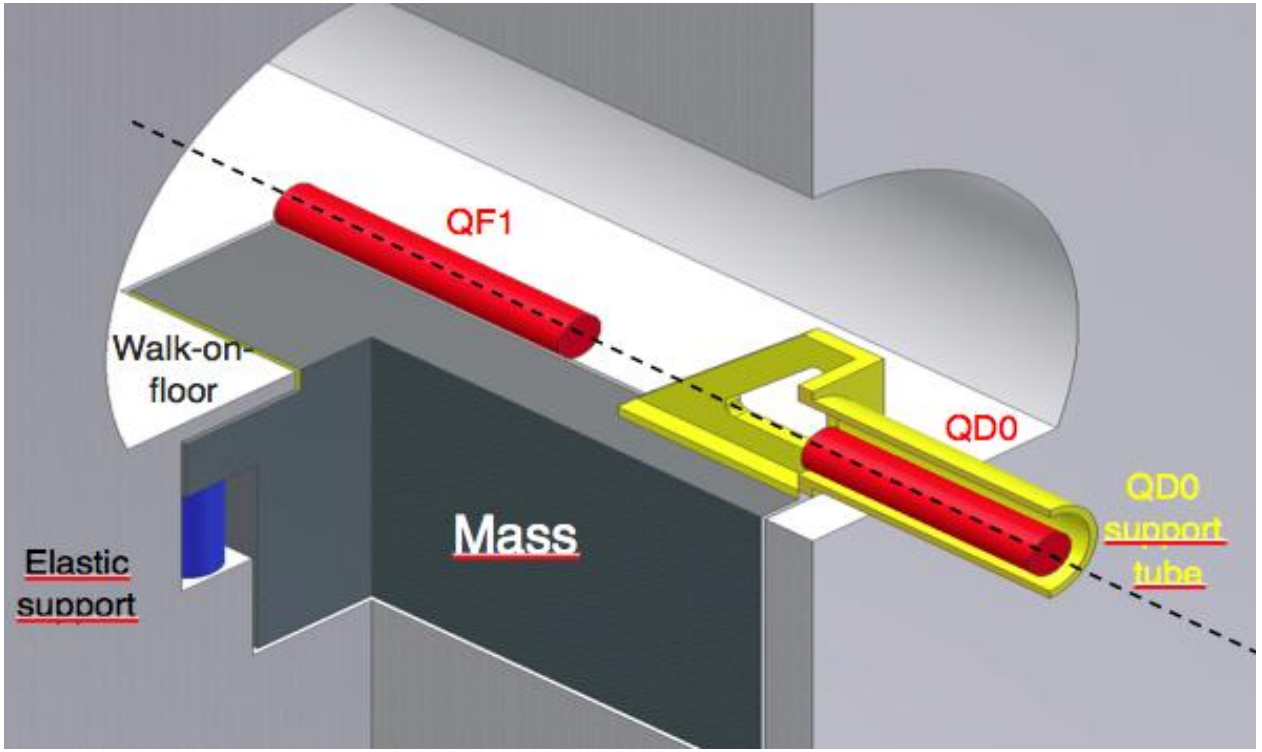
(H. Gerwig / CERN)



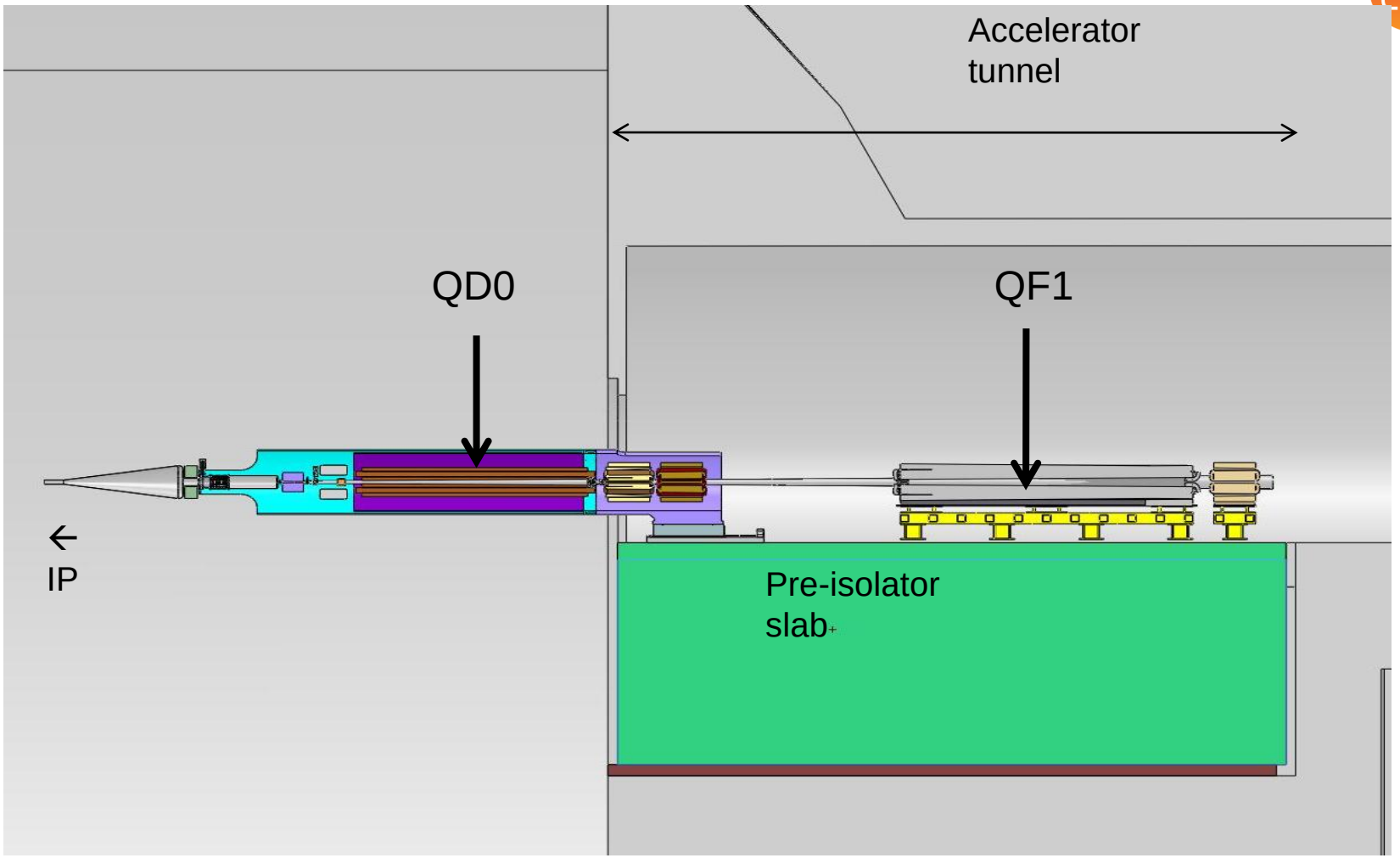
4-Support the QD0 and QF1 from a Pre-Isolator

(Andrea Gaddi et al. / CERN)

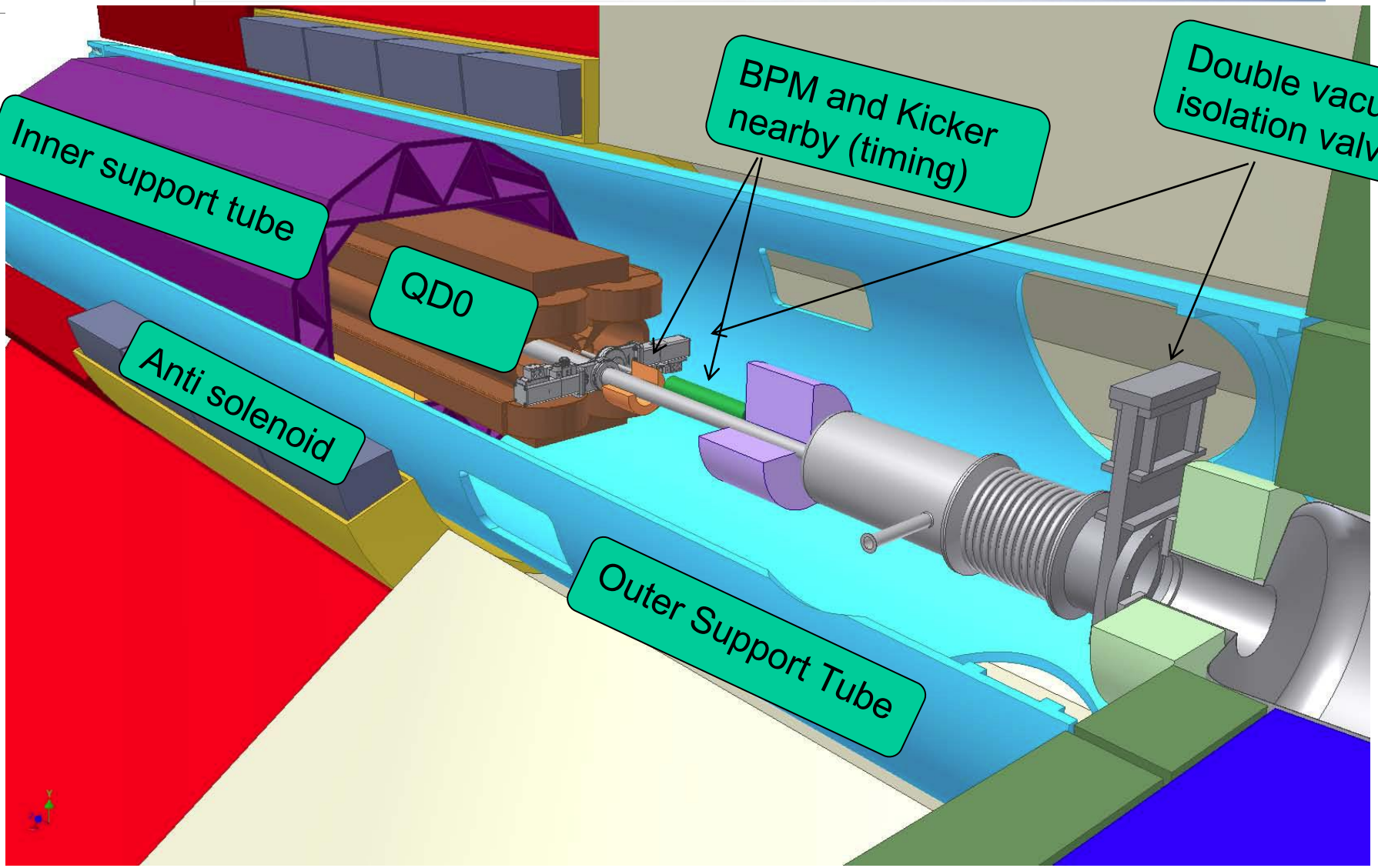
- The idea is to decouple and stabilize the support of QD0 and QF1.
- It must be connected to the active pre-alignment system.



Pre-isolator @ CLIC

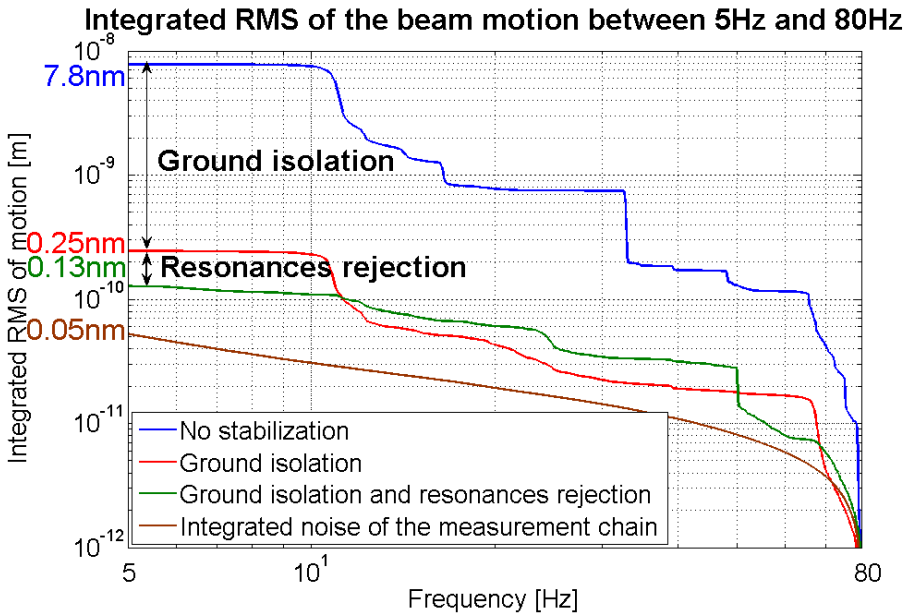


5-Adopt the solution of a double tube



6-Use a sophisticated active Stabilization System
(Andrea Jeremie et al. Annecy)

Proof of principle has been obtained in the lab.



➽ It has to be implemented inside the limited space and environment of the support tube, more integration effort is needed.

Obtaining the utmost beam stability

All these efforts will pay but it must not be forgotten that:

➽ The first important measure will be to choose a 'quiet' site with respect to cultural noise and design a 'quiet' area with respect to technical noise.

Push-Pull Considerations

Reminder

- The push-pull project, to exchange quickly two experiments on IP, is a very ambitious one.
- In size of loads to be moved > 10’000 tons, number of movements, 6 per year ➠ 180 over 15 years.
- It is demanding considering: environment, final precision, and time constraints, (full exchange in less than three or four days) including precise realignment.
- But, one must always be able to extract sideway an experiment for maintenance every year (like Opal, Delphi, Aleph… on LEP).
- Thus the Push-Pull project is just a more demanding normal maintenance displacement scenario!

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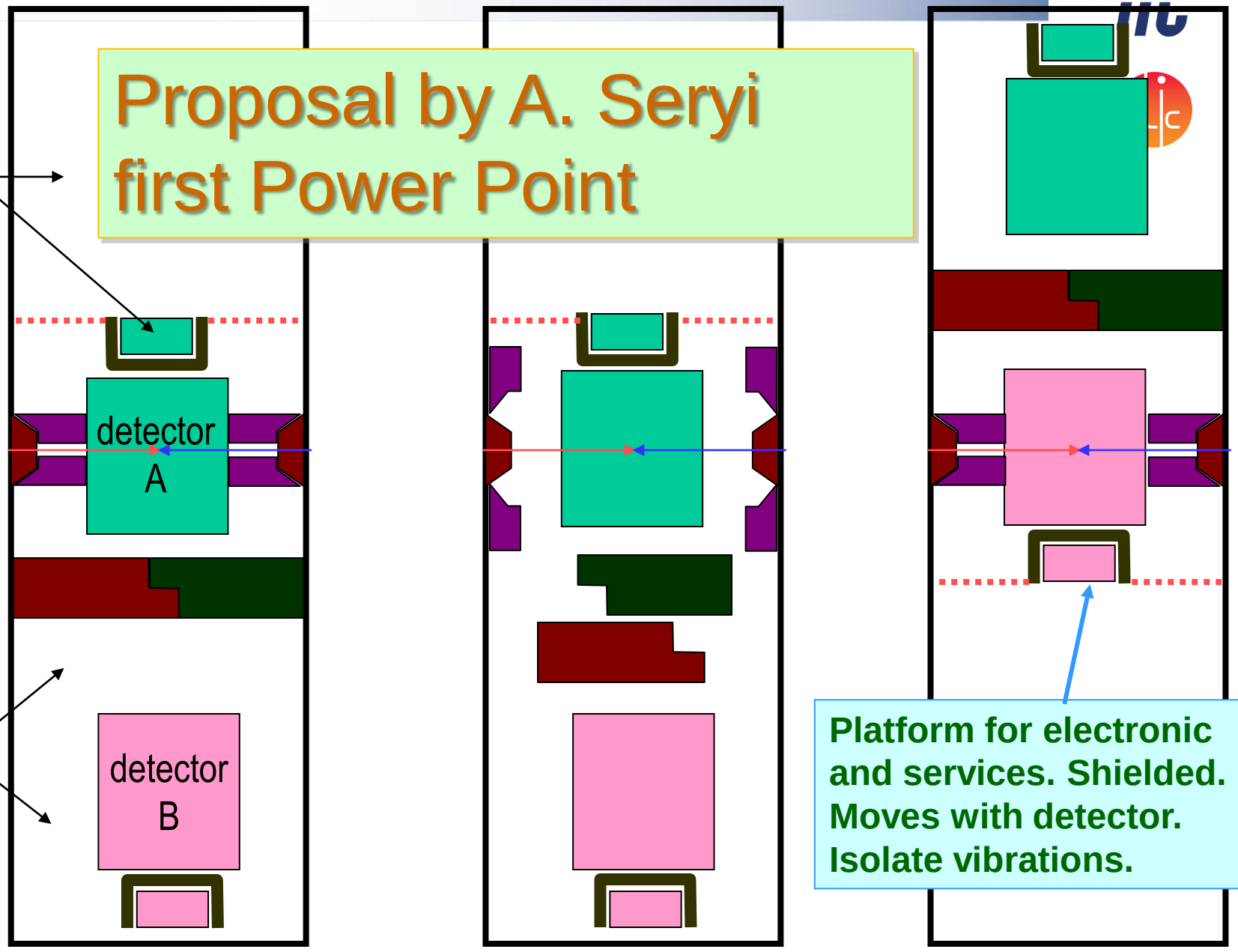
Starting point (~2006) push-pull for ILC

Proposal by A. Seryi
first Power Point

may be accessible during run

accessible during run

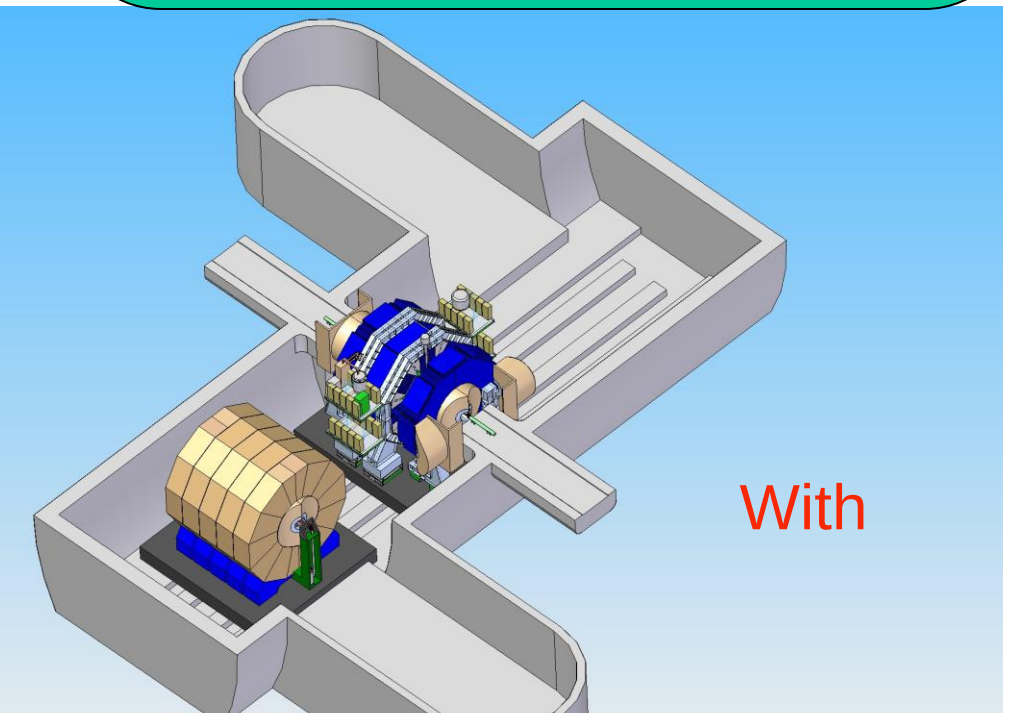


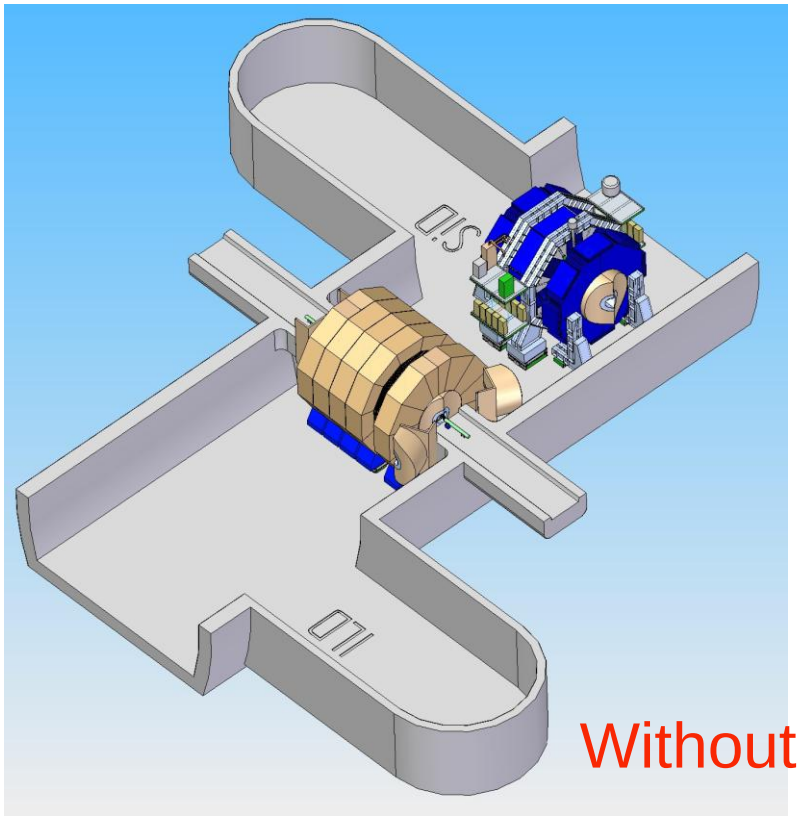
Platform for electronic and services. Shielded. Moves with detector. Isolate vibrations.

SiD and ILD with or without a platform ?

As the idea of push-pull has been introduced during the LoI process, ILD has adopted a platform, however SiD has chosen to move directly on the ground.

Presently the two solutions are not compatible, and discussion are going on and a work plan has been adopted.





(M. Oriunno / SLAC)

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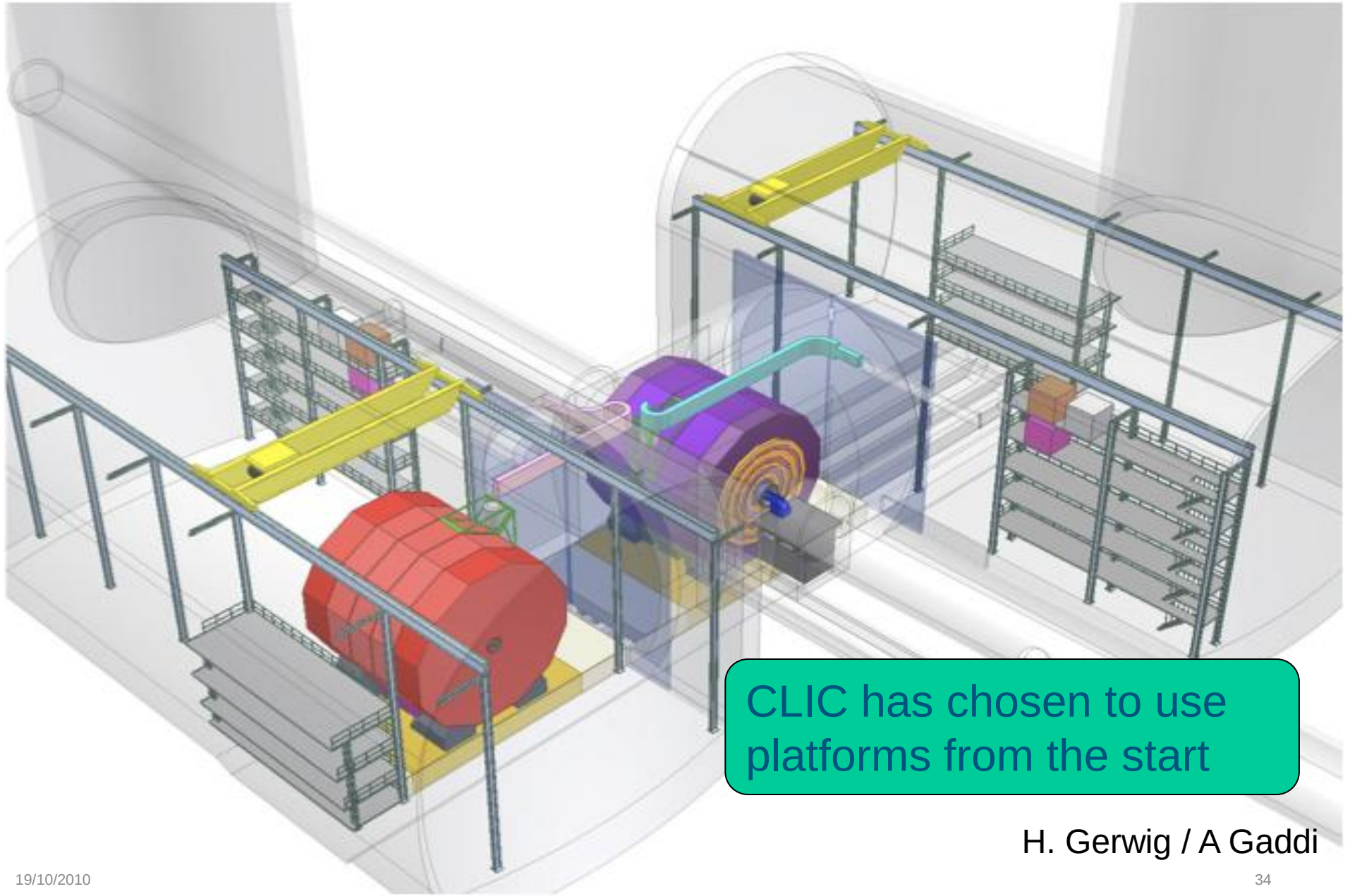
Push-Pull for CLIC detectors



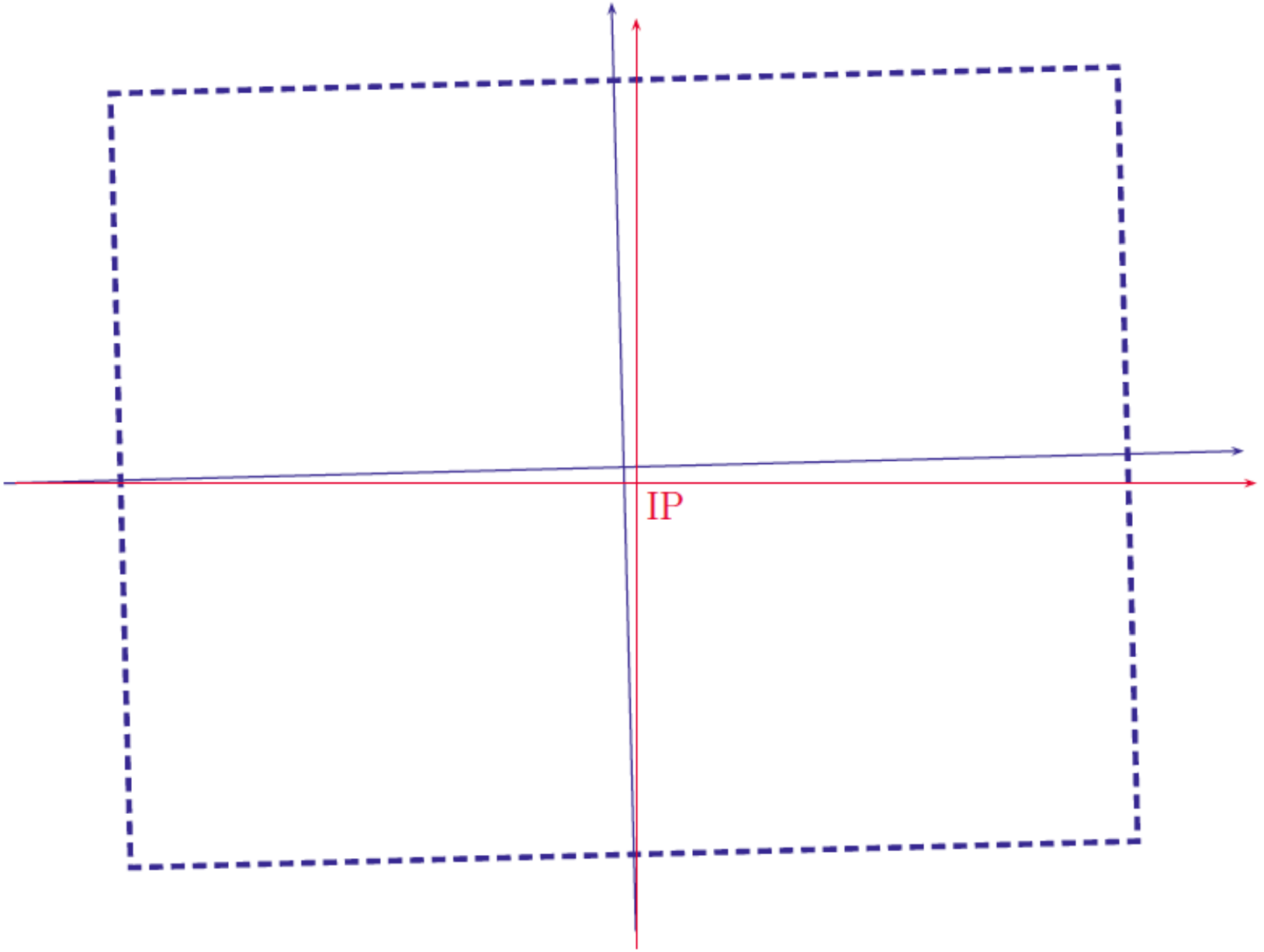
CLIC has chosen to use platforms from the start

H. Gerwig / A Gaddi

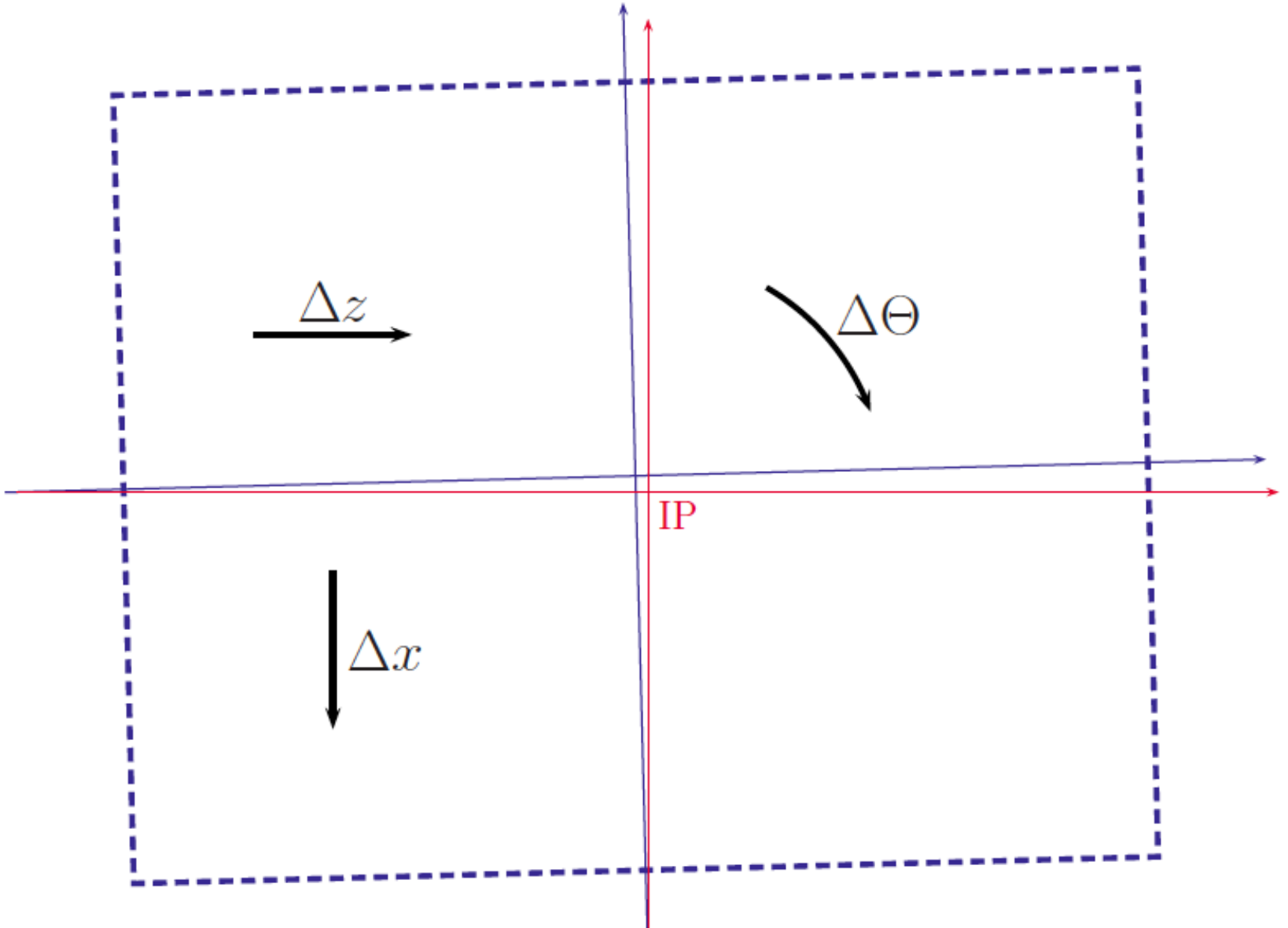
Platform/ Airpad consideration

- The platform solution shows all its advantages when used in conjunction with airpads, because airpads:
  - have no preferred direction of movement.
  - allow an easy repair of the rail / support system, removing the high risk of staying blocked.
  - allow a fast and safe positioning of the experiment on beam.

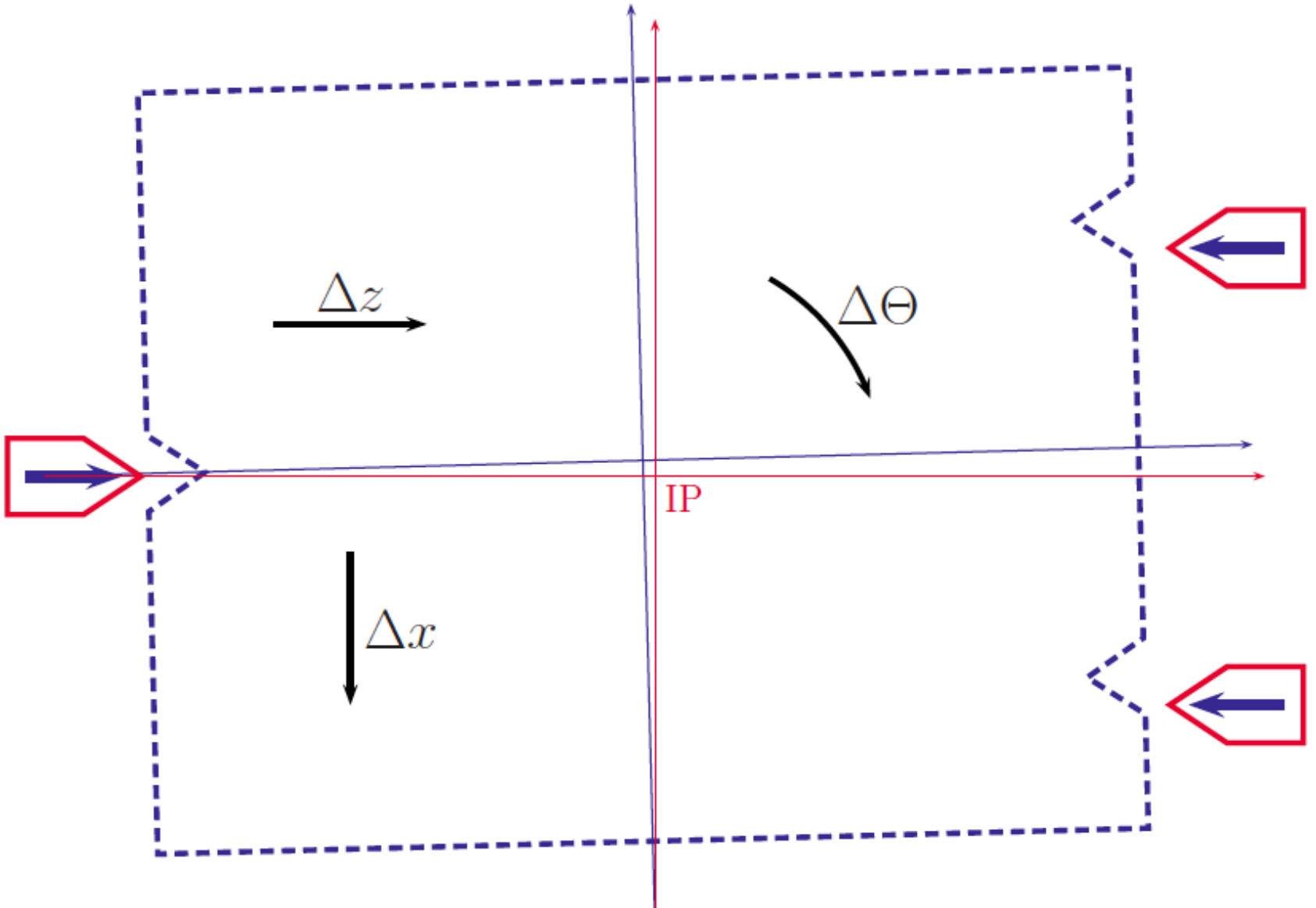
Load will arrive off-center and off-axis



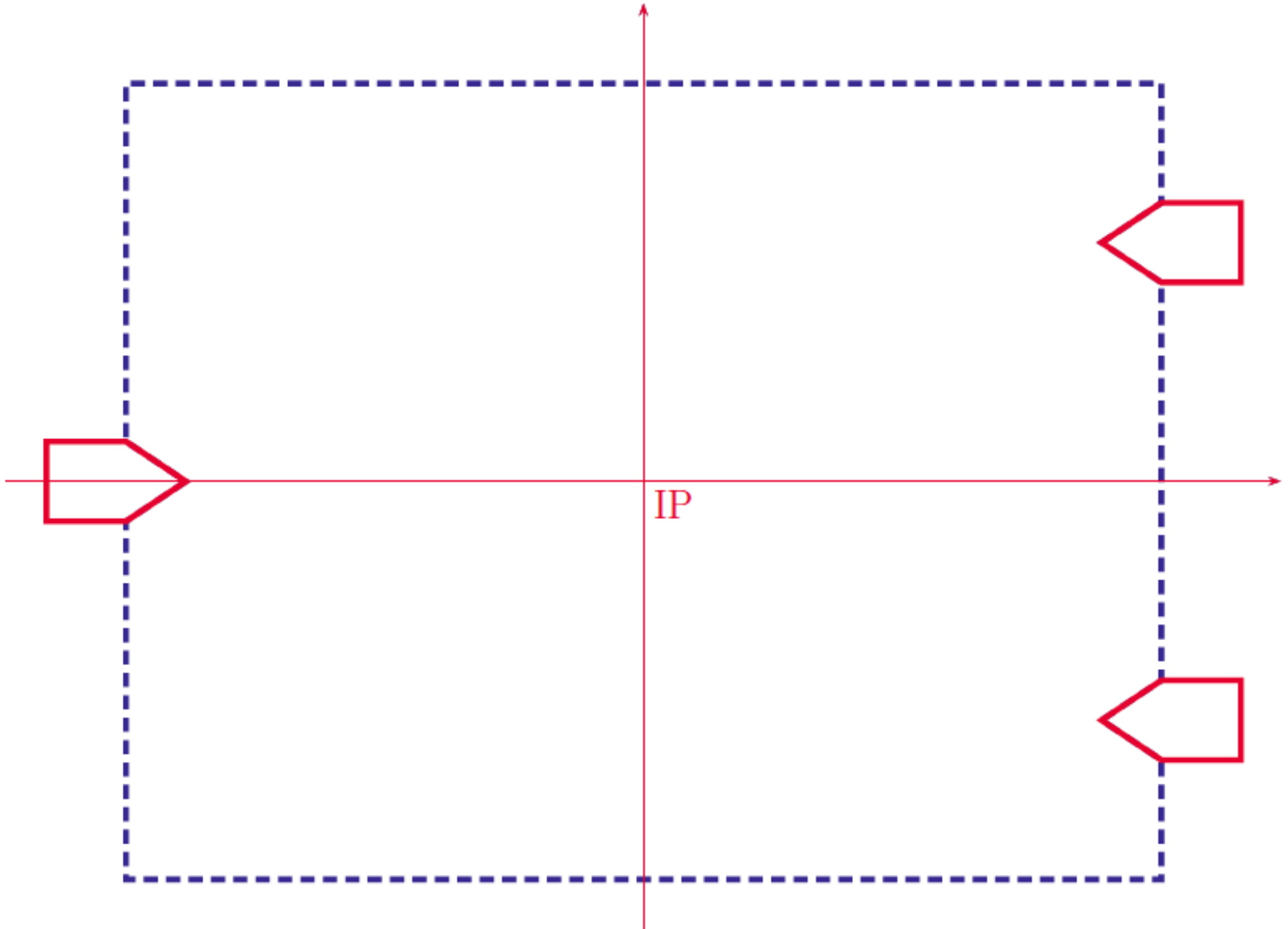
2D movement and a rotation are needed this is very difficult with rollers



With Airpads a simple positive indexing mechanism is possible giving ≈mm precision



The final precision could be +-1 mm and +-0.1 mrad.



Vertical adjustment

- Exchanging 10’000 ton experiments will induce a settlement of the whole experimental zone and adjacent machine tunnels.
- One can expect vertical movements in the millimeter range that can take one month to recover.
- This kind of slow drift will also be taken care of by the active pre-alignment system.

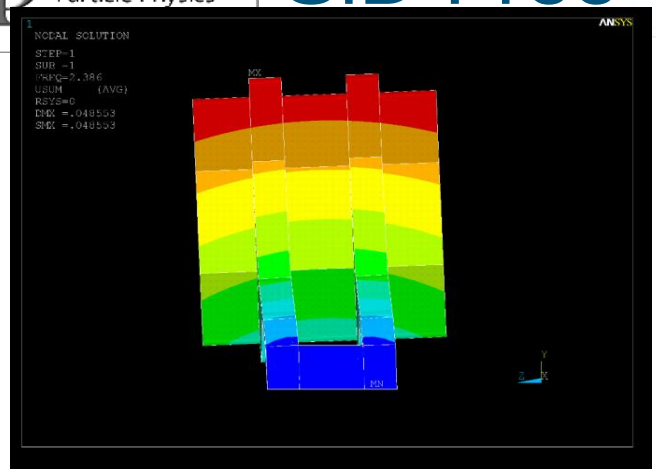
Moving towards a common solution at ILC for the Push-Pull system

- ILD is making studies to justify that it cannot move without a platform.
- At the same time, it must be shown that the use of a platform is not detrimental to SiD that has chosen to support the QD0s from the endcap doors.

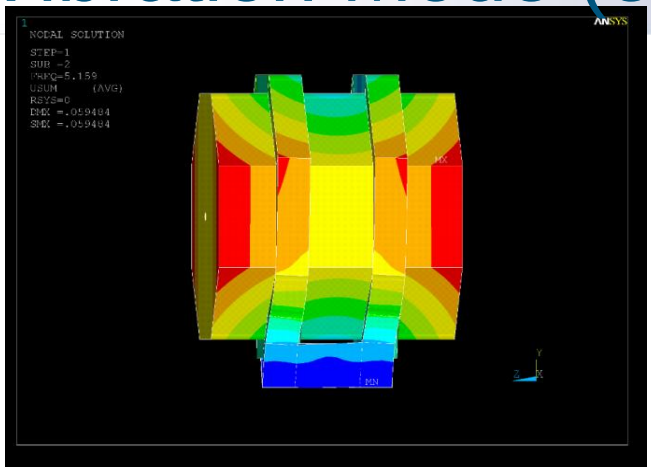
Vibration consideration at ILC moving towards a common solution

- The priority is to develop credible simulation tools, and Marco Oriunno at SLAC for SiD and Hitoshi Yamaoka at KEK for ILD have started extensive studies.
- However, one must make sure that the results of simulations are in agreement with reality and extensive benchmarking is required.

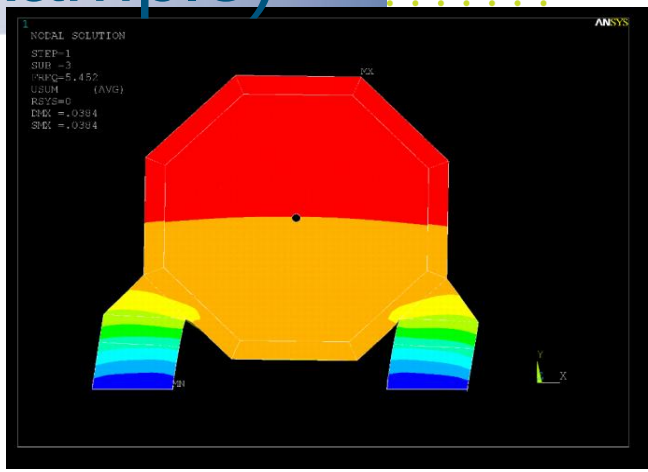
SiD Free Vibration Mode (example)



1st Mode, 2.38 Hz

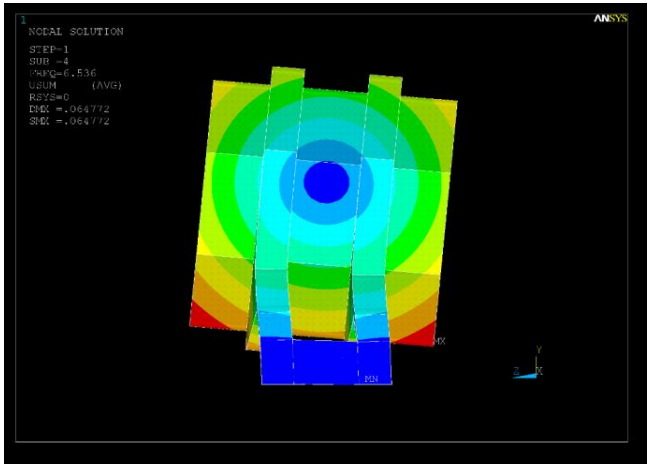


2nd Mode, 5.15 Hz

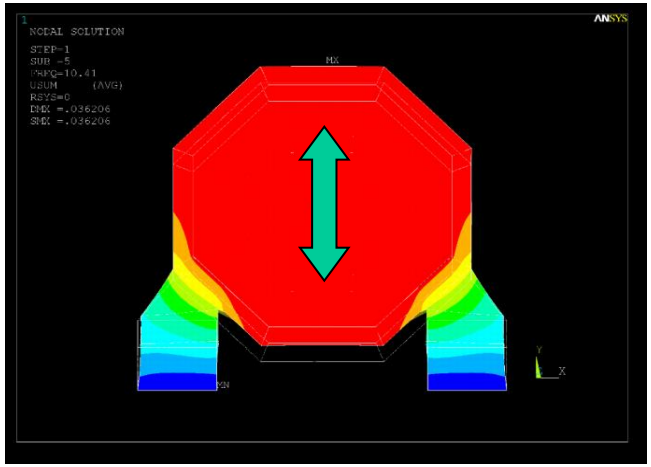


3rd Mode, 5.45 Hz

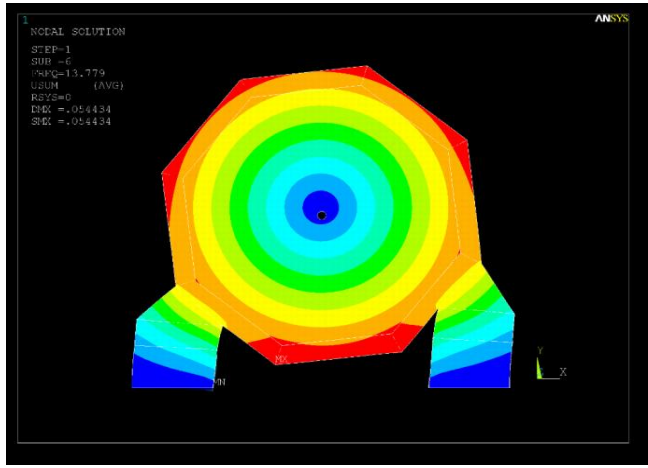
Vertical motion



4th Mode, 6.53 Hz



5th Mode, 10.42 Hz



6th Mode, 13.7 Hz

M. Oriunno / SLAC

Response amplitude (*Comparison of computations and measurements*)

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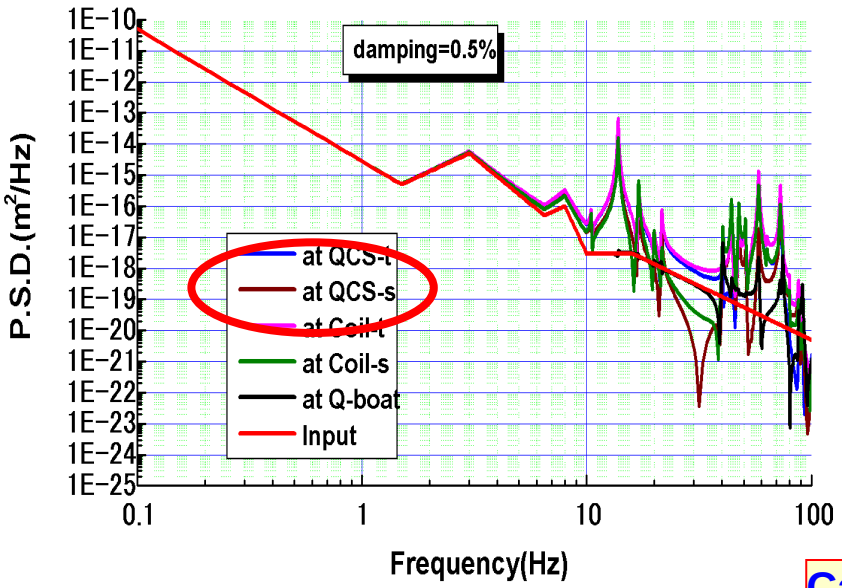
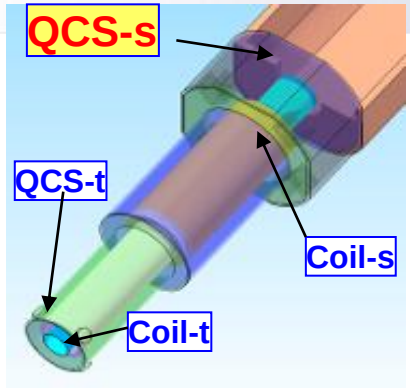
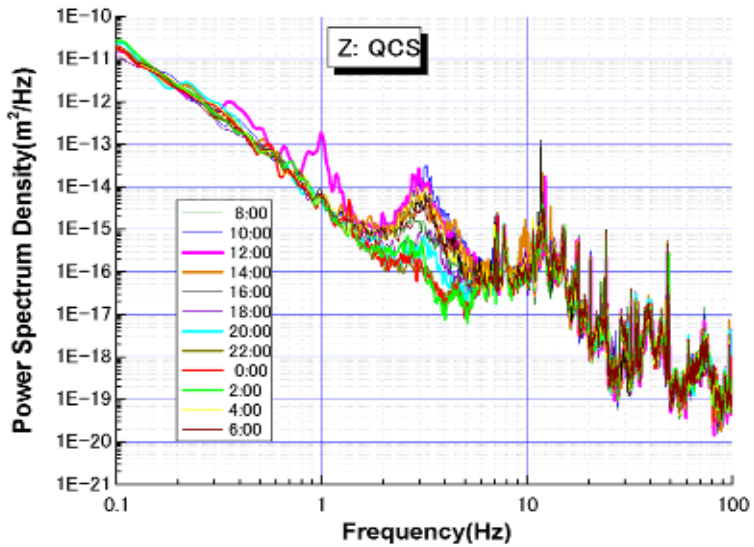
Calculation: *damp=0.5%*

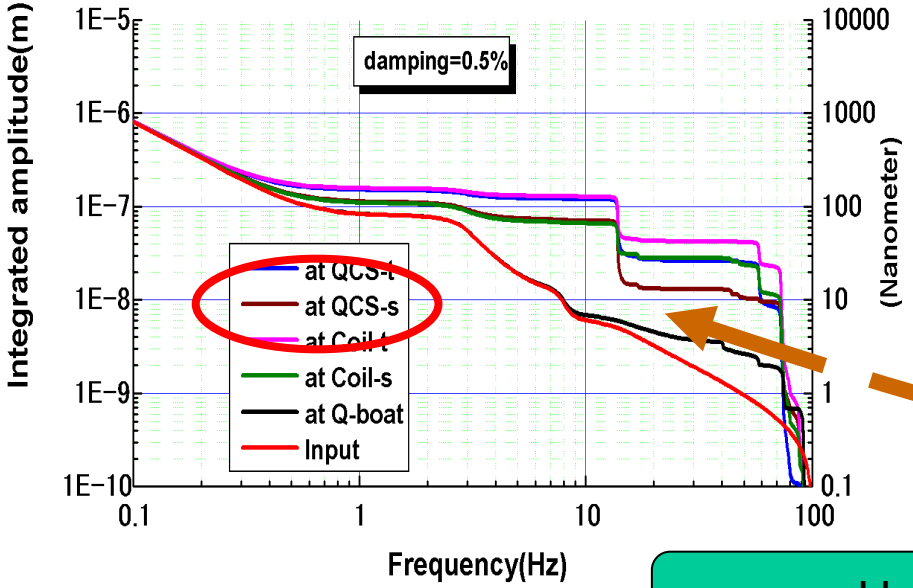


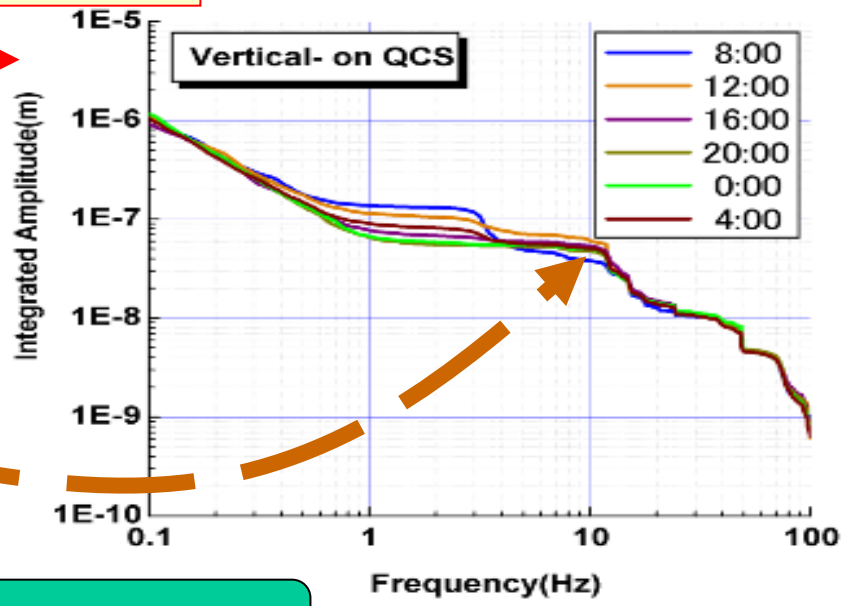


Measurements@QCS-s



Calculation: **Measurement**





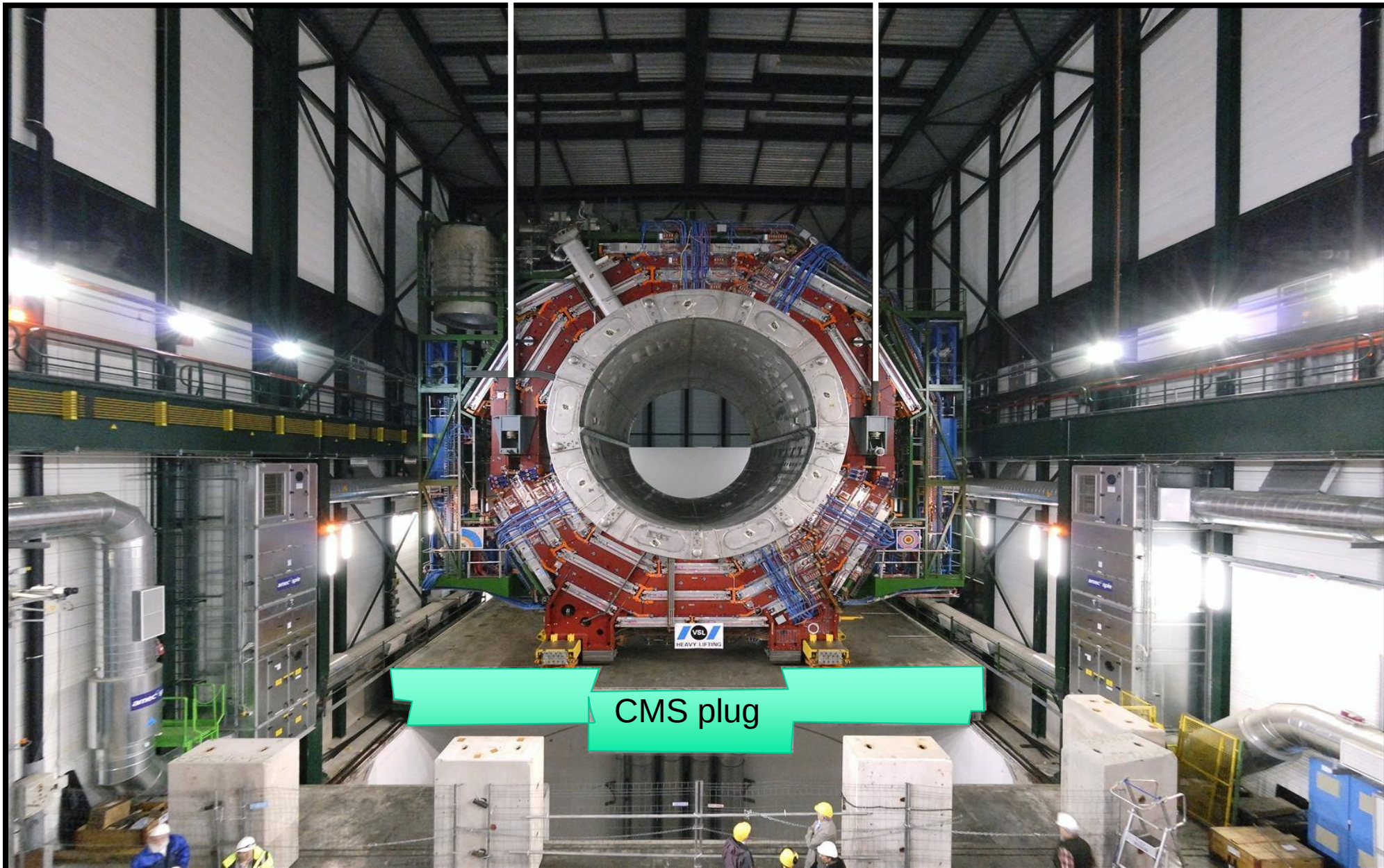
H. Yamaoka / KEK

Vibration considerations connected to the platform

- The CMS plug is a good example of what can be a Push-Pull platform, it has the necessary rigidity.
- It can be used to benchmark the simulation programs.
- First vibration measurements have been carried out end of 2009.
- Last week a new measurement campaign has been performed (K. Artoos, M. Guinchard et al.) for SiD.

ETH Institute for Particle Physics

The 2000-ton CMS Plug has been used for the Heavy Lifting operation



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The CMS Plug finished looks neat!

ETH Institute for Particle Physics

Steel reinforcement of CMS Plug

Clearly models need benchmarking to evaluate damping coefficient and Young's modulus

Vibration consideration connected to the platform

- The study of the CMS plug is a good example of work that is in interest of both ILC and CLIC

(Because CLIC has directly engaged on using two platforms for the Push-Pull operation.)

Conclusions

Conclusions-I

- To maximize luminosity the last focusing element must penetrate inside the experiment to achieve a low L*.
- The small size of the beams imposes to use an active pre-alignment system against slow drifts.
- In addition a beam Fast Feed Back system is needed to correct for movements at higher frequencies.
- This is sufficient for ILC that benefits from a favorable beam time structure.
- For CLIC that has smaller beam size and an unfavorable beam time structure, supplementary efforts are needed.

Conclusions-II

- The Push-Pull system is a very demanding project and there is no example to refer to.
- CLIC has adopted a platform to move each experiment.
- ILC concepts are in discussion to adopt a common solution and a working plan has been drafted.
- It is important to make sure that the platform solution does not worsen the stability of the QD0s that, in SiD, are supported from the endcap doors.

Conclusions-III

- The CMS plug is a good example of what a platform could be.
- It can be used to benchmark simulation models.
- Further vibration measurements on the CMS plug will be needed.
- These measurements are also in the interest of the CLIC project.
- The studies of platform and associated vibrations could be part of the ILC/CLIC Collaboration.

Conclusions-IV

- The MDI studies are now mature for both ILC and CLIC.
- More detailed studies and tests are needed for CLIC due to the level of stability required for the QD0 .
- The requirements are different enough that (apart maybe the Push-Pull system proper) solutions adopted by ILC and CLIC, although similar, are fairly different and are likely to stay different.

Thank You !