Report from the MDI Common Task Group

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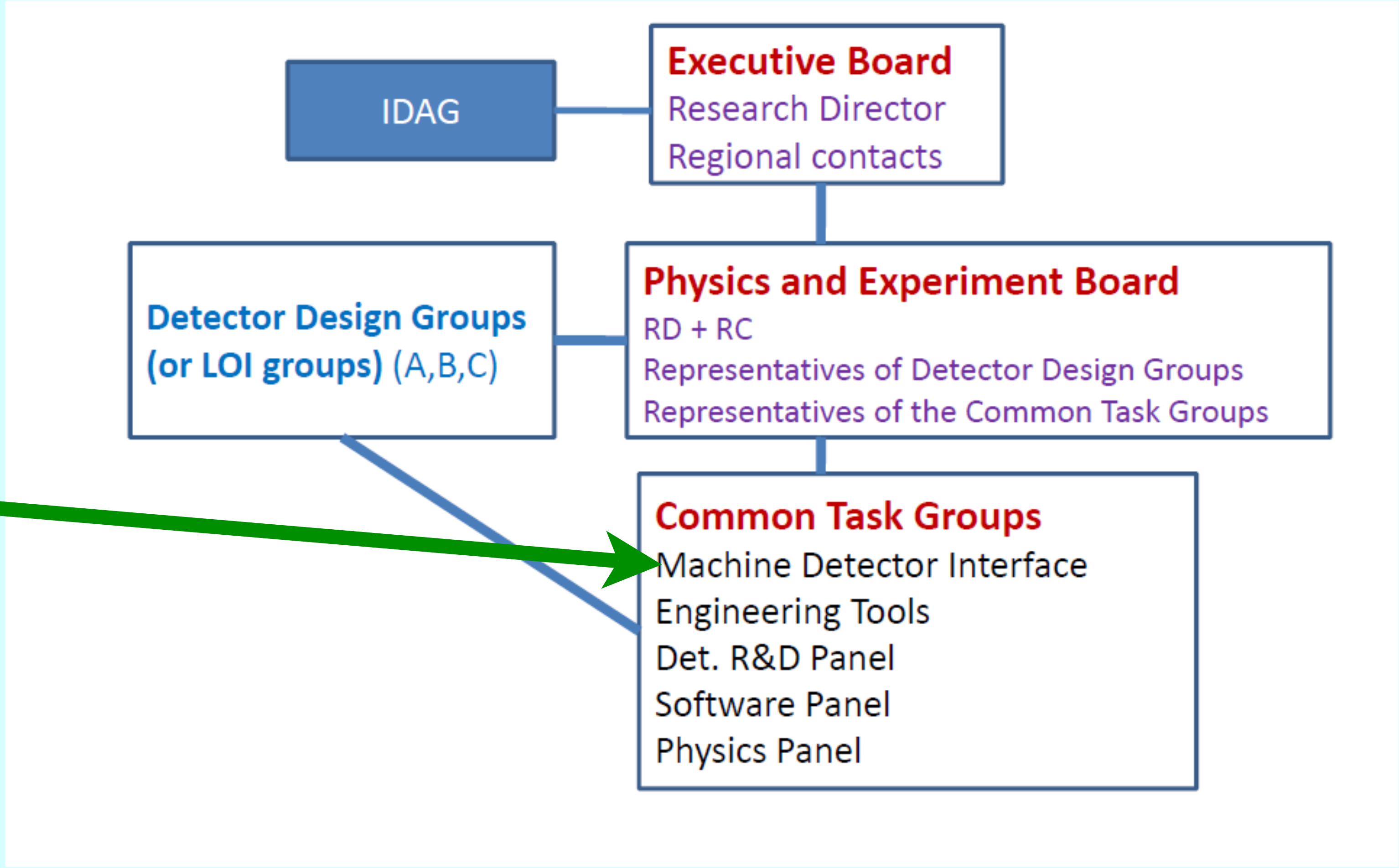
DESY

PAC Review
Vancouver
10 May 2009

The MDI Common Task Group

- Common task group of the Research Director‘s organisation:

- Members:
  - J. Hauptman
  - A. Mikhailichenko
  - P. Burrows (deputy convener)
  - M. Oriunno
  - K. Buesser (convener)
  - T. Tauchi



IDAG

Executive Board
Research Director
Regional contacts

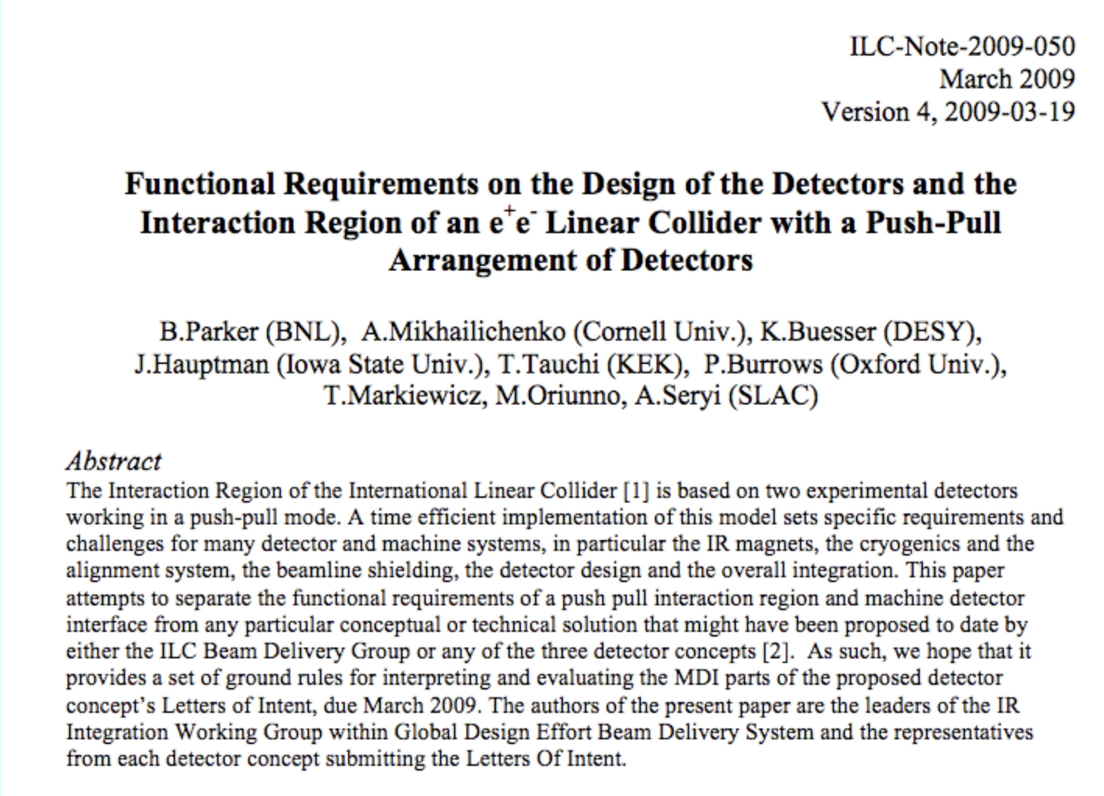
Detector Design Groups (or LOI groups) (A,B,C)

Physics and Experiment Board
RD + RC
Representatives of Detector Design Groups
Representatives of the Common Task Groups

Common Task Groups
Machine Detector Interface
Engineering Tools
Det. R&D Panel
Software Panel
Physics Panel

- Usually meets in phone meetings
- Close contact to the GDE BDS group

IR Interface Document



ILC-Note-2009-050
March 2009
Version 4, 2009-03-19

Functional Requirements on the Design of the Detectors and the Interaction Region of an e^+e^- Linear Collider with a Push-Pull Arrangement of Detectors

B.Parker (BNL), A.Mikhailichenko (Cornell Univ.), K.Buesser (DESY),
J.Hauptman (Iowa State Univ.), T.Tauchi (KEK), P.Burrows (Oxford Univ.),
T.Markiewicz, M.Oriunno, A.Seryi (SLAC)

Abstract

The Interaction Region of the International Linear Collider [1] is based on two experimental detectors working in a push-pull mode. A time efficient implementation of this model sets specific requirements and challenges for many detector and machine systems, in particular the IR magnets, the cryogenics and the alignment system, the beamline shielding, the detector design and the overall integration. This paper attempts to separate the functional requirements of a push pull interaction region and machine detector interface from any particular conceptual or technical solution that might have been proposed to date by either the ILC Beam Delivery Group or any of the three detector concepts [2]. As such, we hope that it provides a set of ground rules for interpreting and evaluating the MDI parts of the proposed detector concept's Letters of Intent, due March 2009. The authors of the present paper are the leaders of the IR Integration Working Group within Global Design Effort Beam Delivery System and the representatives from each detector concept submitting the Letters Of Intent.

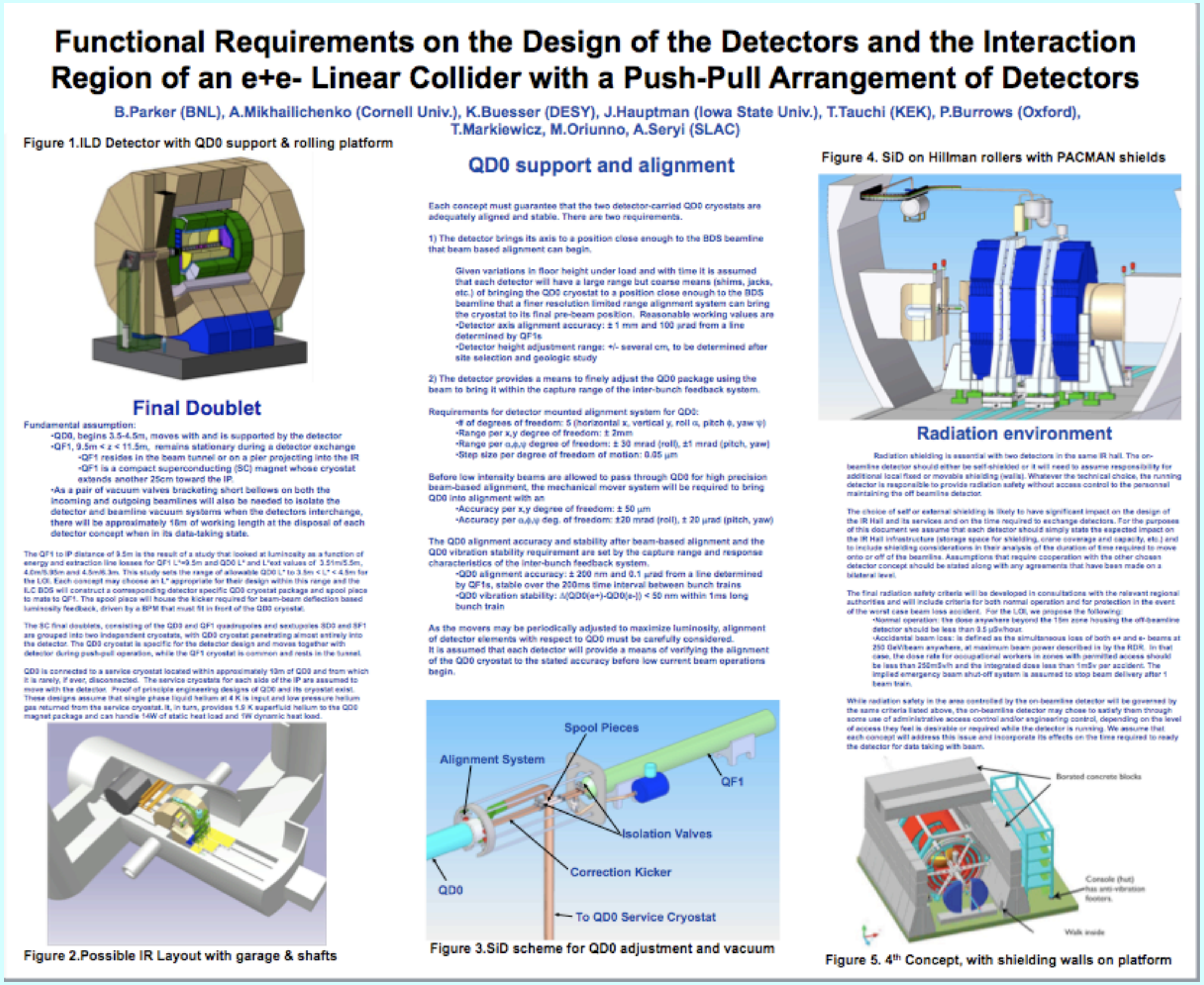
IR Interface Document

- Common document of the MDI-D common task group together with the GDE-BDS group
- Definition of the functional requirements to allow a friendly co-existence of two detectors and the ILC machine in a push-pull scenario
- Provide a set of ground rules, not technical solutions to the problems!

- Document has been discussed in the workshops in Warsaw and Chicago
- Several phone meetings of the MDI-D group together with GDE-BDS
- Sent to the detector concept groups and the RD for comments
- Approved by concept groups, BDS technical area leaders and PM for accelerator systems
- Published as ILC-Note-2009-050

Requirement Document at PAC

- Slightly edited version of the paper has been submitted to PAC’09 (the conference)
- Presented in the form of a poster
- Abstract WE6PFP078



Functional Requirements on the Design of the Detectors and the Interaction Region of an e+e- Linear Collider with a Push-Pull Arrangement of Detectors

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Figure 1.ILD Detector with QD0 support & rolling platform

Final Doublet

Fundamental assumption:
- QD0, begins 3.5-4.5m, moves with and is supported by the detector
- QF1, 9.5m < z < 11.5m, remains stationary during a detector exchange
  - QF1 resides in the beam tunnel or on a pier projecting into the IR
  - QF1 is a compact superconducting (SC) magnet whose cryostat extends another 25cm toward the IP.
- As a pair of vacuum valves bracketing short bellows on both the incoming and outgoing beamlines will also be needed to isolate the detector and beamline vacuum systems when the detectors interchange, there will be approximately 18m of working length at the disposal of each detector concept when in its data-taking state.

The QF1 to IP distance of 9.5m is the result of a study that looked at luminosity as a function of energy and extraction line losses for QF1 L*=9.5m and QD0 L* and L*ext values of 3.51m/5.5m, 4.0m/5.95m and 4.5m/6.3m. This study sets the range of allowable QD0 L* to 3.5m < L* < 4.5m for the LOI. Each concept may choose an L* appropriate for their design within this range and the ILC BDS will construct a corresponding detector specific QD0 cryostat package and spool piece to mate to QF1. The spool piece will house the kicker required for beam-beam deflection based luminosity feedback, driven by a BPM that must fit in front of the QD0 cryostat.

The SC final doublets, consisting of the QD0 and QF1 quadrupoles and sextupoles SD0 and SF1 are grouped into two independent cryostats, with QD0 cryostat penetrating almost entirely into the detector. The QD0 cryostat is specific for the detector design and moves together with detector during push-pull operation, while the QF1 cryostat is common and rests in the tunnel.

QD0 is connected to a service cryostat located within approximately 10m of QD0 and from which it is rarely, if ever, disconnected. The service cryostats for each side of the IP are assumed to move with the detector. Proof of principle engineering designs of QD0 and its cryostat exist. These designs assume that single phase liquid helium at 4 K is input and low pressure helium gas returned from the service cryostat. It, in turn, provides 1.9 K superfluid helium to the QD0 magnet package and can handle 14W of static heat load and 1W dynamic heat load.

Figure 2.Possible IR Layout with garage & shafts

QD0 support and alignment

Each concept must guarantee that the two detector-carried QD0 cryostats are adequately aligned and stable. There are two requirements.

1) The detector brings its axis to a position close enough to the BDS beamline that beam based alignment can begin.

Given variations in floor height under load and with time it is assumed that each detector will have a large range but coarse means (shims, jacks, etc.) of bringing the QD0 cryostat to a position close enough to the BDS beamline that a finer resolution limited range alignment system can bring the cryostat to its final pre-beam position. Reasonable working values are
- Detector axis alignment accuracy: ± 1 mm and 100 μrad from a line determined by QF1s
- Detector height adjustment range: +/- several cm, to be determined after site selection and geologic study

2) The detector provides a means to finely adjust the QD0 package using the beam to bring it within the capture range of the inter-bunch feedback system.

Requirements for detector mounted alignment system for QD0:
- # of degrees of freedom: 5 (horizontal x, vertical y, roll α, pitch ϕ, yaw ψ)
- Range per x,y degree of freedom: ± 2mm
- Range per α,ϕ,ψ degree of freedom: ± 30 mrad (roll), ±1 mrad (pitch, yaw)
- Step size per degree of freedom of motion: 0.05 μm

Before low intensity beams are allowed to pass through QD0 for high precision beam-based alignment, the mechanical mover system will be required to bring QD0 into alignment with an
- Accuracy per x,y degree of freedom: ± 50 μm
- Accuracy per α,ϕ,ψ deg. of freedom: ±20 mrad (roll), ± 20 μrad (pitch, yaw)

The QD0 alignment accuracy and stability after beam-based alignment and the QD0 vibration stability requirement are set by the capture range and response characteristics of the inter-bunch feedback system.
- QD0 alignment accuracy: ± 200 nm and 0.1 μrad from a line determined by QF1s, stable over the 200ms time interval between bunch trains
- QD0 vibration stability: Δ(QD0(e+)-QD0(e-)) < 50 nm within 1ms long bunch train

As the movers may be periodically adjusted to maximize luminosity, alignment of detector elements with respect to QD0 must be carefully considered.
It is assumed that each detector will provide a means of verifying the alignment of the QD0 cryostat to the stated accuracy before low current beam operations begin.

Figure 3.SiD scheme for QD0 adjustment and vacuum

Figure 4. SiD on Hillman rollers with PACMAN shields

Radiation environment

Radiation shielding is essential with two detectors in the same IR hall. The on-beamline detector should either be self-shielded or it will need to assume responsibility for additional local fixed or movable shielding (walls). Whatever the technical choice, the running detector is responsible to provide radiation safety without access control to the personnel maintaining the off beamline detector.

The choice of self or external shielding is likely to have significant impact on the design of the IR Hall and its services and on the time required to exchange detectors. For the purposes of this document we assume that each detector should simply state the expected impact on the IR Hall infrastructure (storage space for shielding, crane coverage and capacity, etc.) and to include shielding considerations in their analysis of the duration of time required to move onto or off of the beamline. Assumptions that require cooperation with the other chosen detector concept should be stated along with any agreements that have been made on a bilateral level.

The final radiation safety criteria will be developed in consultations with the relevant regional authorities and will include criteria for both normal operation and for protection in the event of the worst case beam loss accident. For the LOI, we propose the following:
- Normal operation: the dose anywhere beyond the 15m zone housing the off-beamline detector should be less than 0.5 μSv/hour.
- Accidental beam loss: is defined as the simultaneous loss of both e+ and e- beams at 250 GeV/beam anywhere, at maximum beam power described in by the RDR. In that case, the dose rate for occupational workers in zones with permitted access should be less than 250mSv/h and the integrated dose less than 1mSv per accident. The implied emergency beam shut-off system is assumed to stop beam delivery after 1 beam train.

While radiation safety in the area controlled by the on-beamline detector will be governed by the same criteria listed above, the on-beamline detector may chose to satisfy them through some use of administrative access control and/or engineering control, depending on the level of access they feel is desirable or required while the detector is running. We assume that each concept will address this issue and incorporate its effects on the time required to ready the detector for data taking with beam.

Figure 5. 4th Concept, with shielding walls on platform

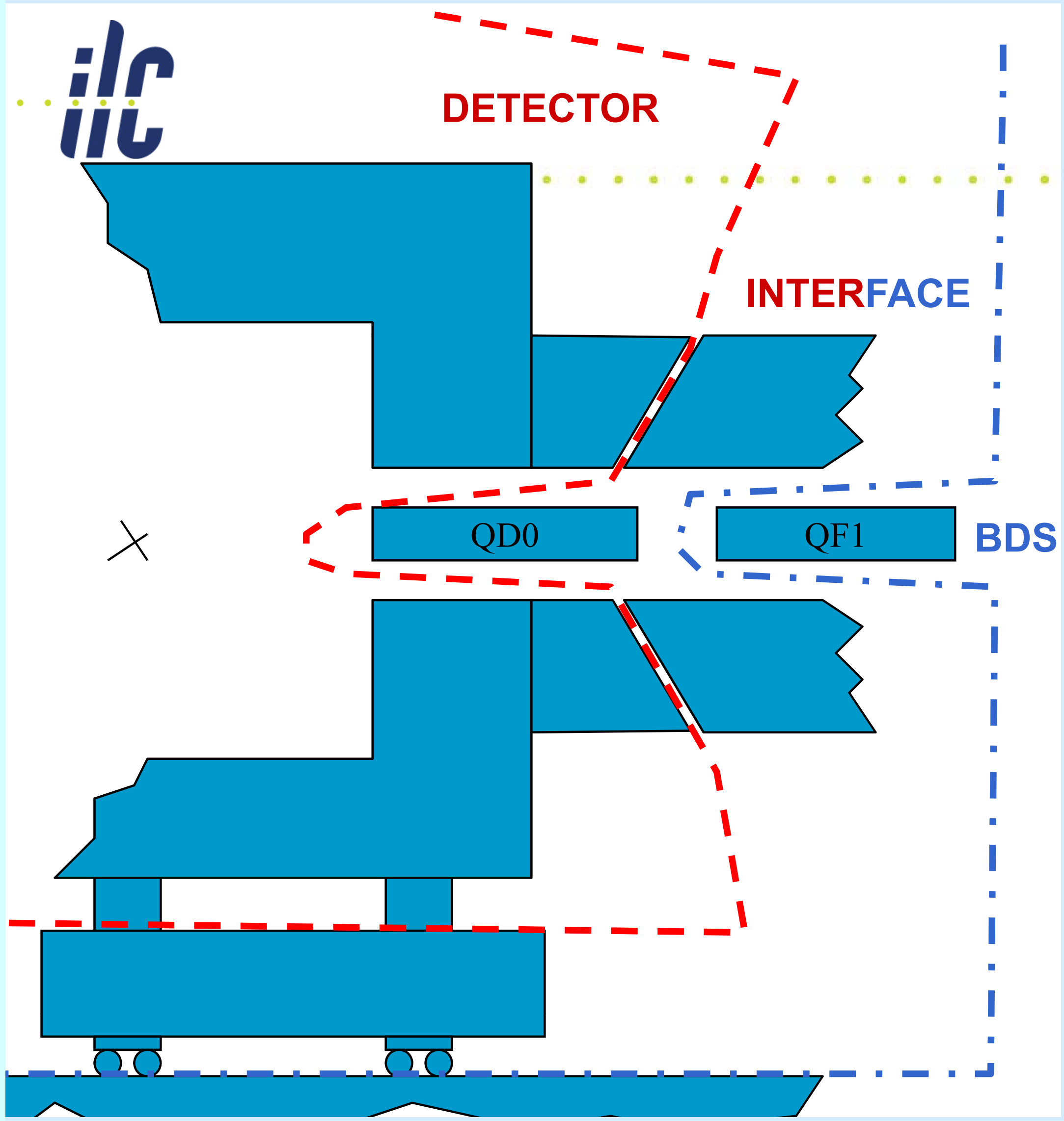
IR Interface Document

The following functional requirements have been identified:

- Final Doublet
- Elapsed time for an exchange of detectors
  - Roll-in and roll-out times
  - Cryogenic safety assumptions
- Vacuum
- Beam Feedback Systems
- Beam-beam parameter space
- QD0 support and alignment
- IR Hall geometry
  - Length
  - Beam height
- Radiation and magnetiv environment

Final Doublet

- QD0 moves with the detector
- QF1 remains stationary and is shared by both push-pull detectors
- Vaccum valve interface between QF1 and QD0
- QD0 L* between 3.5 and 4.5m, to be chosen by each detector
- QF1 L*=9.5m (magnet, cryostat and valves will extend to 9.0m), i.e. available space for detector is 18m along the beamline
- Helium supply (2K) for QD0 must be provided by service cryostat which moves with the detector
- QD0/QF1 magnets will be built and maintained by ILC-BDS
- QD0 alignment discussed later



4th Concept Suggestion

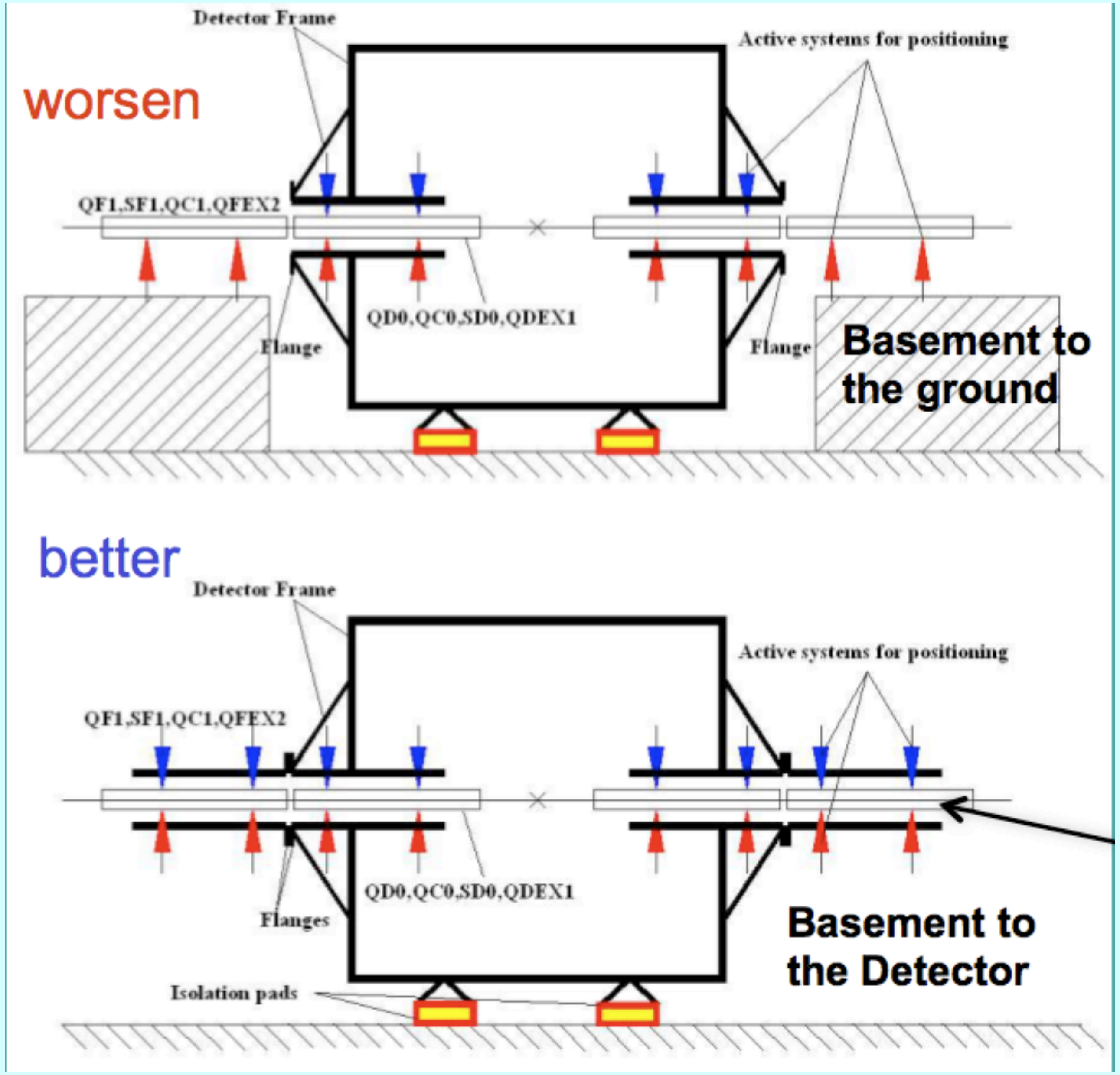
Stability concerns on final lens

Proposal:

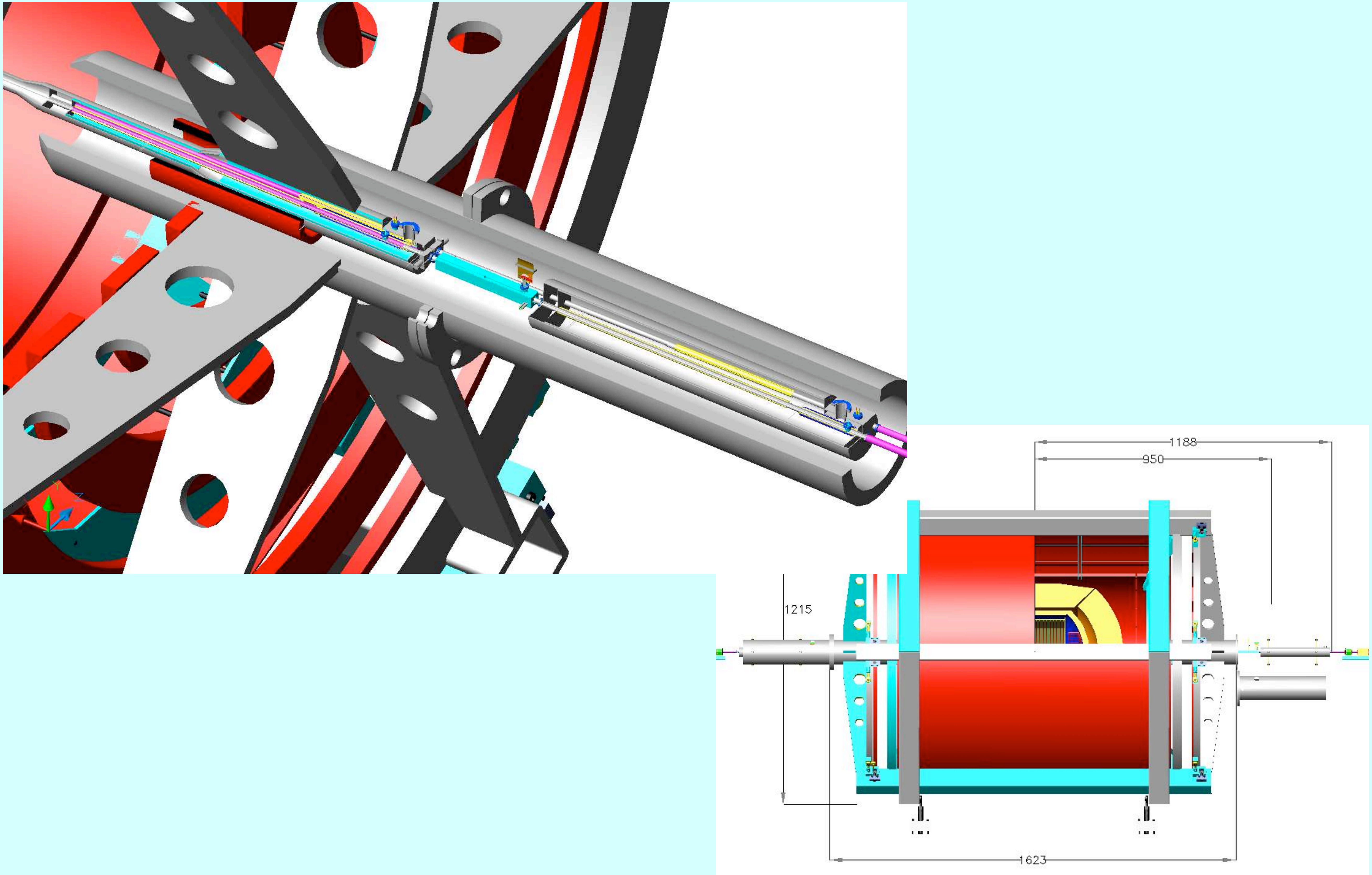
- Move QD0 with the detector
- Attach QF1 to detector frame in beam position

Problems:

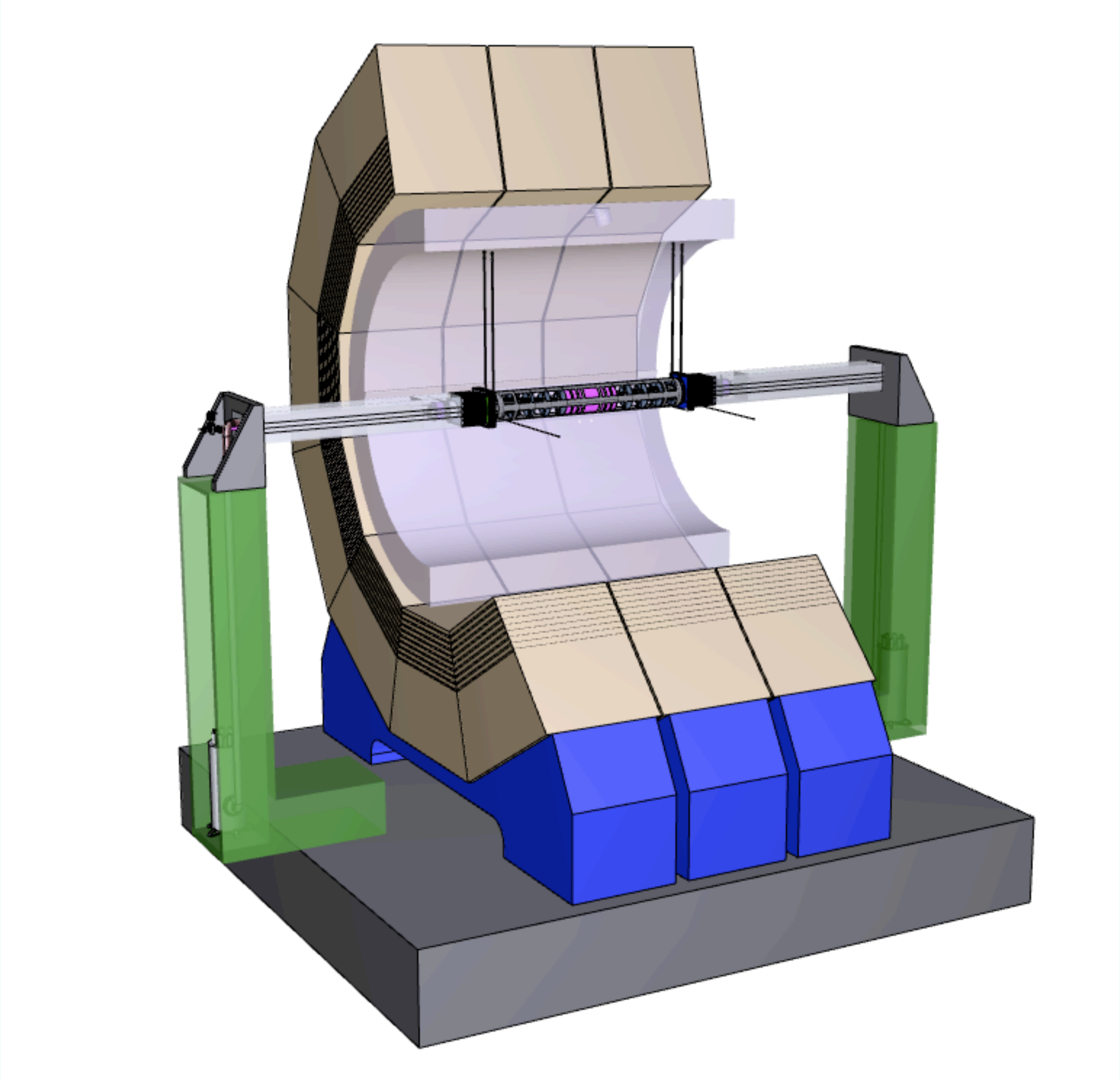
- QF1 is the reference for the alignment of the detector and the QD0 magnets
- Needs further studies



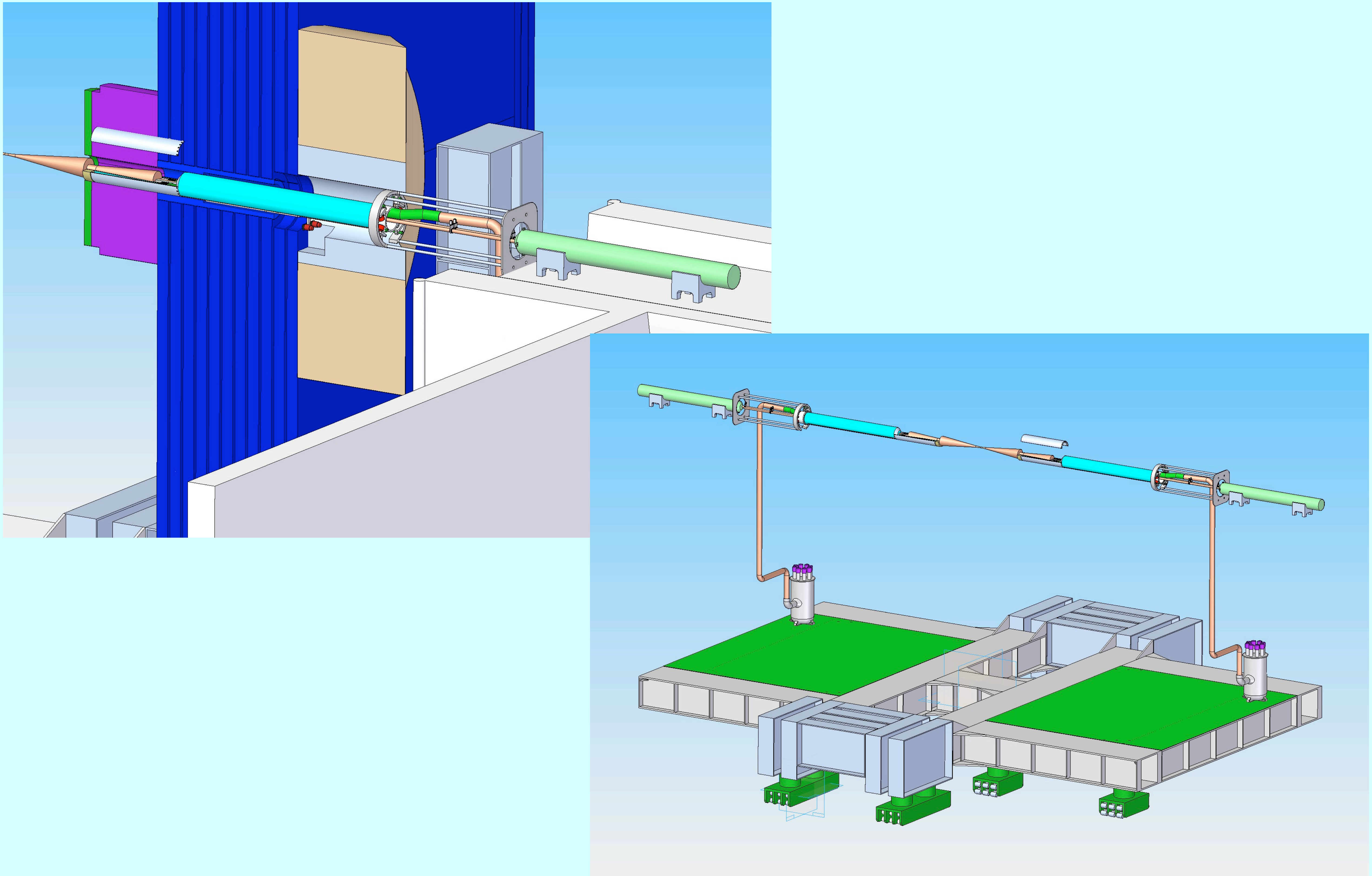
QD0/QF1 Support in the 4th Concept



QD0 Support in ILD



QD0 Support in SiD



Time for the Exchange of the Detectors

IR Interface document does not define times for roll-in/out or frequency of push-pulls!

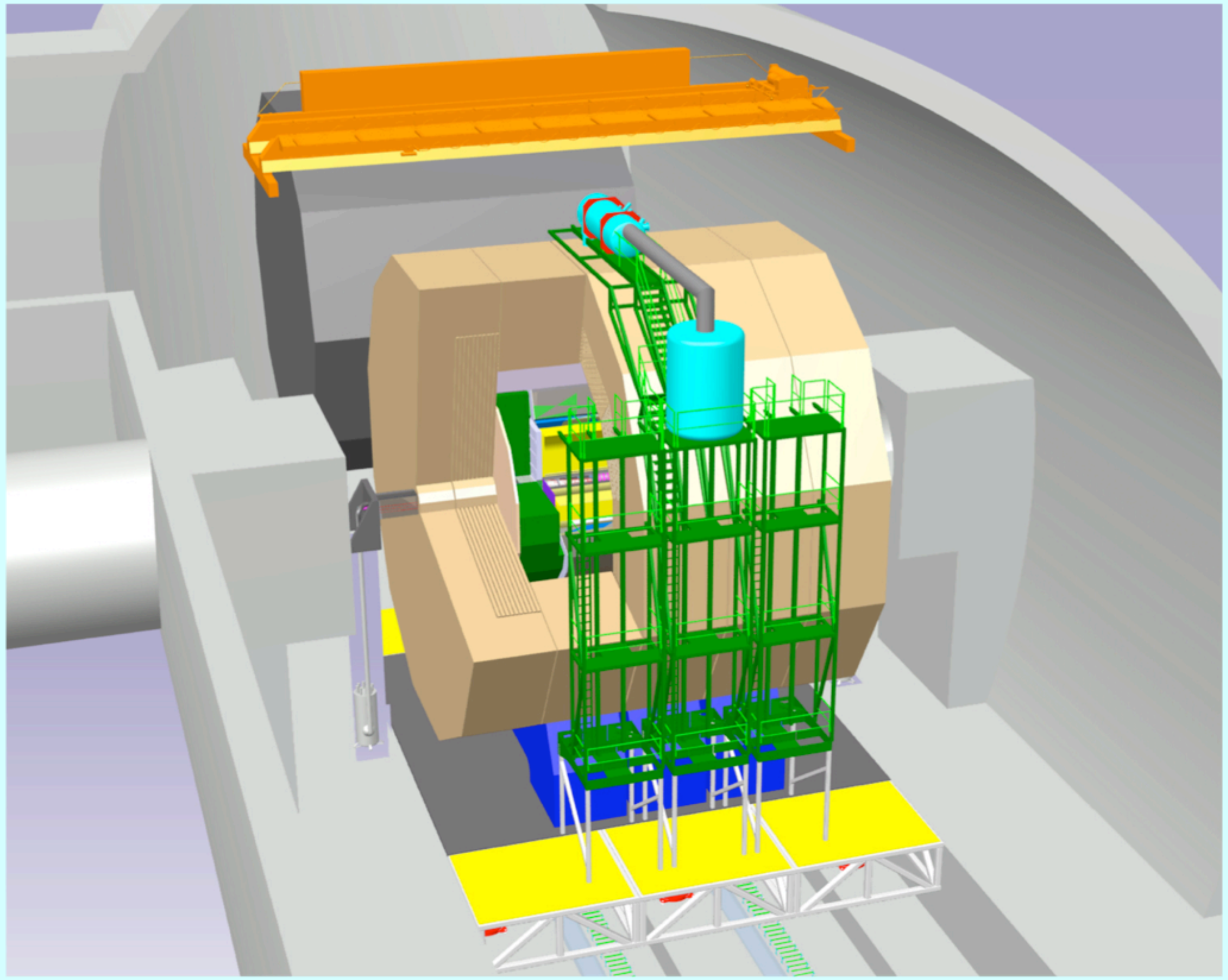
- Try to define how times for roll-in/out are measured
- Roll-out:
  - Start with end of ILC operations.
  - End when detector leaving the beamline could grant safe beneficial occupancy of the agreed upon floor space and shared resources (cranes, etc.) to the entering detector.
  - Would include time for the removal of shieldings (if any).
- Roll-in:
  - Would start with the granted beneficial occupancy as defined above.
  - Would end when safety authorities allow access to the garaged detector whatever the programme of the detector on the beamline is.

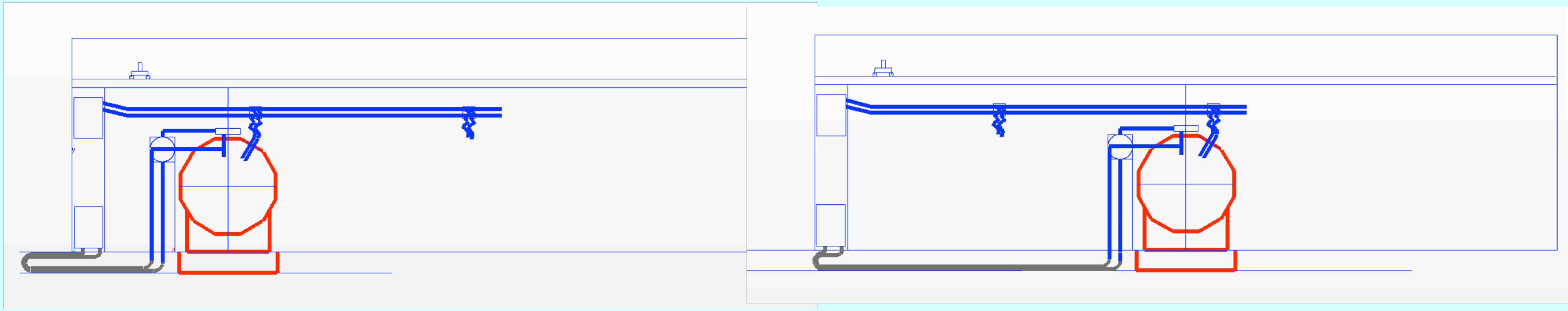
- Frequency of push-pull depends on the yet to be defined physics programme
  - Just state that time for push-pull should be less than 10% of the total operations time

Pushing and Pulling ILD

ILD would move on a platform

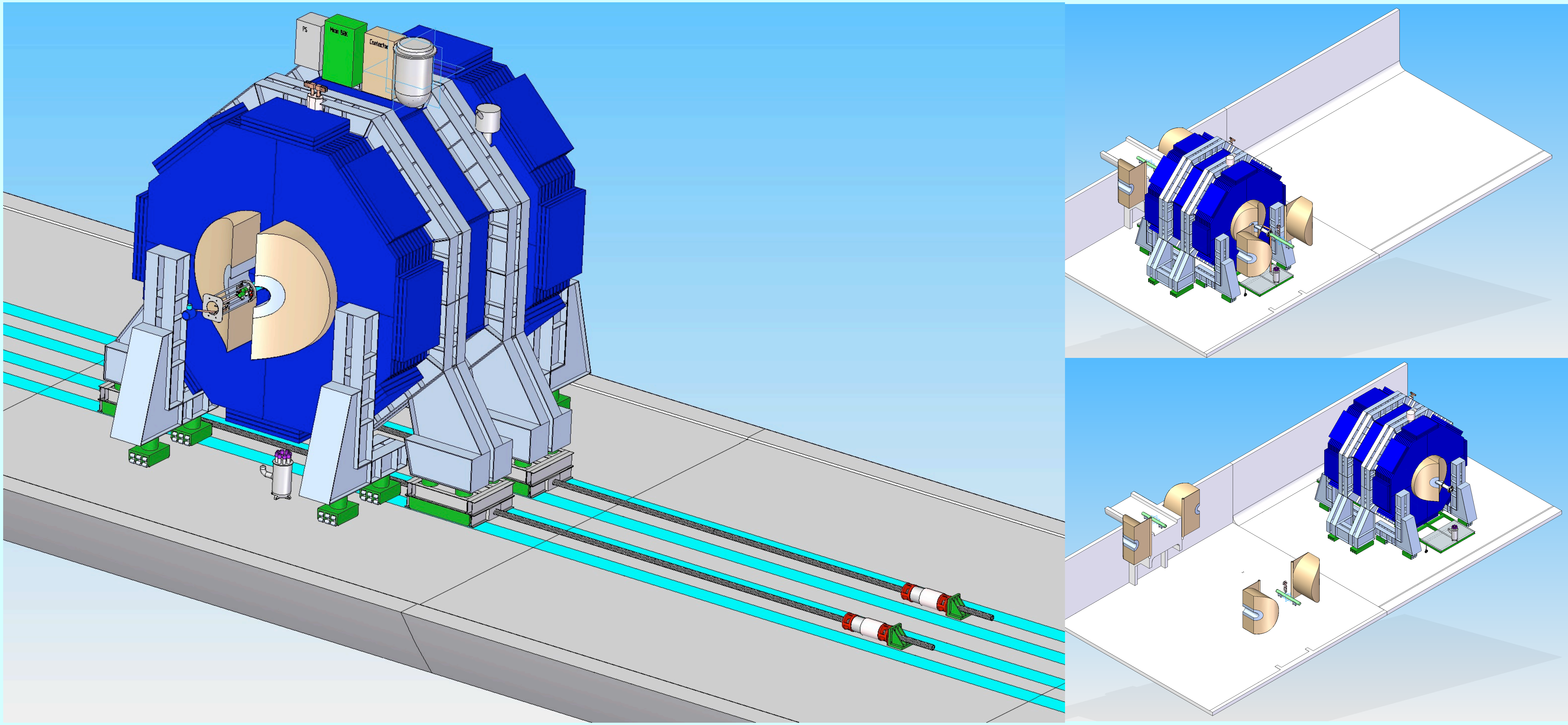
- Minimise vibrations during movement
- All services would be run through cable-chains (including cryogenics)
- Main bus-bar for voltage supply to the detector solenoid
- Aim: two days for the push- or pull-operation
  - one day for the mechanical movement
  - one day for calibration





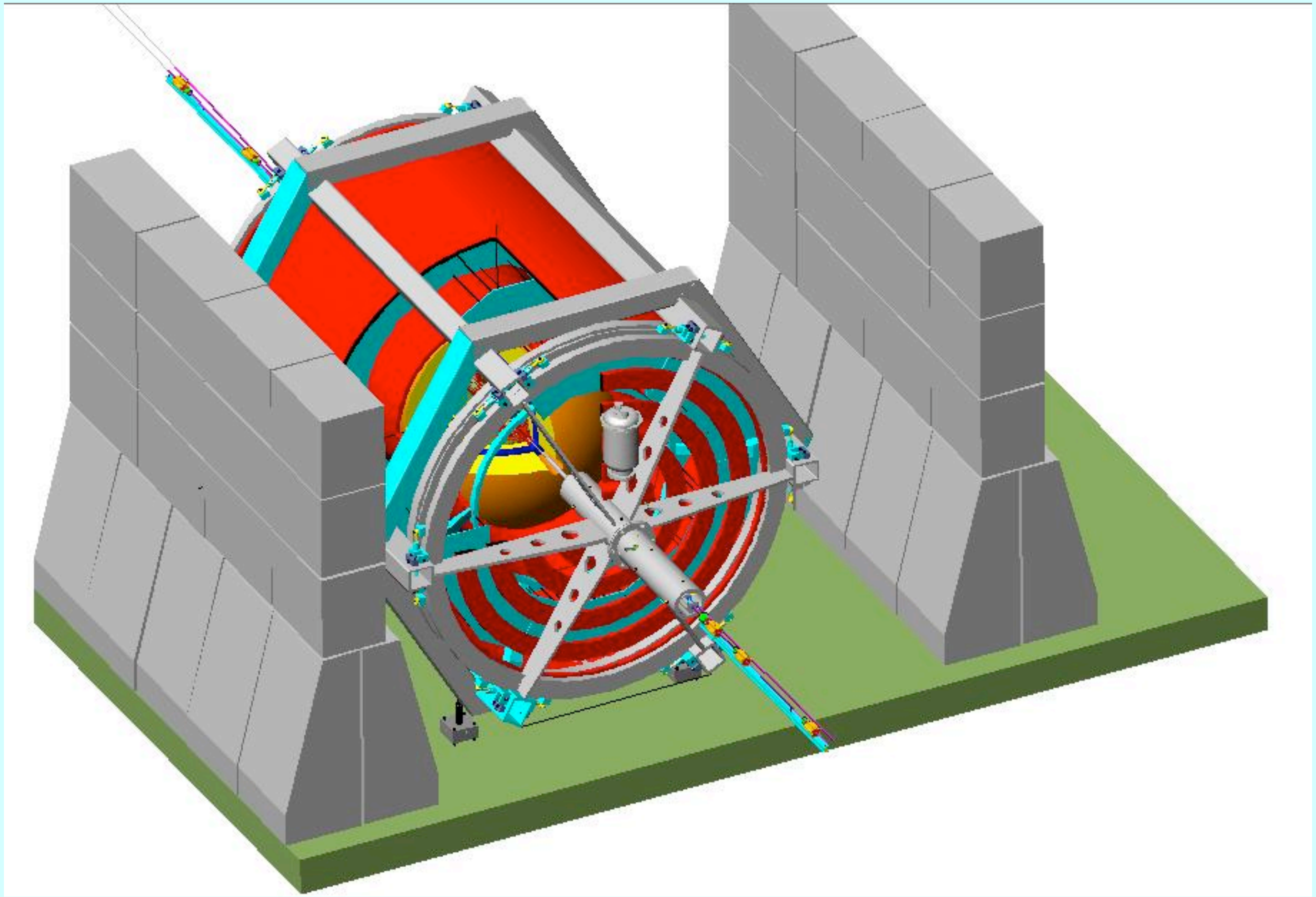
SiD Push-Pull Concept

- SiD will run on hardened steel rails using Hilman rollers
- Time needed ~1 day for luminosity-luminosity transition



4th Push-Pull Concept

- 4th is a very lightweight detector, which makes push-pull easier
- could also move on a platform to ease intereface with other detector

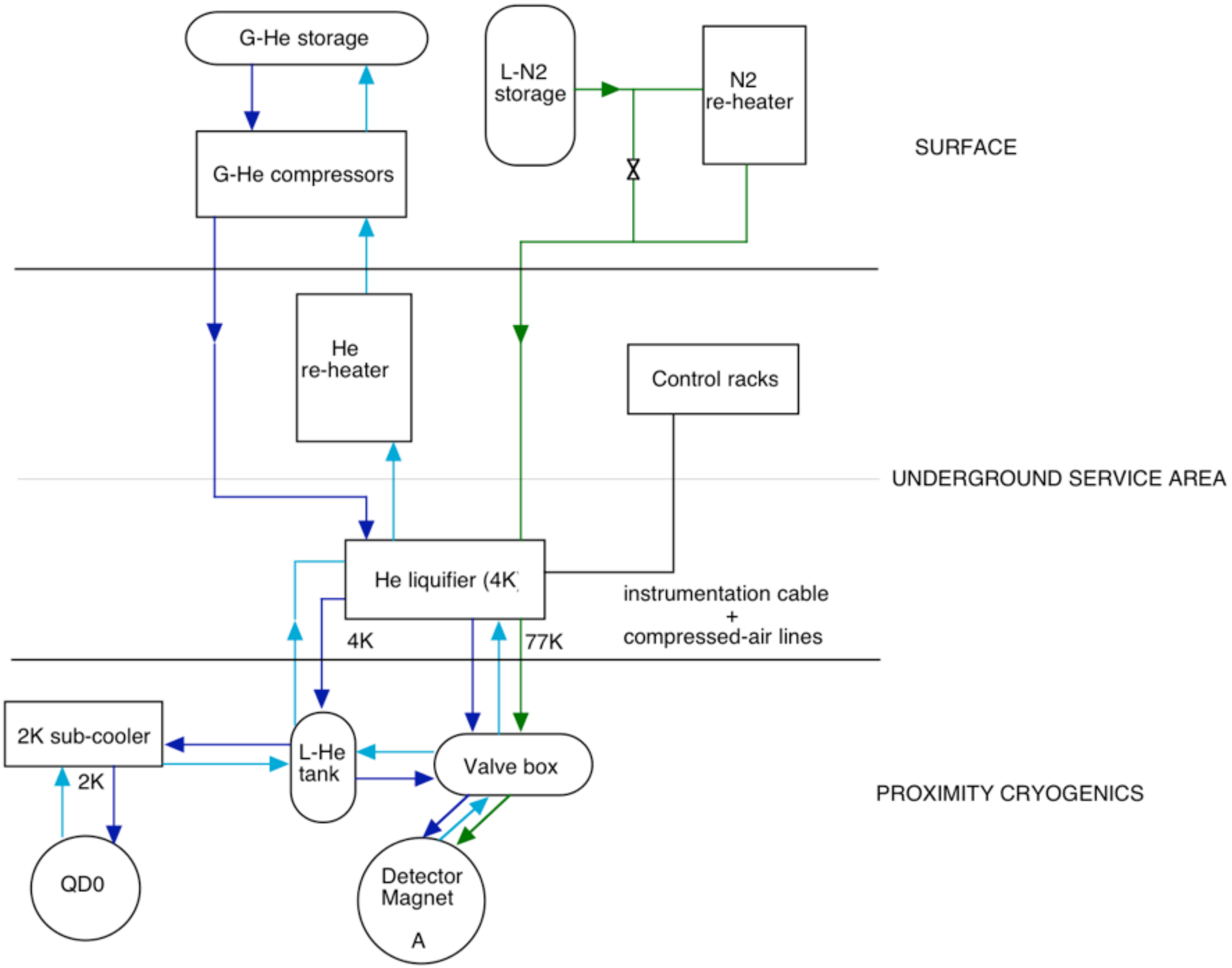


Cryogenics Safety Assumptions

Detector magnets need to be kept cold but de-energised during the movement

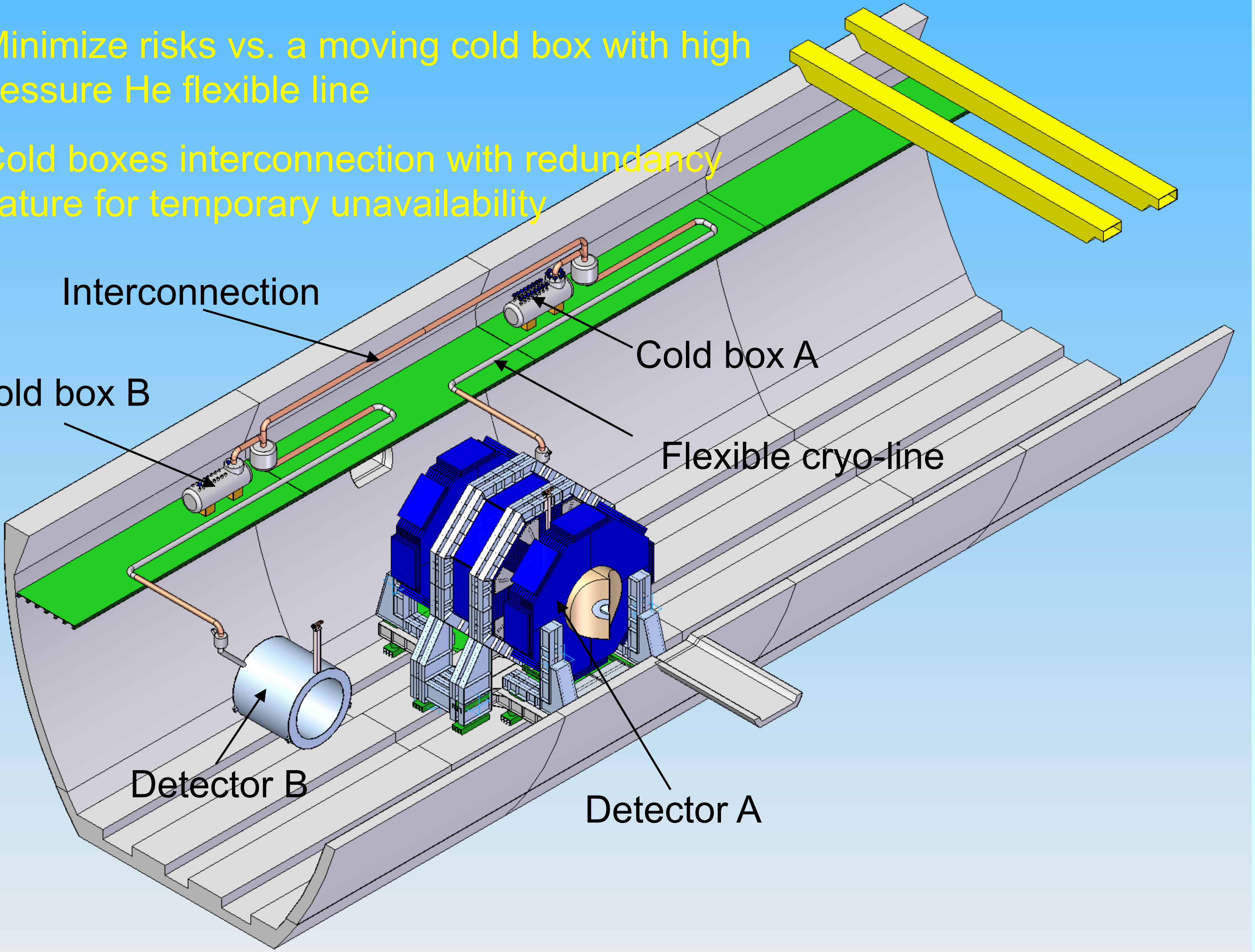
- Helium supply during the movement is needed
  - Either have the cryo cold-box on the platform and supply warm helium
  - Or have the cryo plant somewhere else (service cavern) and provide cold helium via flexible cryo lines
- Both solutions could work but need major R&D efforts

Helium Supply Example (ILD)



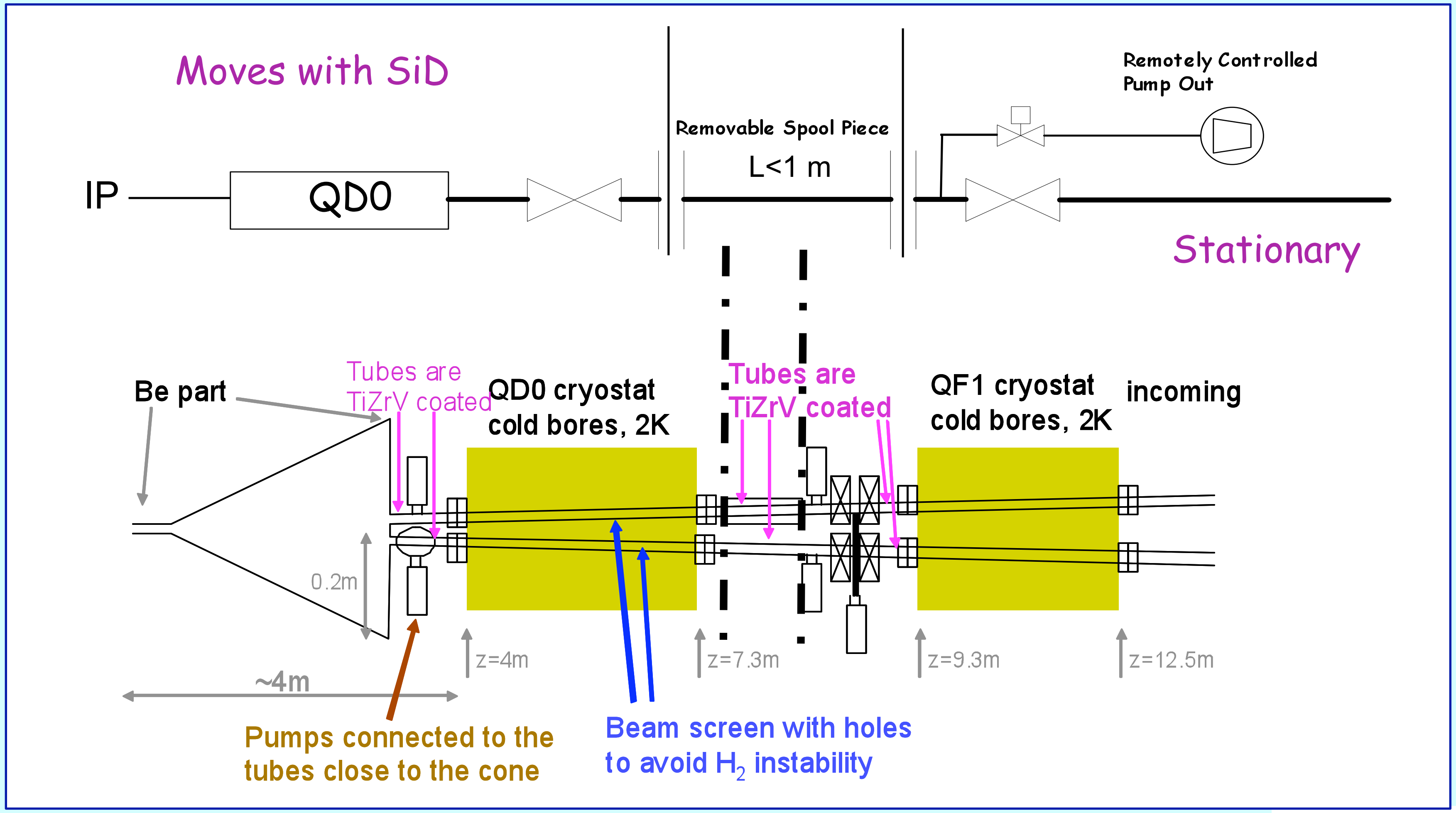
Cryogenics Study (SiD)

- Stationary cold box with flexible cryo-transfer line
- Minimize risks vs. a moving cold box with high pressure He flexible line
- Cold boxes interconnection with redundancy feature for temporary unavailability



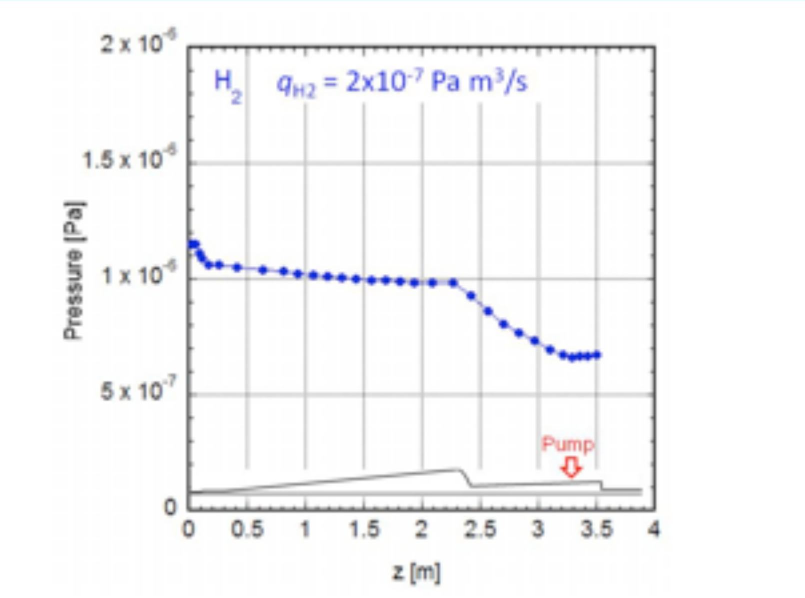
Vacuum

- Vacuum up to the valves between QD0 and QF1 will be provided by the BDS ($<10^{-9}$ mbar)
- Vacuum downstream of these valves is the choice and responsibility of the detectors

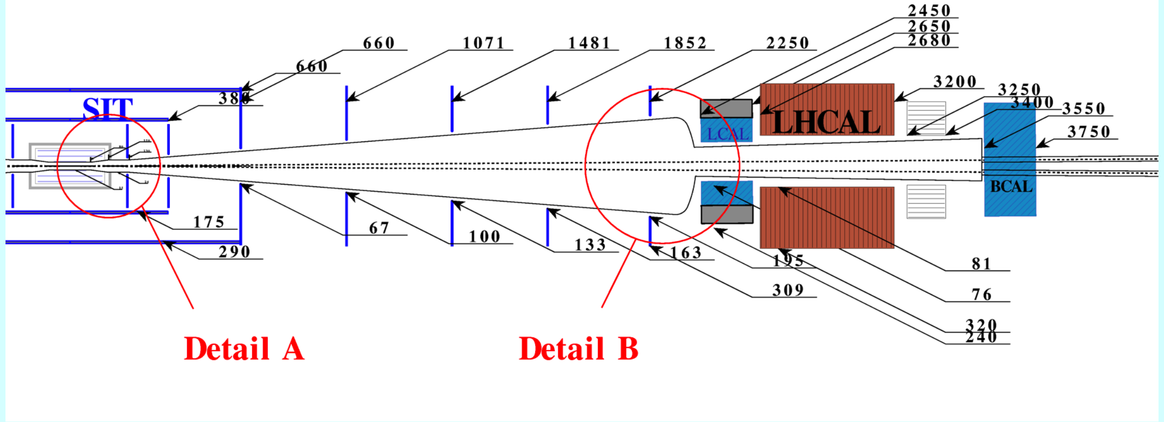


Pumps connected to the tubes close to the cone

Beam screen with holes to avoid H_2 instability

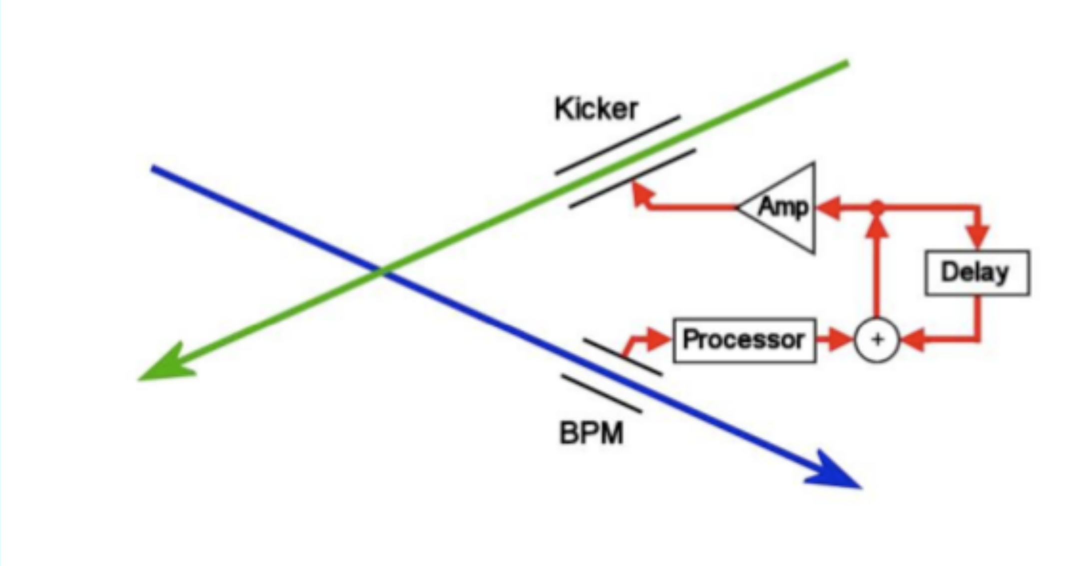


- ILD beam pipe conceptual design:
  - Made from beryllium (8kg mass in total)
  - Vacuum simulation study done, 10^{-9}mbar will be difficult to reach

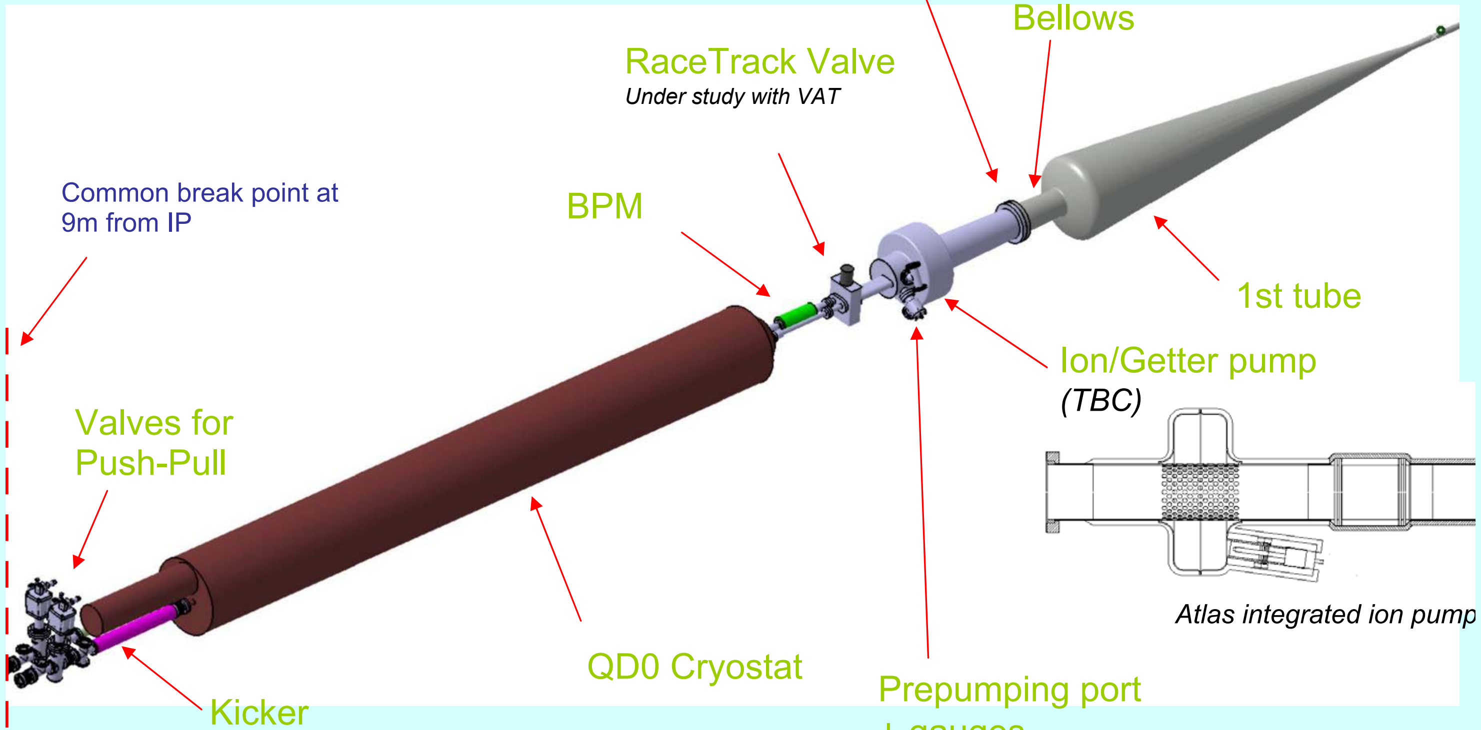


Beam Feedback System

- Luminosity feed-back system is required at the ILC
- BPM and stripline kicker need to be implemented in the detector environment
  - kicker at the back of QD0
  - BPM behind the BeamCal in a region with low backgrounds



- Beam line design for 14mrad and L* 4,5m



DN150CF flange

IP

Bellows

RaceTrack Valve

Under study with VAT

Common break point at 9m from IP

BPM

1st tube

Ion/Getter pump

(TBC)

Valves for Push-Pull

Atlas integrated ion pump

QD0 Cryostat

Prepumping port + gauges

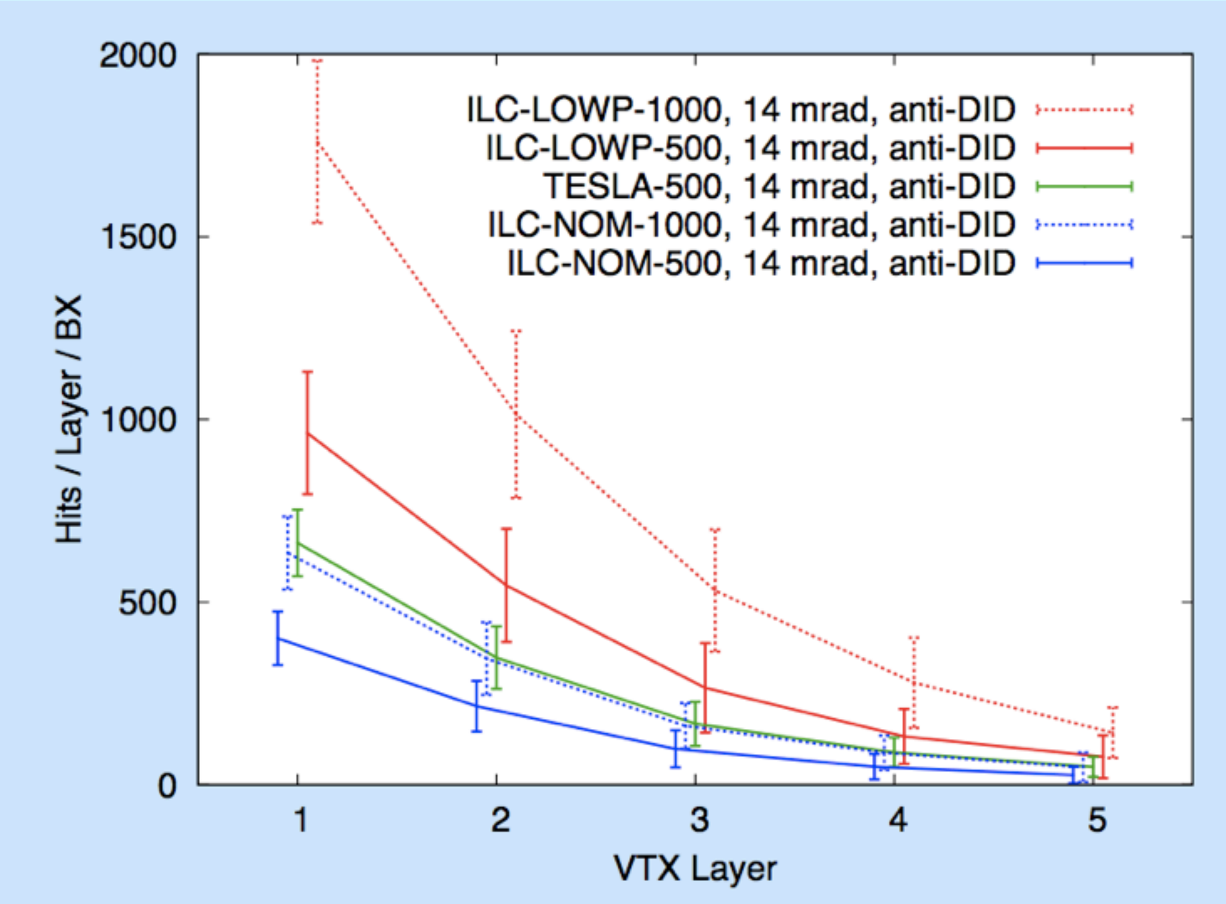
Kicker

More BPM's?

Beam Parameter Space

The beam parameters for ILC are defined in a parameter space in the RDR. Examples parameter sets are defined, e.g. Nominal, Low-P, etc.)

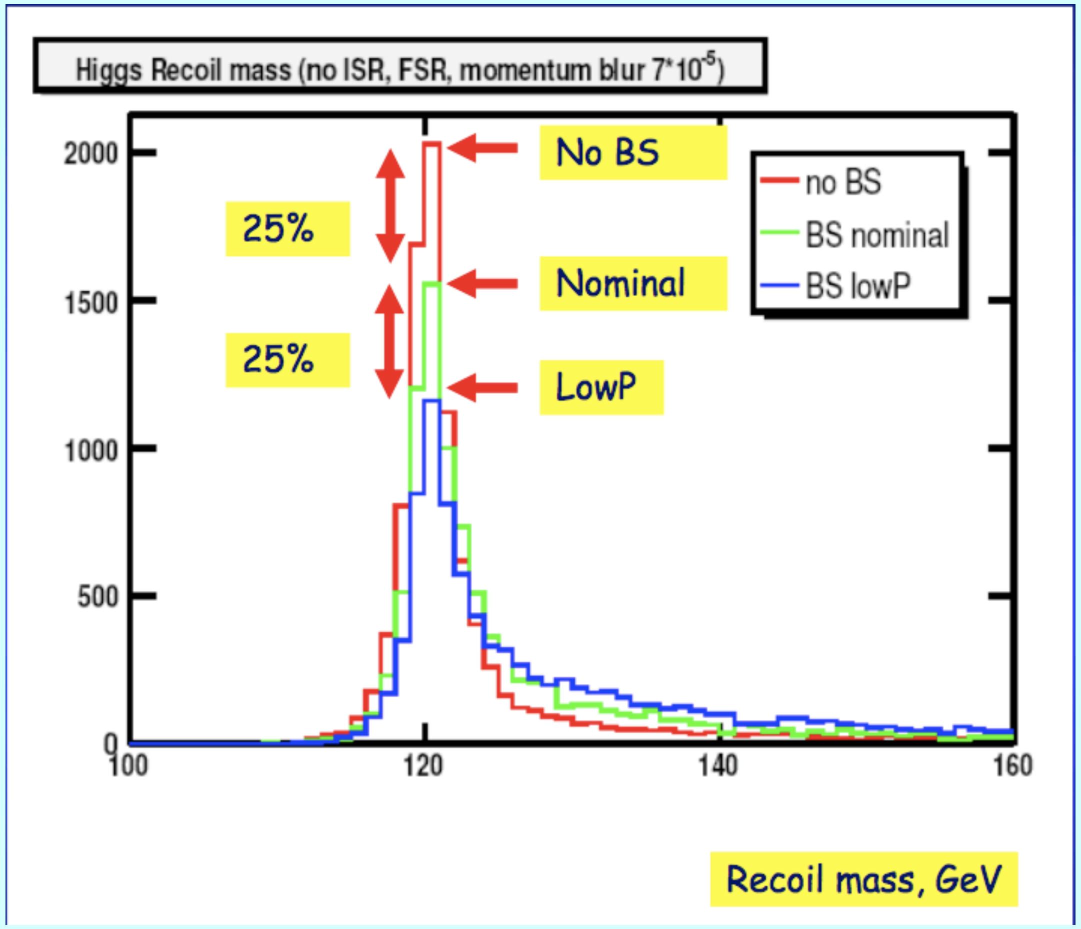
- Each detector must be able to function with nominal parameters
- Discussions for other parameter sets (Low-P, Low-N, Large-Y) is ongoing
- Concept groups comment on impact of parameter sets in their LoIs

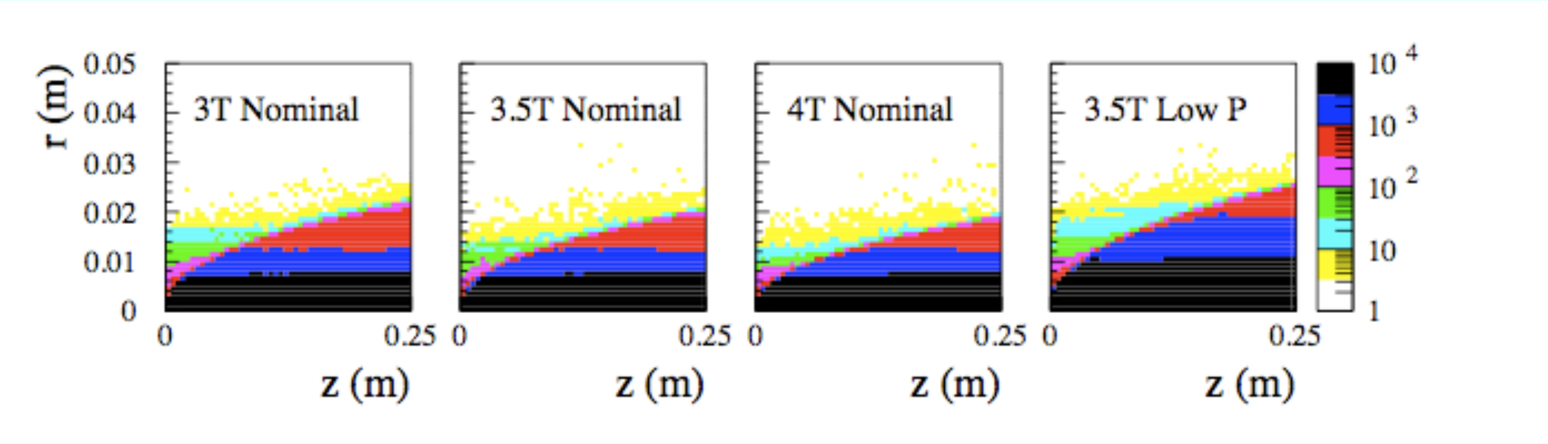


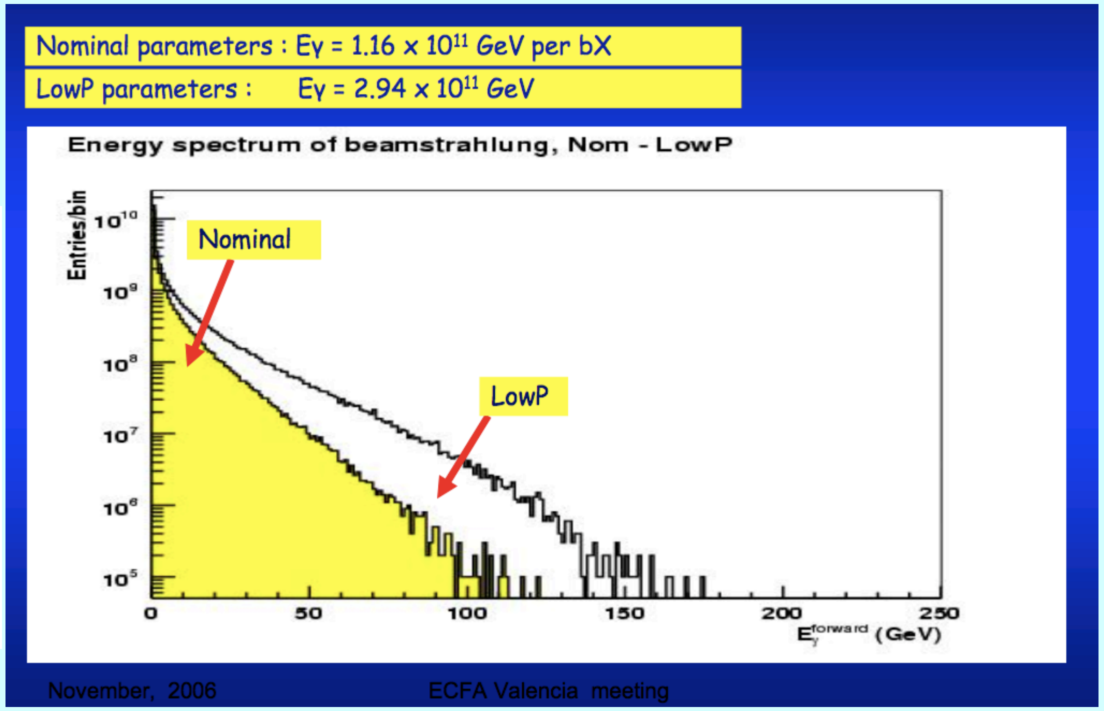
Beam Parameters Impact on Physics

ILC Beam Parameter Plane

- Low-P parameter (RDR) set is most critical for backgrounds
  - Might have impact on VTX design (e.g. radius of inner layers)
- Larger beamstrahlung losses have also impact on physics via dilution of luminosity spectrum
- Alternative parameter sets using e.g. the travelling focus concept might help
  - Needs further study by the BDS groups
  - Part of the minimum machine discussions





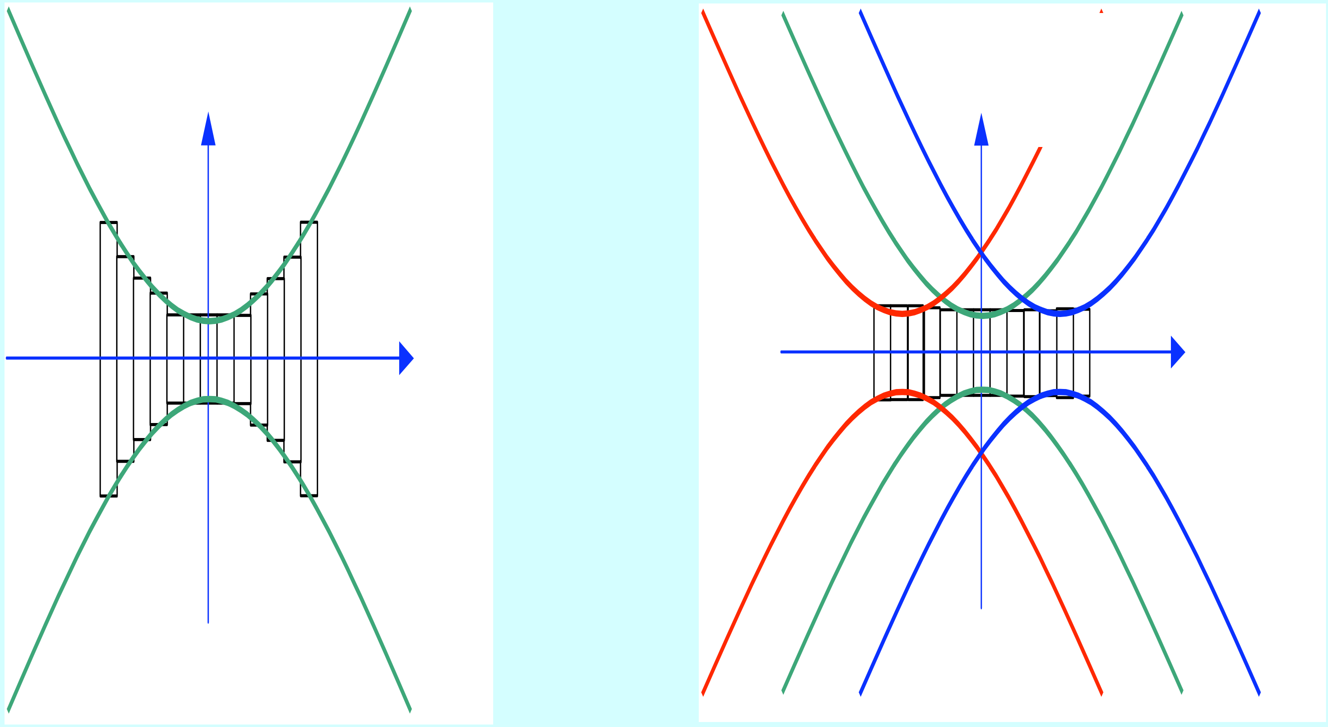

Nominal parameters : Eγ = 1.16 x 10¹¹ GeV per bX

LowP parameters : Eγ = 2.94 x 10¹¹ GeV

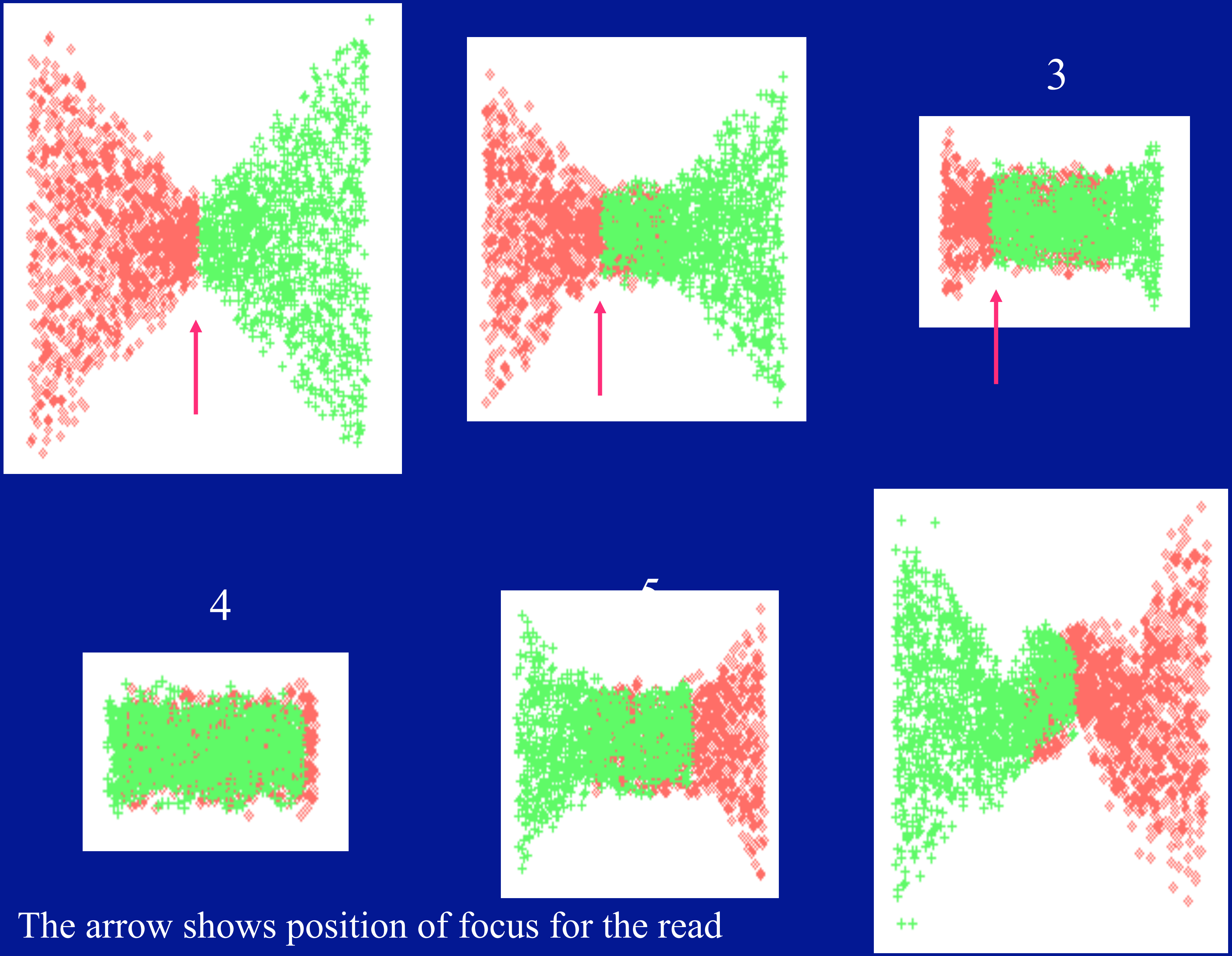
November, 2006 ECFA Valencia meeting

Travelling Focus Concept

- Idea:
  - Arrange for finite chromaticity at the IP
  - Create z-correlated energy spread along the bunch
- Beats the hourglass effect at the IP, increases luminosity!
- Could help to ease the effects of the Low-P parameters by allowing for larger bunch length
- Needs more studies



Travelling Focus Concept



The arrow shows position of focus for the read beam during travelling focus collision

Alignment Requirements

Detector axis:

- ±1mm and 100µrad w.r.t. line defined by QF1
- detector height adjustment range: ± several cm, depending on geological requirements

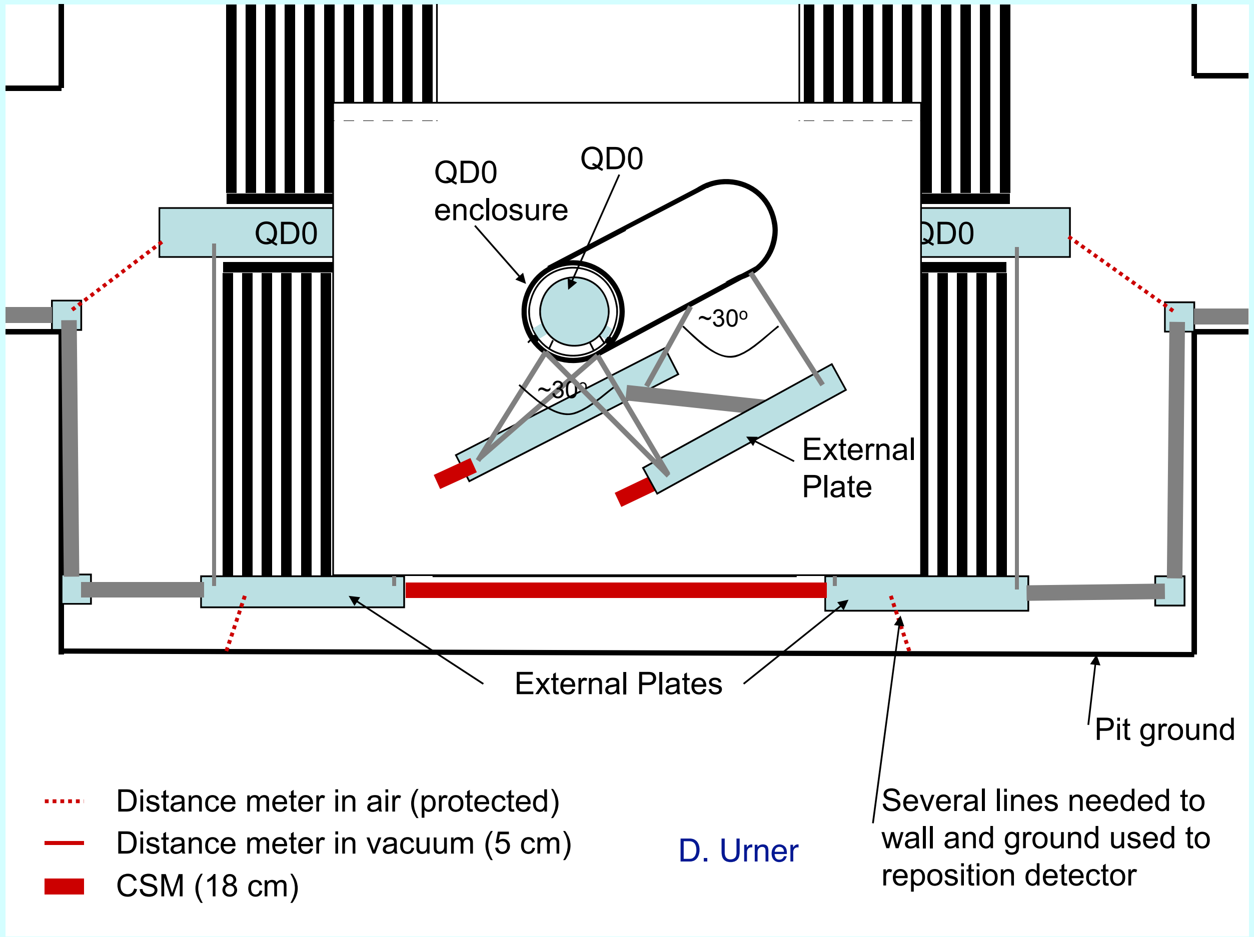
QD0 alignment:

- Alignment system:
  - Degrees of freedom: 5 (x,y,pitch,yaw,roll)
  - Range per d.o.f.: ±2mm, ±30mrad (roll), ±1 mrad (pitch, yaw)
  - Step size per d.o.f.: 0.05 µm
- Accuracy before low-intensity beams are allowed to pass:
  - ±50µm (x,y), ±20mrad (roll), ±20µrad (pitch, yaw)
- Accuracy and stability after beam-based alignment:
  - ±200nm and 0.1 µrad w.r.t. line defined by QF1 stable over 200ms between bunch trains
  - QD0 vibration stability: less than 50 nm within 1ms bunch train

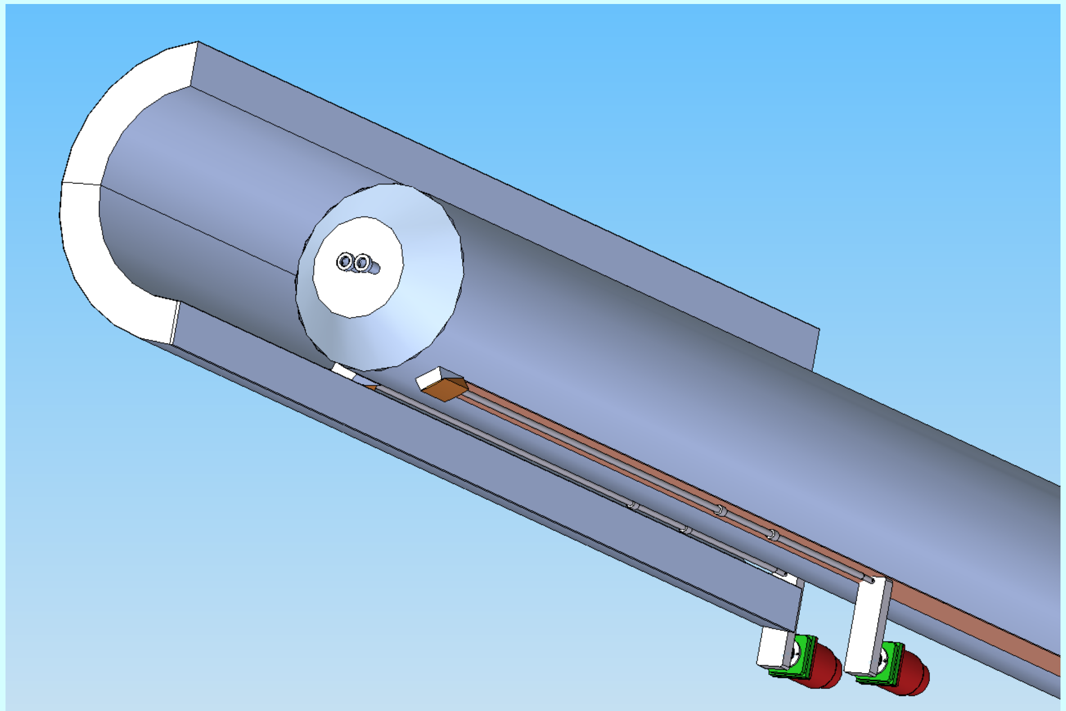
  - Control of the mover system will remain under control of BDS system and might be adjusted during the run

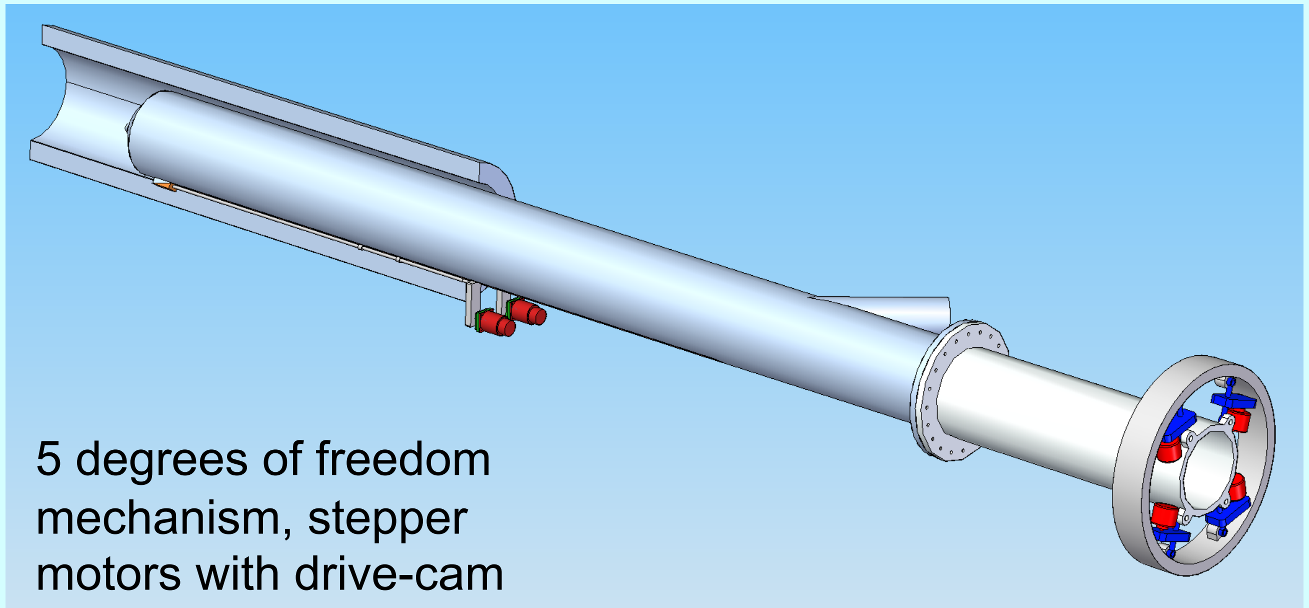
Alignment

- Interferometric laser system could be used to align both QD0 magnets with respect to each other and to the beam axis
- Could also be used to align the detector itself
- Conceptual studies have started



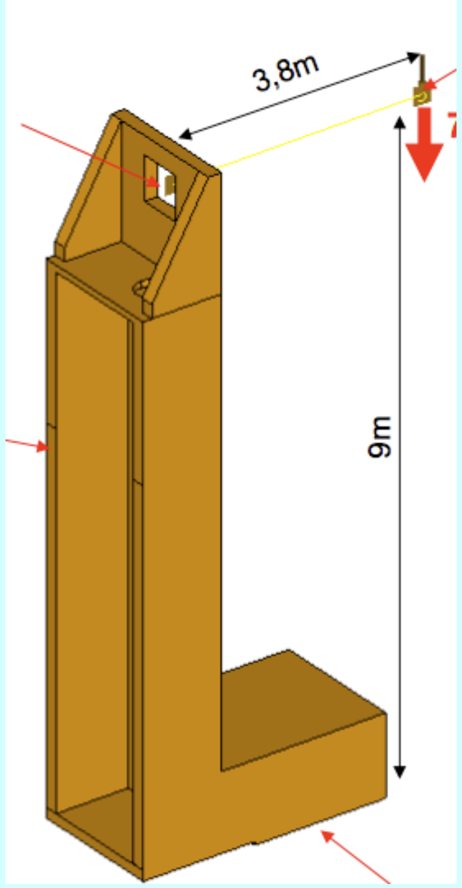
D. Urner

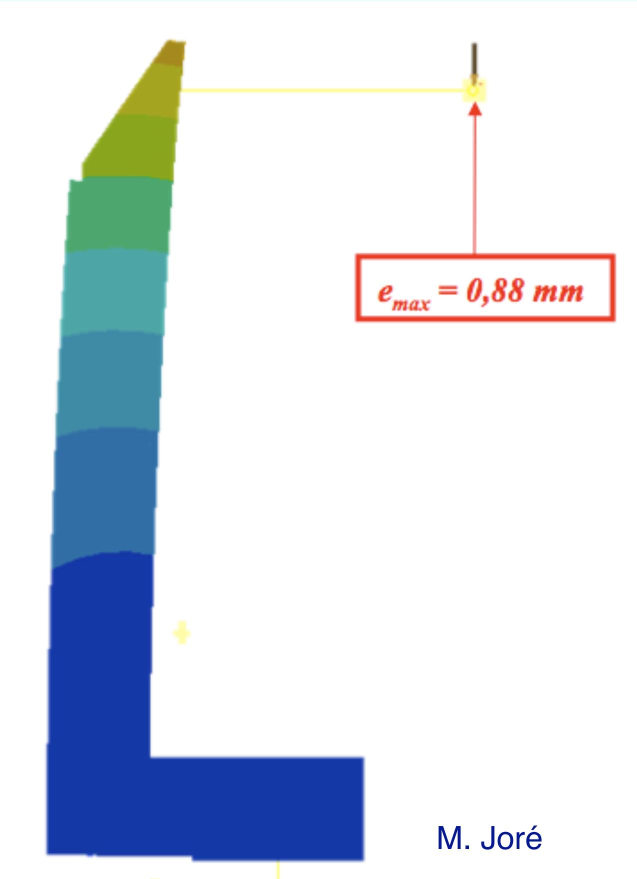




5 degrees of freedom mechanism, stepper motors with drive-cam

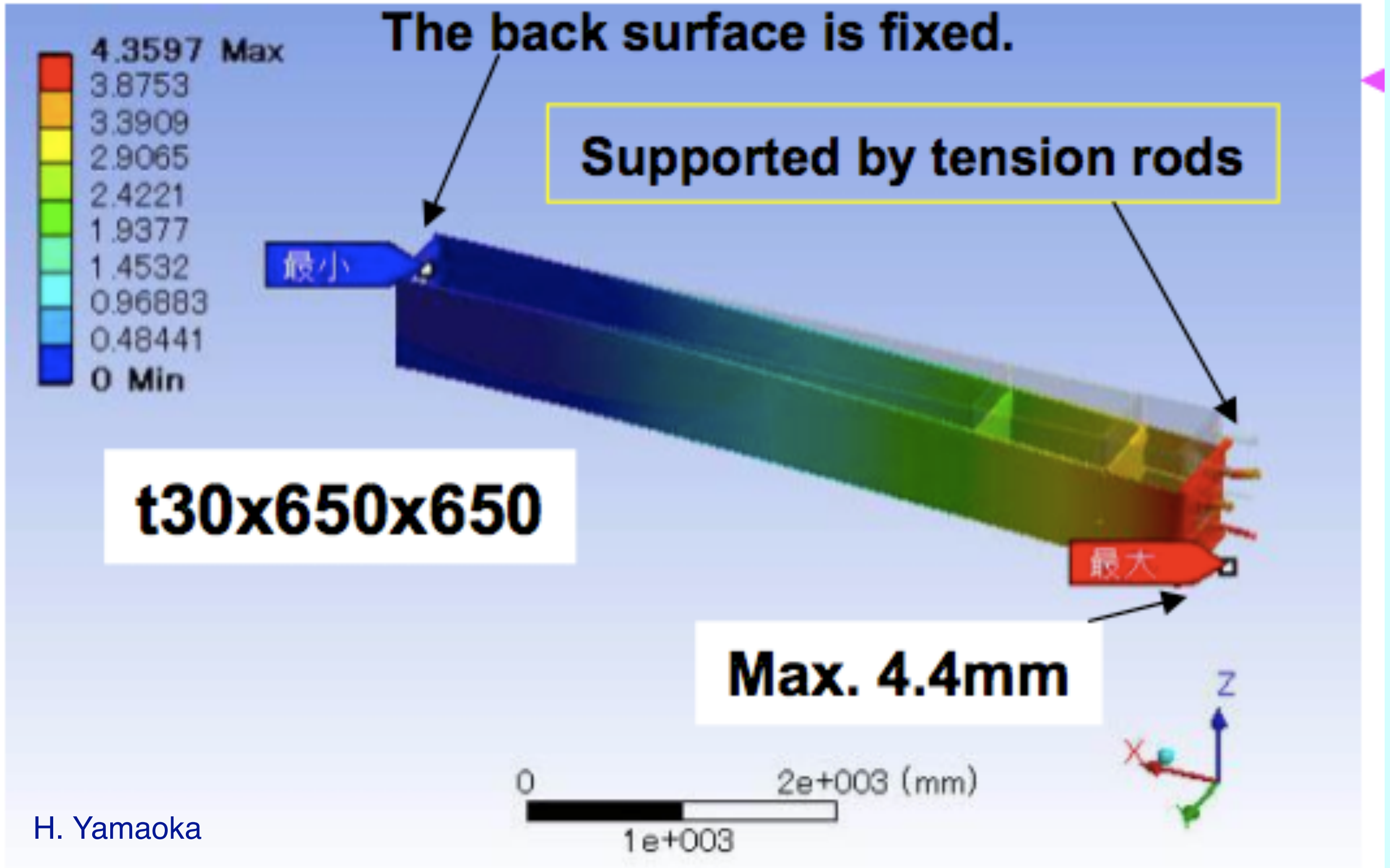
QD0 Support (ILD)





$e_{max} = 0{,}88\ mm$

M. Joré



The back surface is fixed.

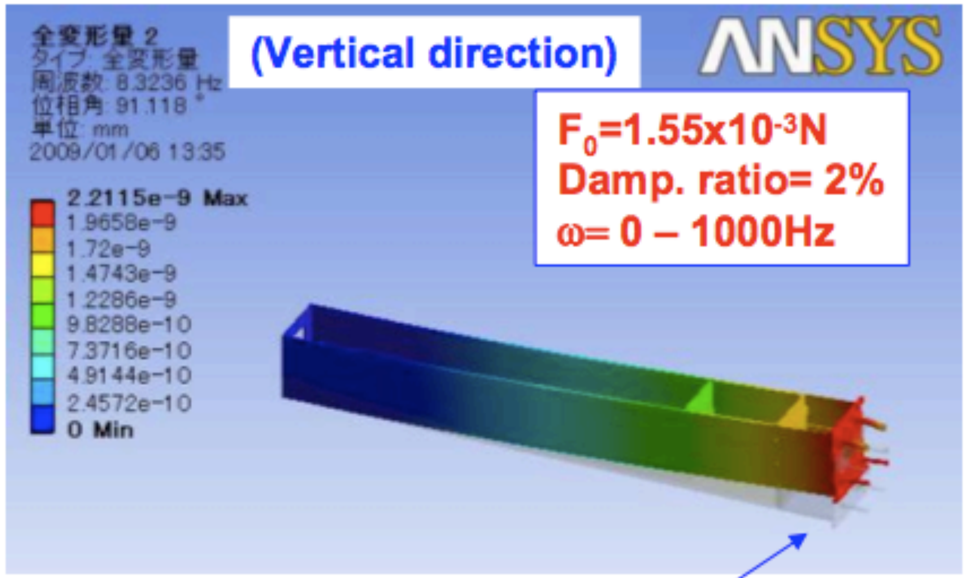
Supported by tension rods

t30x650x650

Max. 4.4mm

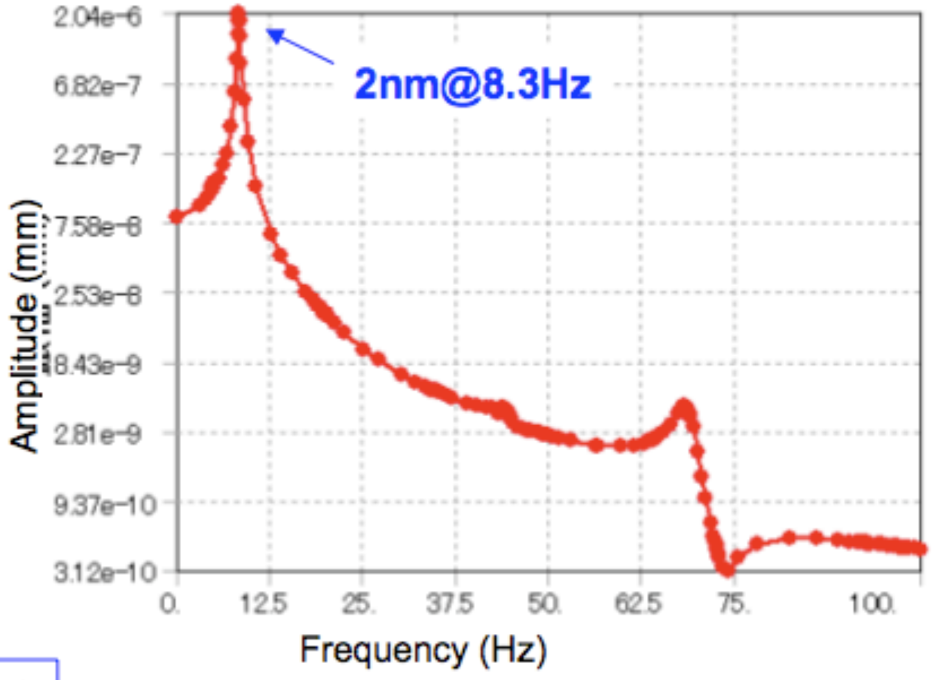
H. Yamaoka

Amplitude due to ground motion



(Vertical direction)

$F_0 = 1.55 \times 10^{-3}$N
Damp. ratio= 2%
ω= 0 – 1000Hz



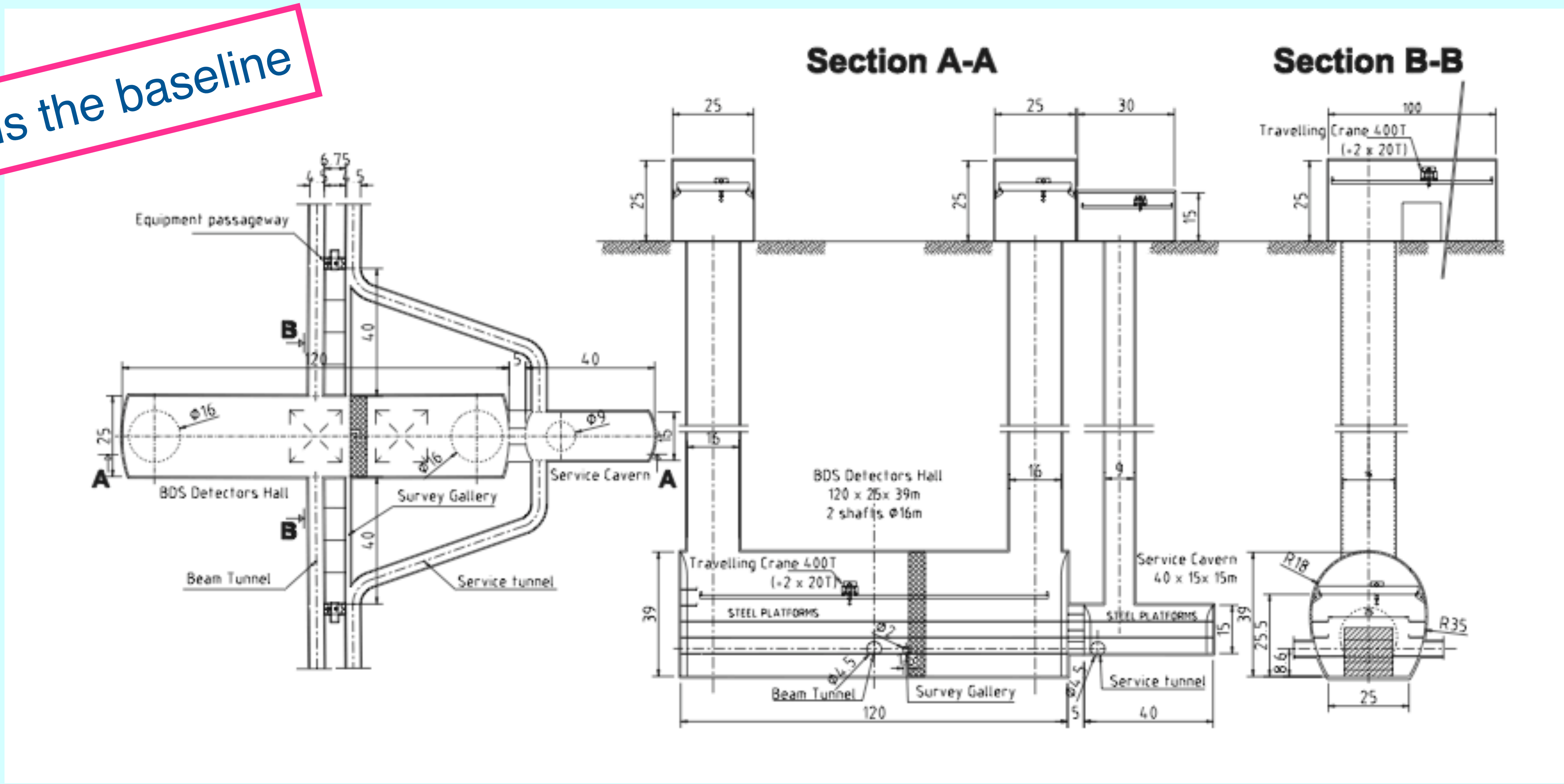
2nm@8.3Hz

→ Amplitude: 2nm< 50nm @8.3Hz (Vetical direction)

H. Yamaoka

Underground Cavern Issues

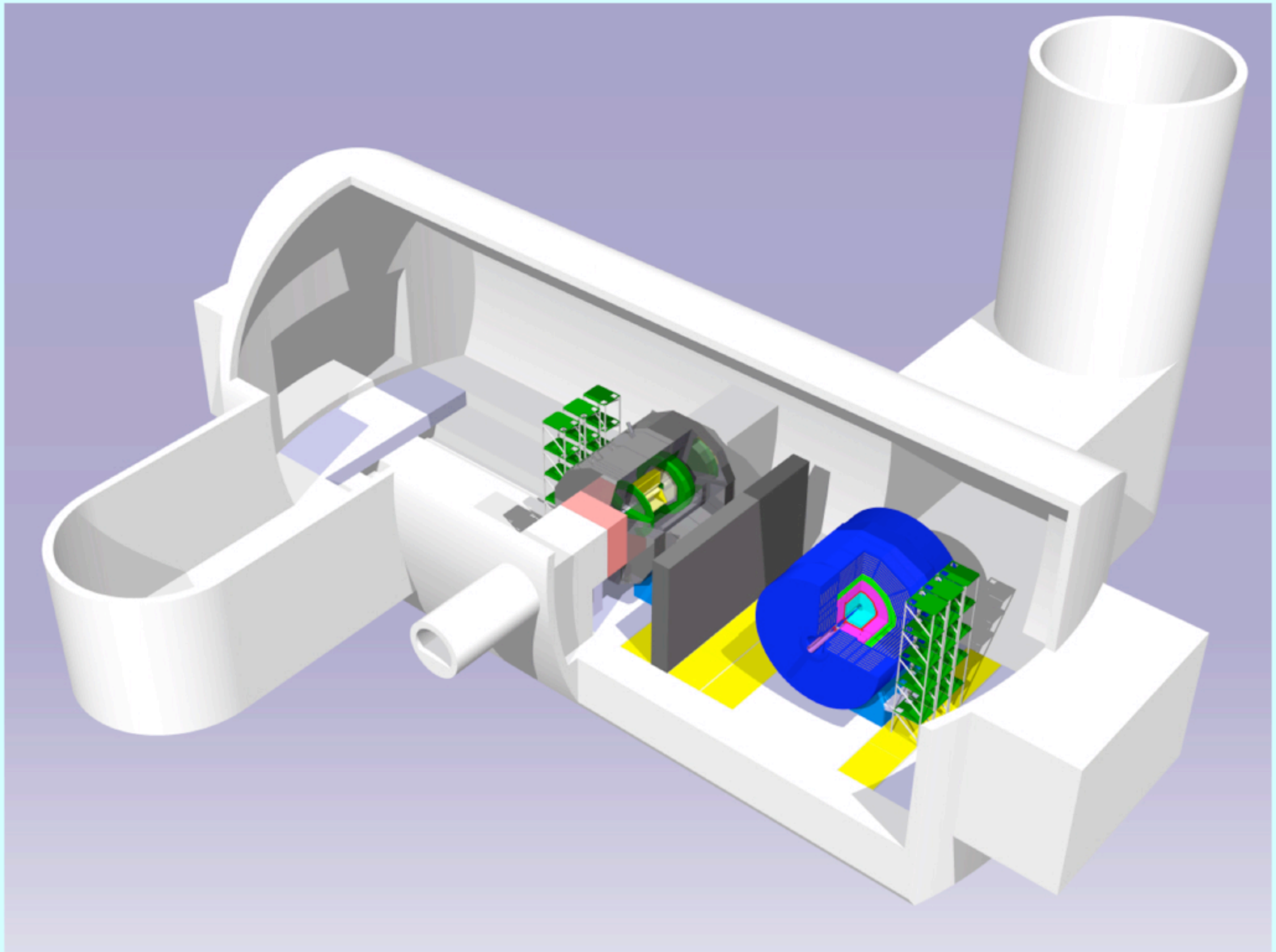
- Detectors can occupy up to 18m along the beamline (discussed before)
- Beam height is 10-12m above floor (sufficient for ILD on platform)
- Garage position of the off-beamline detector starts 15m perpendicular from the beam pipe
  - This has consequences for radiation and magnetic environment
  - The garaged detector should not be disturbed by the operation of the beamline detector and vice-versa



RDR is the baseline

Underground Cavern Study

- ILD presents study for underground cavern in the LoI
- More transverse space in the garage position for detector assembly
- Shafts relocated to the side alcoves
  - safety issue!
- Service cavern for both detectors

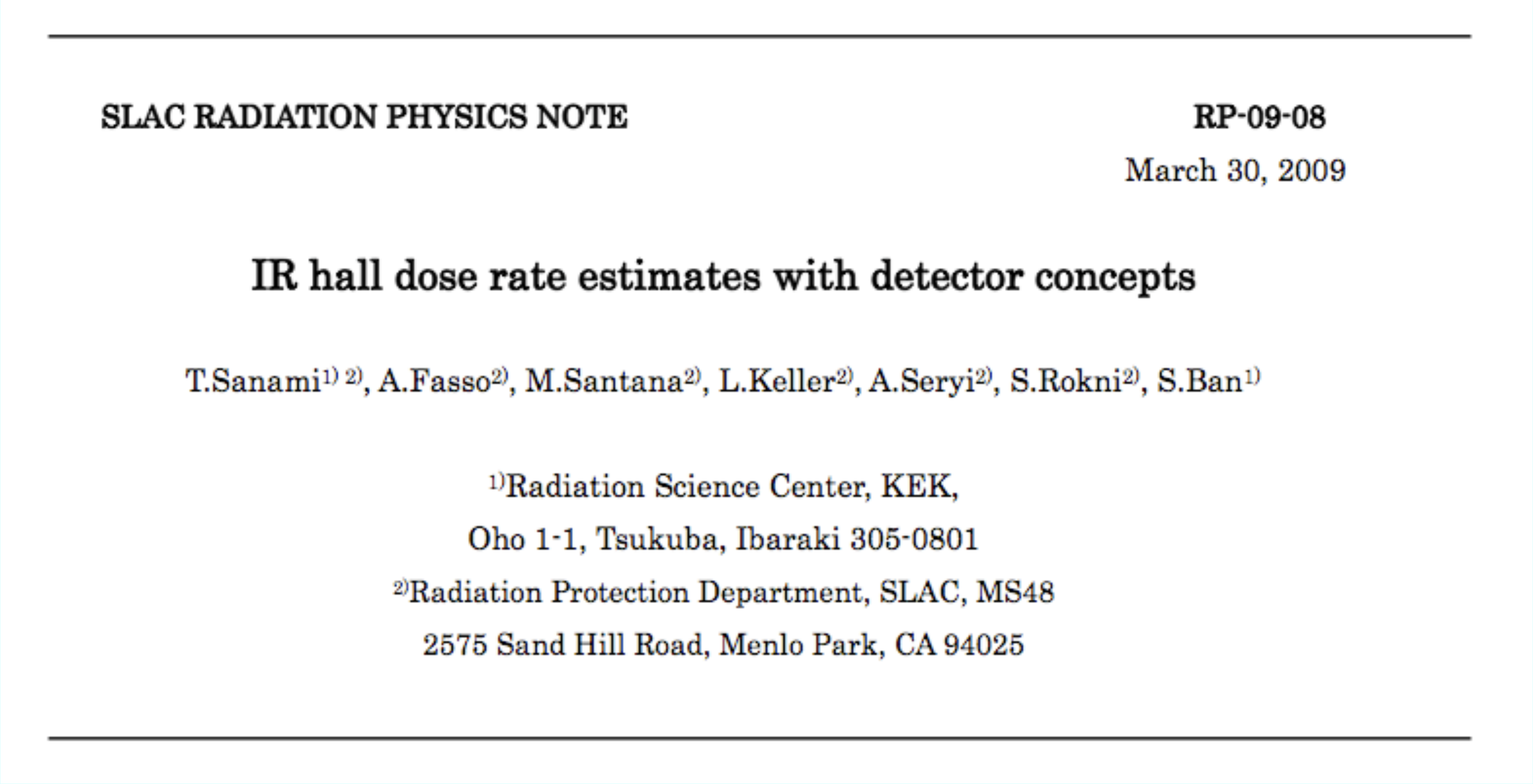


Radiation Environment

- Radiation shielding is crucial if two detectors occupy the same hall
- Detectors need to be either self-shielding or take responsibility for additional shields
  - choice of shielding will have impact on hall design
- Radiation requirements depend on the site. For the time being assume:
  - normal operation: less than 0.5µSv/h everywhere beyond the 15m-line
  - accidental beam loss: simultaneous loss of both beams with maximum power anywhere in the BDS or detector: dose less than 250 mSv/h and 1mSv per accident. Beam shut-off assumed after one beam train.
  - these numbers are compatible with regulations at KEK, CERN, FNAL for supervised access or similar
- Radiation levels on the beamline could be different, but depend on the access procedures of the on-beamline detector

Radiation Shielding

Simulations done by T. Sanami et al.:



SLAC RADIATION PHYSICS NOTE **RP-09-08**

March 30, 2009

IR hall dose rate estimates with detector concepts

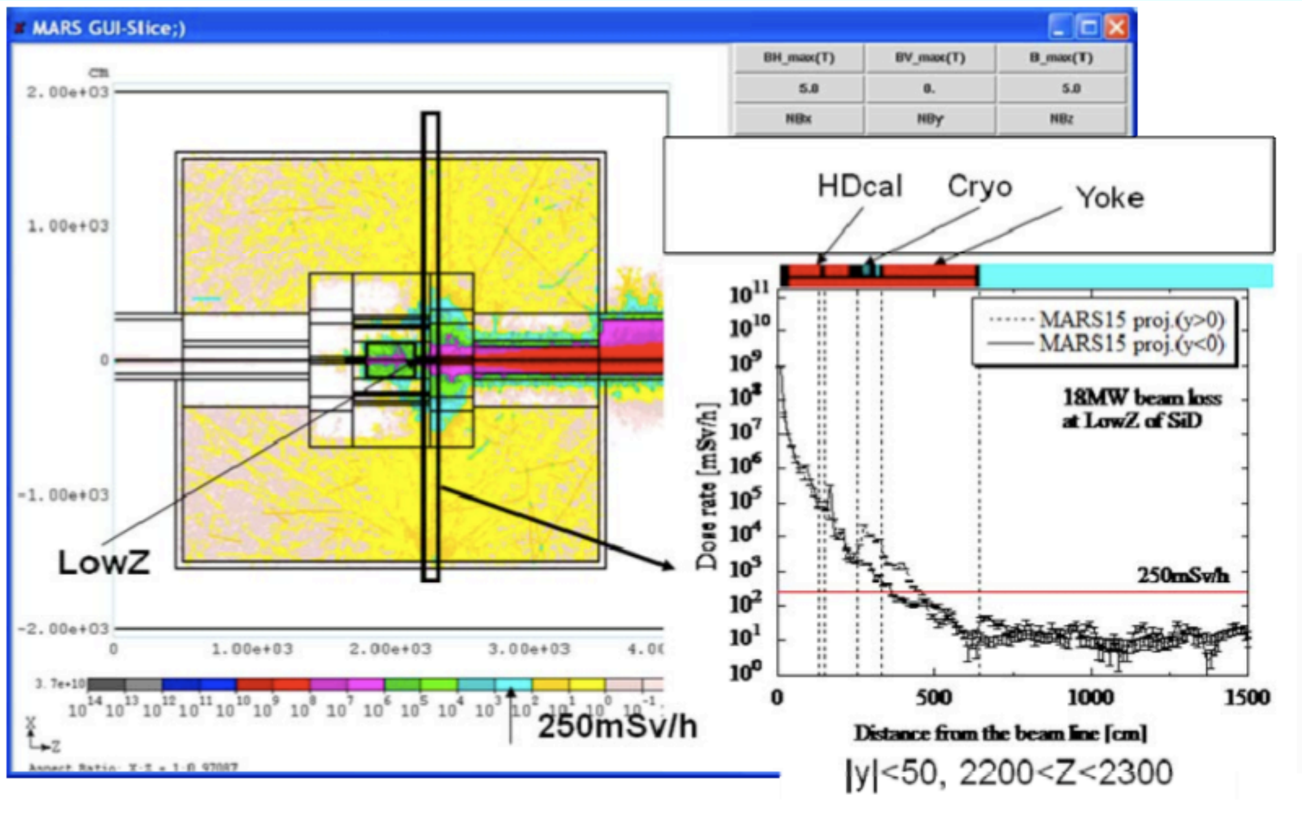
T.Sanami[1) 2)], A.Fasso[2)], M.Santana[2)], L.Keller[2)], A.Seryi[2)], S.Rokni[2)], S.Ban[1)]

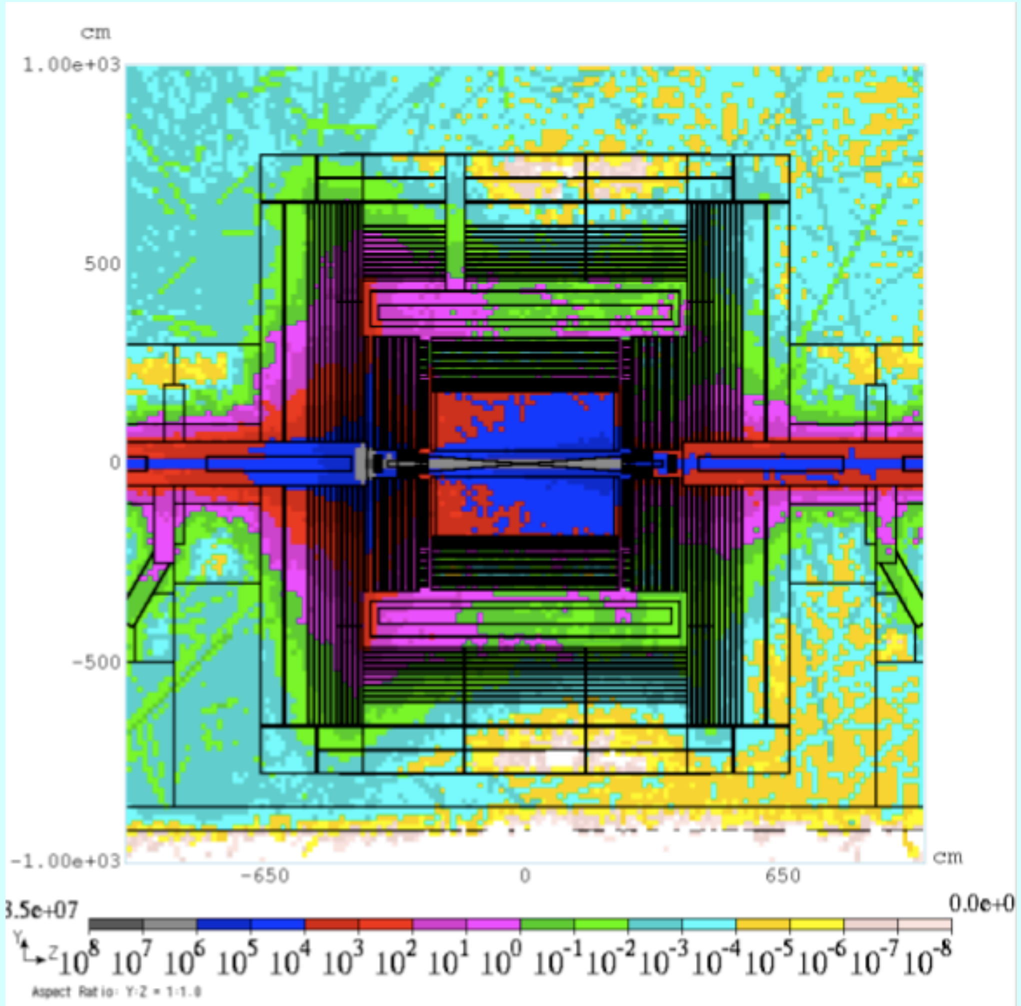
[1)]Radiation Science Center, KEK,
Oho 1-1, Tsukuba, Ibaraki 305-0801
[2)]Radiation Protection Department, SLAC, MS48
2575 Sand Hill Road, Menlo Park, CA 94025

- Studying dose rate distributions for maximum credible beam loss scenarios: 18 MW beam at 500 GeV
- Dose rate limit: 0.014 mSv/h/kW

SiD and ILD

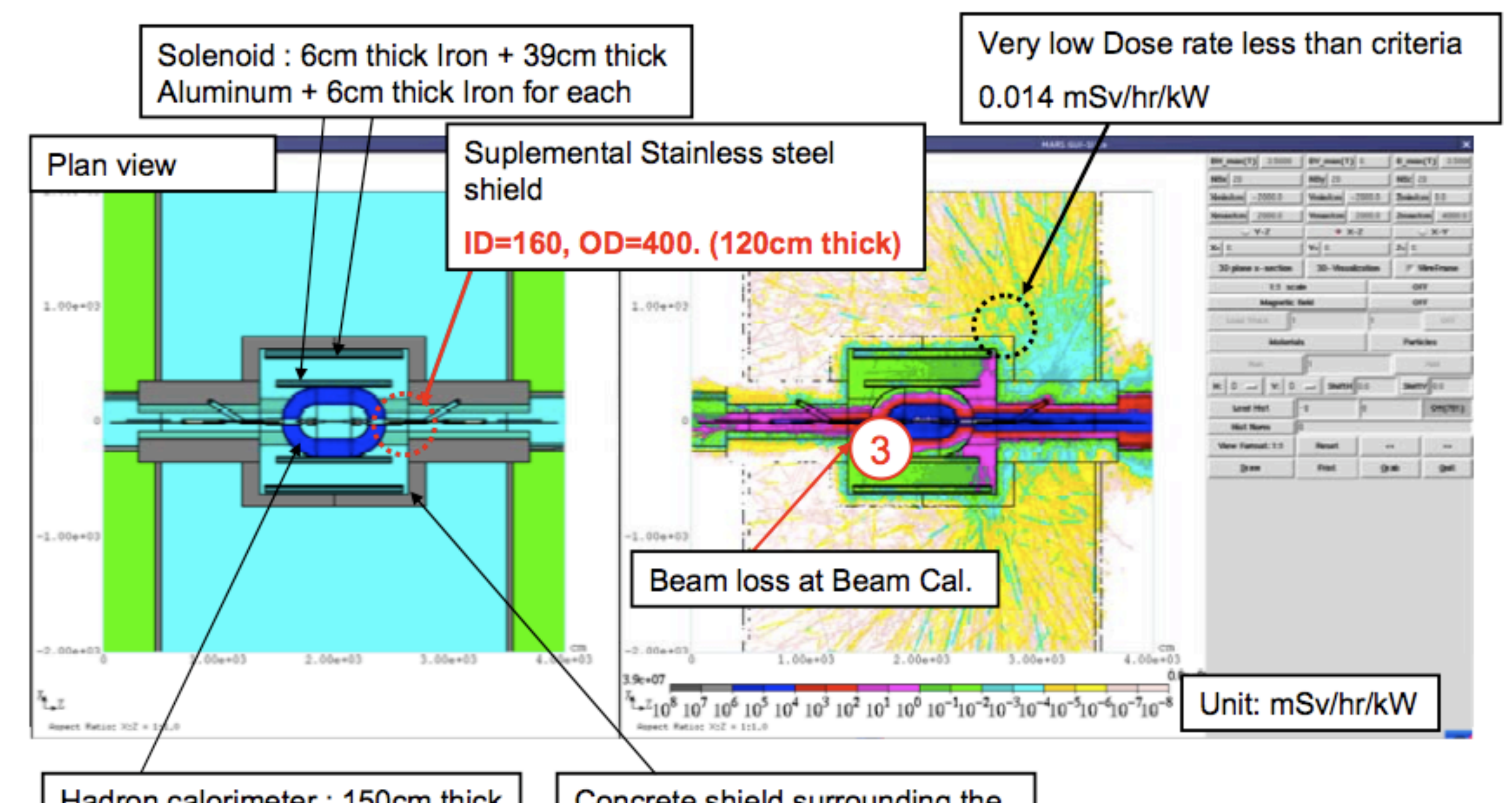
- SiD and ILD will be self-shielding if properly designed
- Careful study of the yoke geometries is needed
- Dose rate limits will be reached





4th Concept Shielding

- 4th concept is not self-shielding
- Additional concrete and iron shieldings under study
- Dose rate limits can be reached with the proper shielding configuration



Solenoid : 6cm thick Iron + 39cm thick Aluminum + 6cm thick Iron for each

Very low Dose rate less than criteria 0.014 mSv/hr/kW

Plan view

Suplemental Stainless steel shield

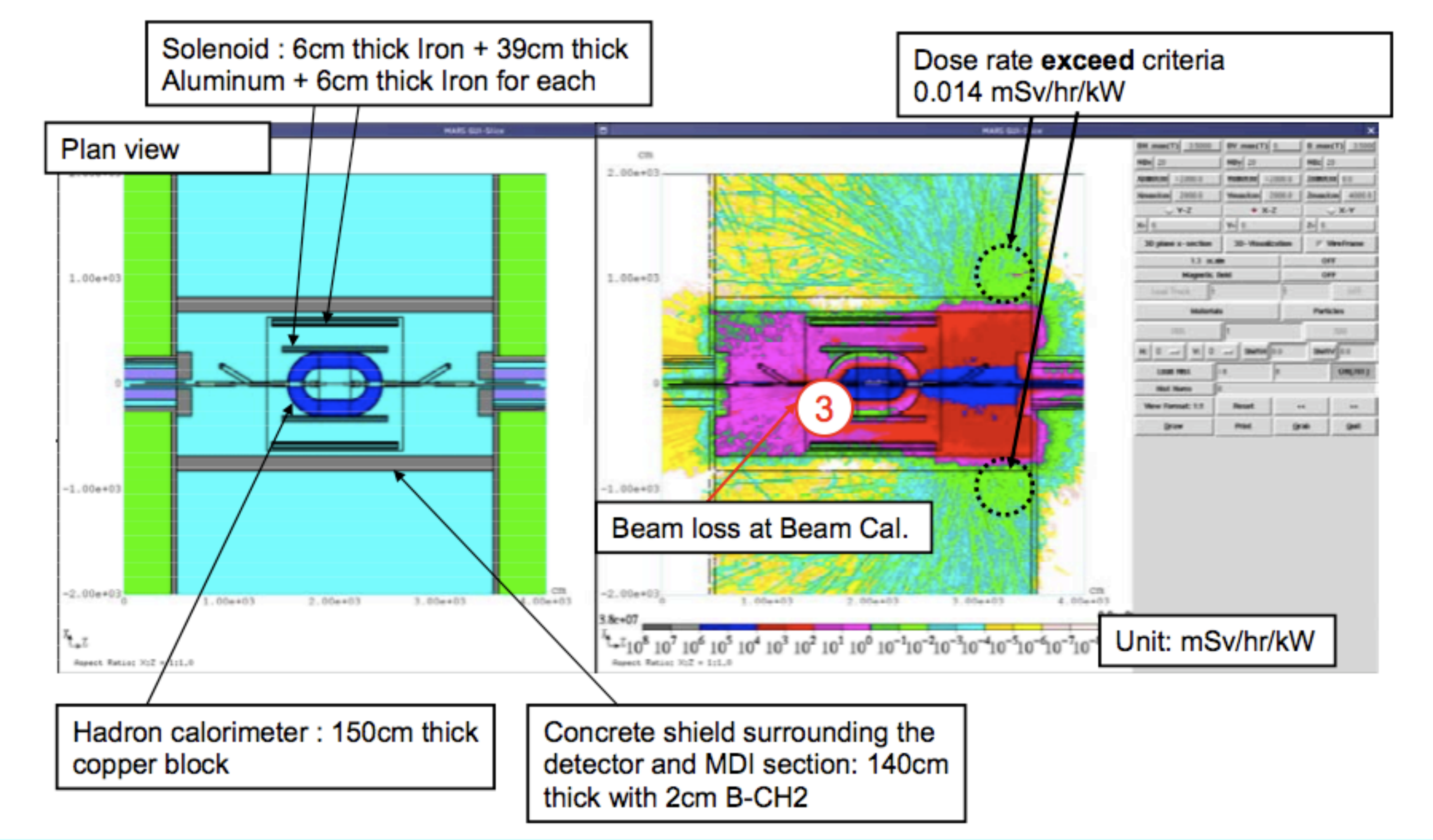
ID=160, OD=400. (120cm thick)

Beam loss at Beam Cal.

Unit: mSv/hr/kW

Hadron calorimeter : 150cm thick

Concrete shield surrounding the



Solenoid : 6cm thick Iron + 39cm thick Aluminum + 6cm thick Iron for each

Dose rate **exceed** criteria 0.014 mSv/hr/kW

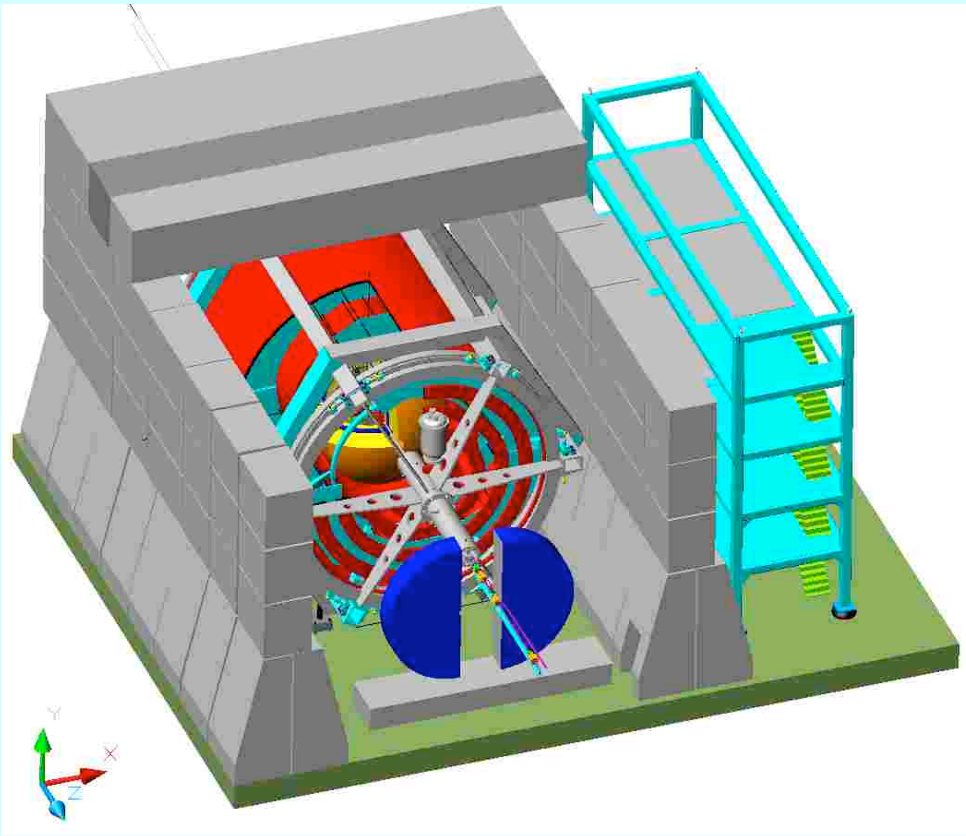
Plan view

Beam loss at Beam Cal.

Unit: mSv/hr/kW

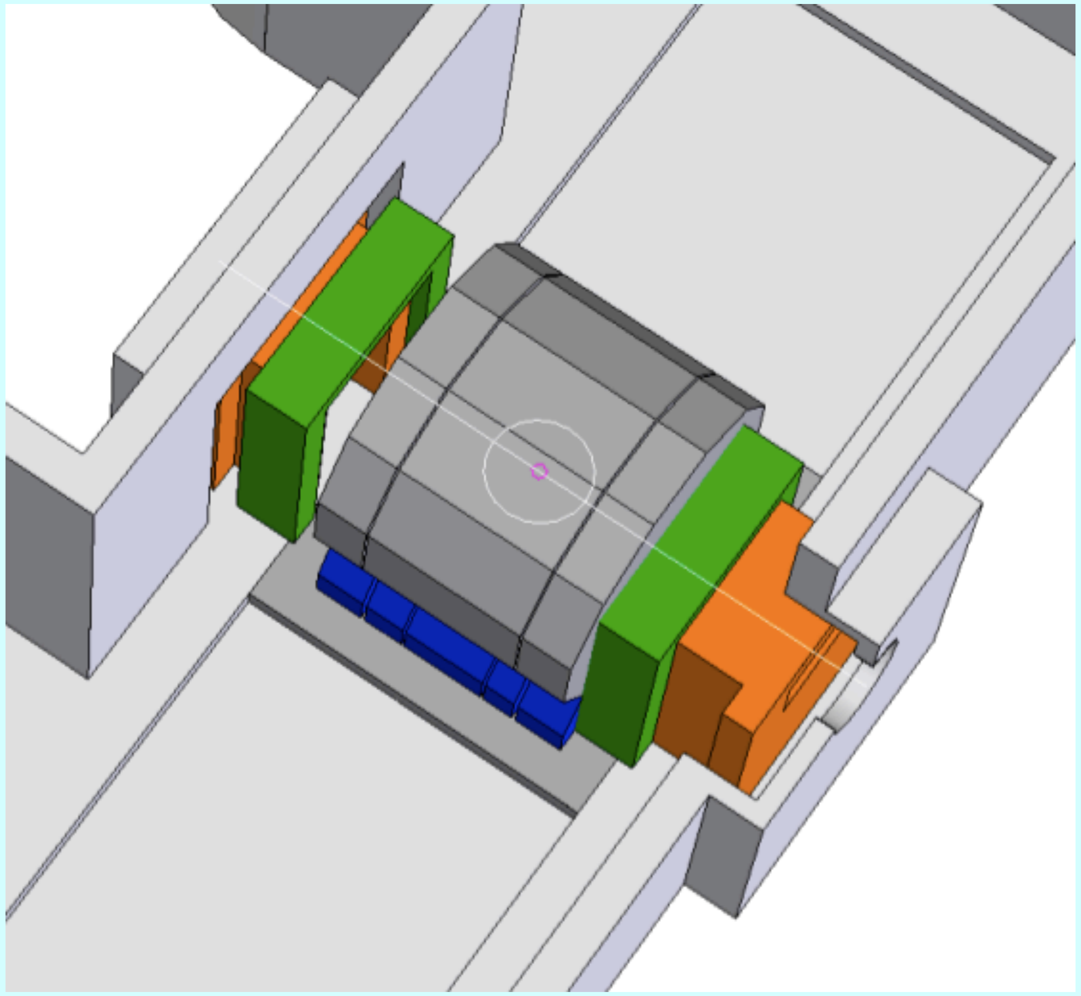
Hadron calorimeter : 150cm thick copper block

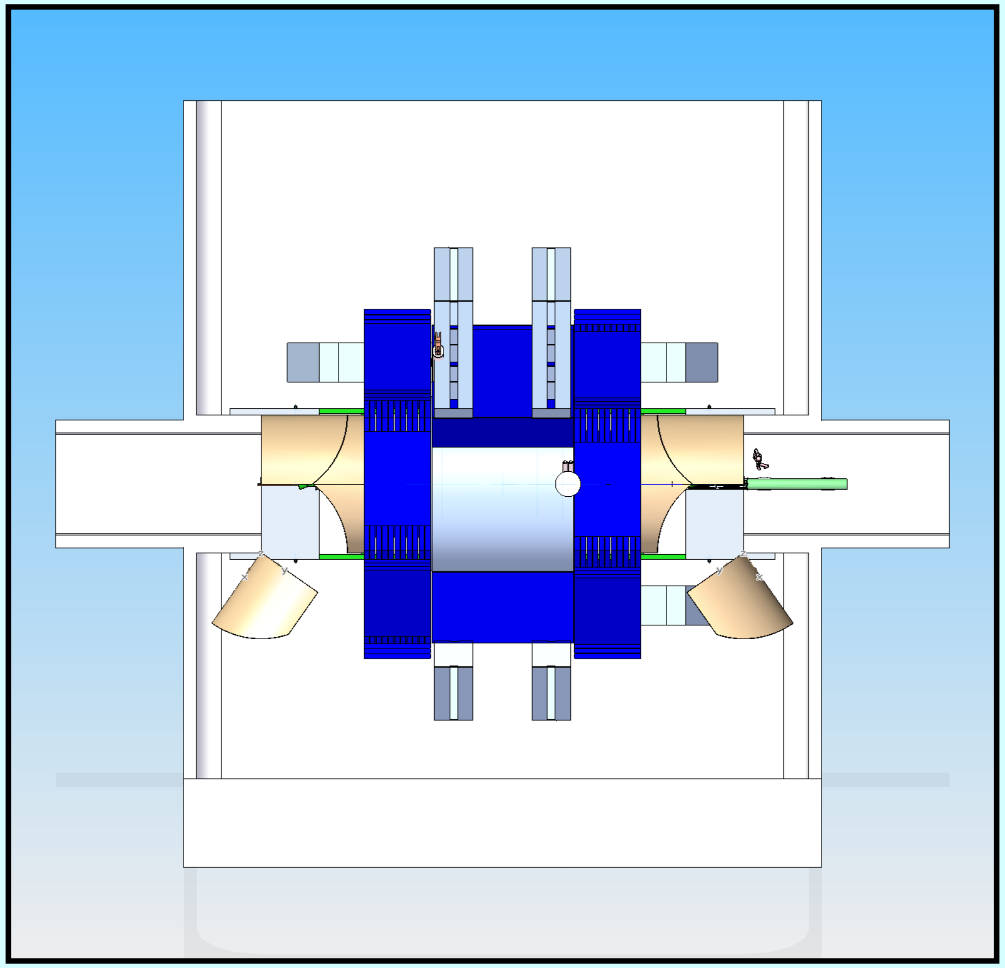
Concrete shield surrounding the detector and MDI section: 140cm thick with 2cm B-CH2



„Pacman“ Shielding

- „Pacman“ Shielding of ~2.5m concrete/iron is needed for radiation protection
- Solution needs to fit to both detectors
- Should be part of the bilateral discussions of the two final detectors





Magnetic Environment

- Requirements on the magnetic fields outside of the detectors define the amount of iron (or compensating coils) on the detectors
- Agree on the following numbers (CERN):
  - 5 Gauss for people wearing pacemakers
  - 50 Gauss for the use of iron-based tools
  - 100 Gauss for the general public
  - 2000 Gaus for occupational exposure
- Less than 50 Gauss at the start of the garage position (15m) to allow the parked detector to be maintained with whatever the respective collaboration needs.
- No restrictions for the fields along the beamline. Assumes that any static field can be corrected.

- Field of the parked detector must have less than 0.01% effect on the field in the tracking region of the beamline detector.

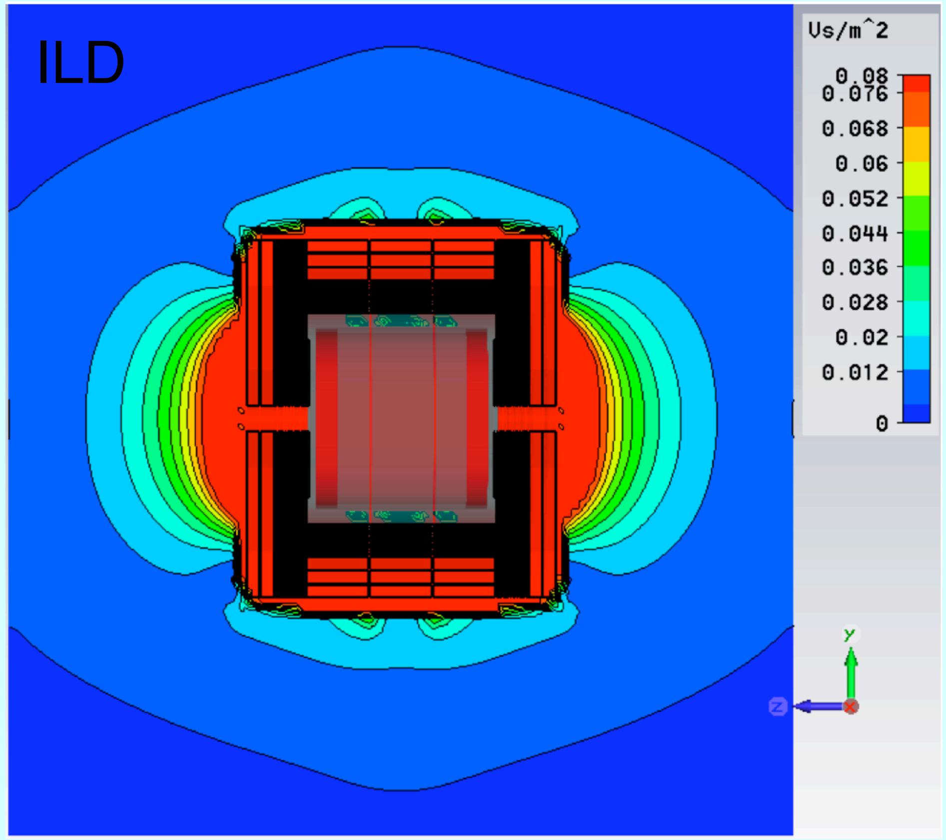
- All requirements for static fields as well as rampings, quenches, etc.

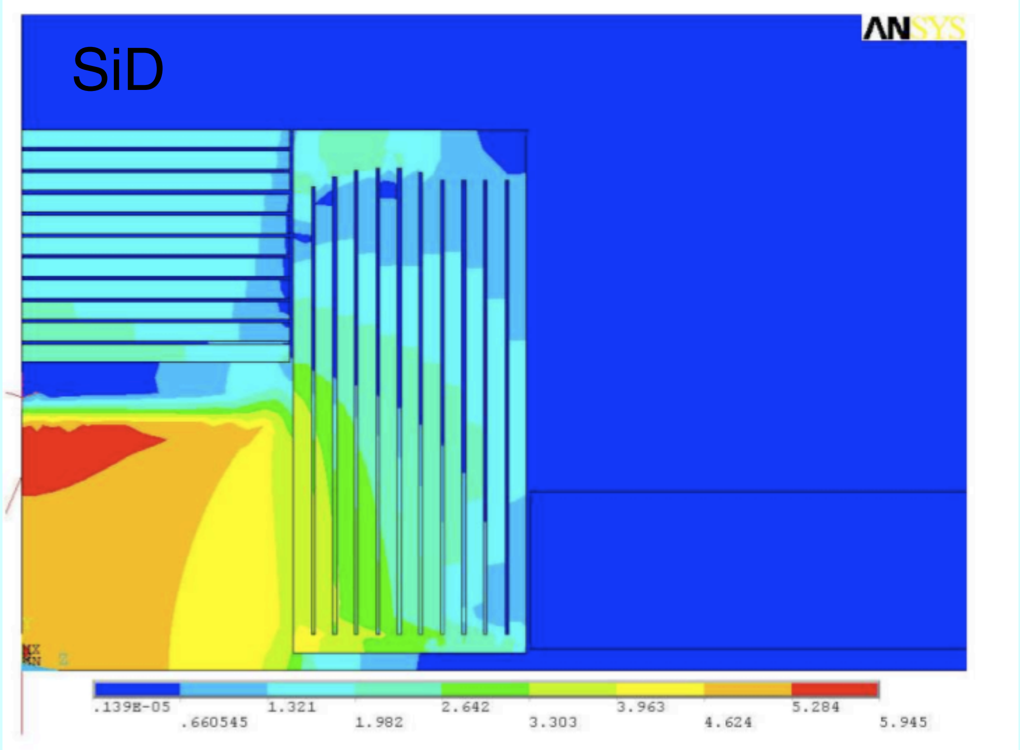
SiD and ILD Stray Fields

- ILD: less than 40 Gauss outside the 15m line
- SiD: 100 Gauss at 1m from the iron surface

- Major cost item: lots of iron needed!

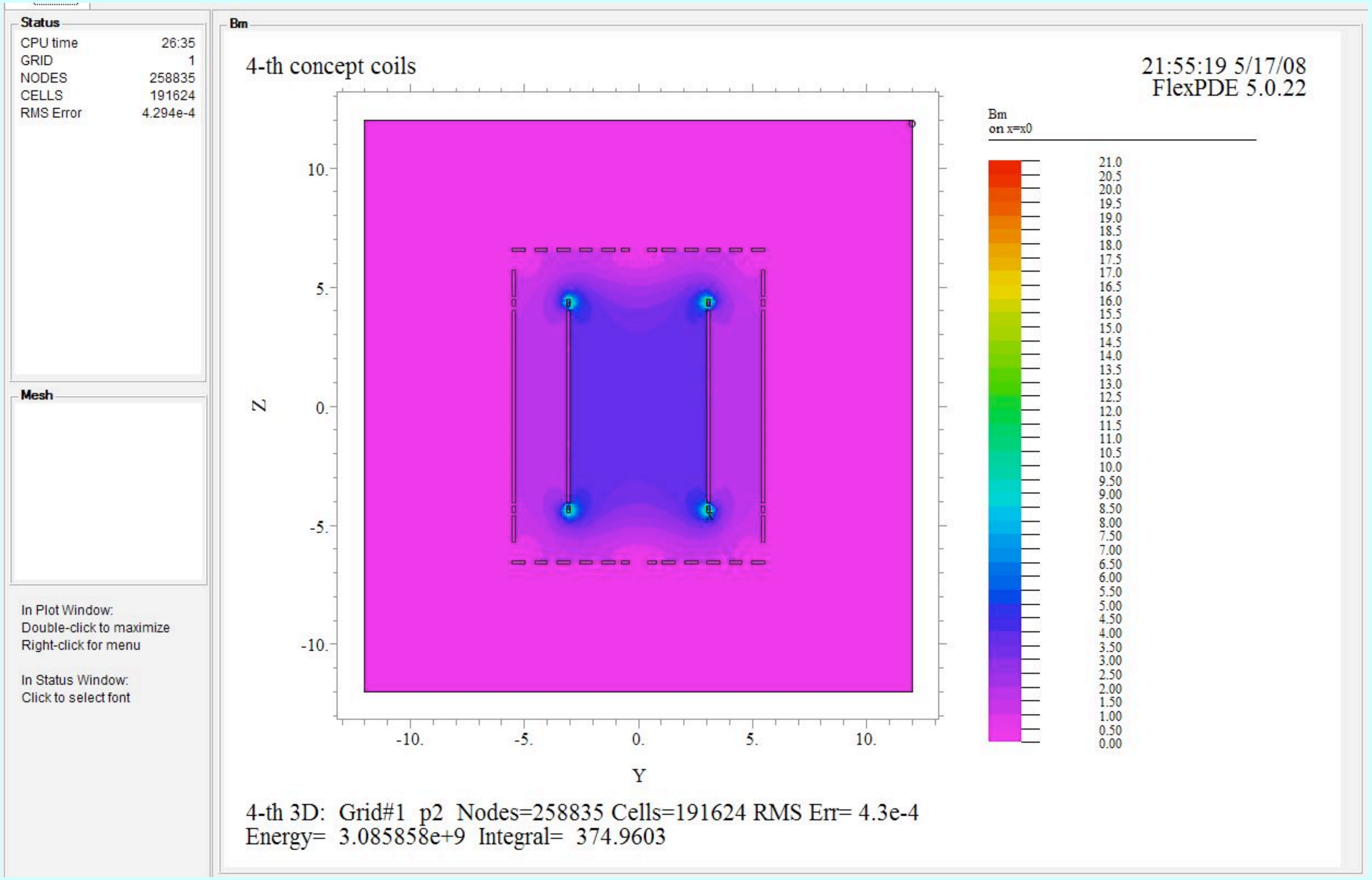
- e.g. CMS has much less iron and much larger stray fields - but is alone in the hall!





4th Concept Stray Fields

- 4th compensates the magnetic field actively
- fringe fields are very low



CPU time	26:35
GRID	1
NODES	258835
CELLS	191624
RMS Error	4.294e-4

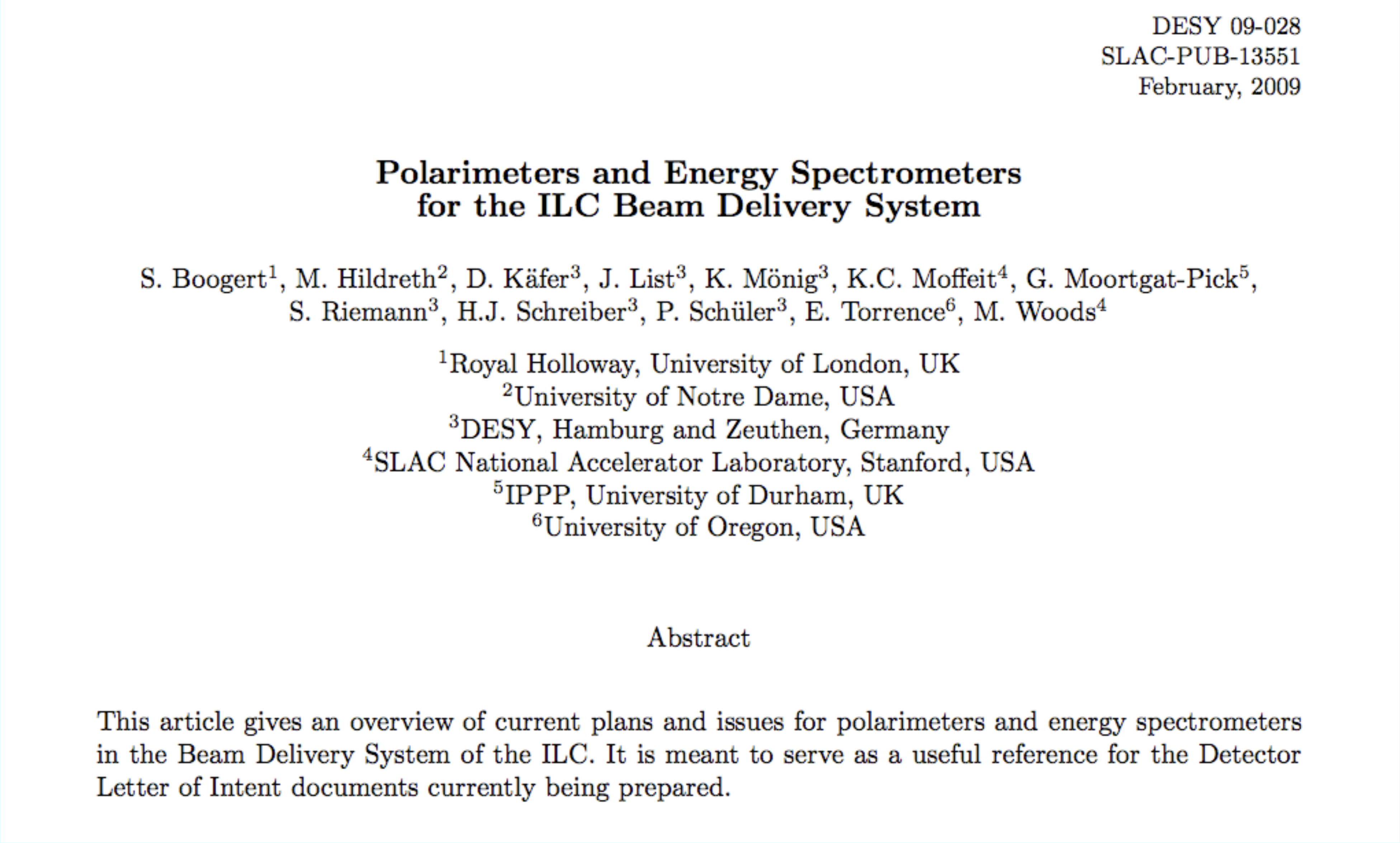
In Plot Window:
Double-click to maximize
Right-click for menu

In Status Window:
Click to select font

4-th 3D: Grid#1 p2 Nodes=258835 Cells=191624 RMS Err= 4.3e-4
Energy= 3.085858e+9 Integral= 374.9603

Polarisation and Energy Measurement

- Expert group produced a document (ILC-Note-2009-049) which describes the common design for the polarimeters and the energy spectrometers:



DESY 09-028
SLAC-PUB-13551
February, 2009

Polarimeters and Energy Spectrometers for the ILC Beam Delivery System

S. Boogert[1], M. Hildreth[2], D. Käfer[3], J. List[3], K. Mönig[3], K.C. Moffeit[4], G. Moortgat-Pick[5], S. Riemann[3], H.J. Schreiber[3], P. Schüler[3], E. Torrence[6], M. Woods[4]

[1]Royal Holloway, University of London, UK
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[5]IPPP, University of Durham, UK
[6]University of Oregon, USA

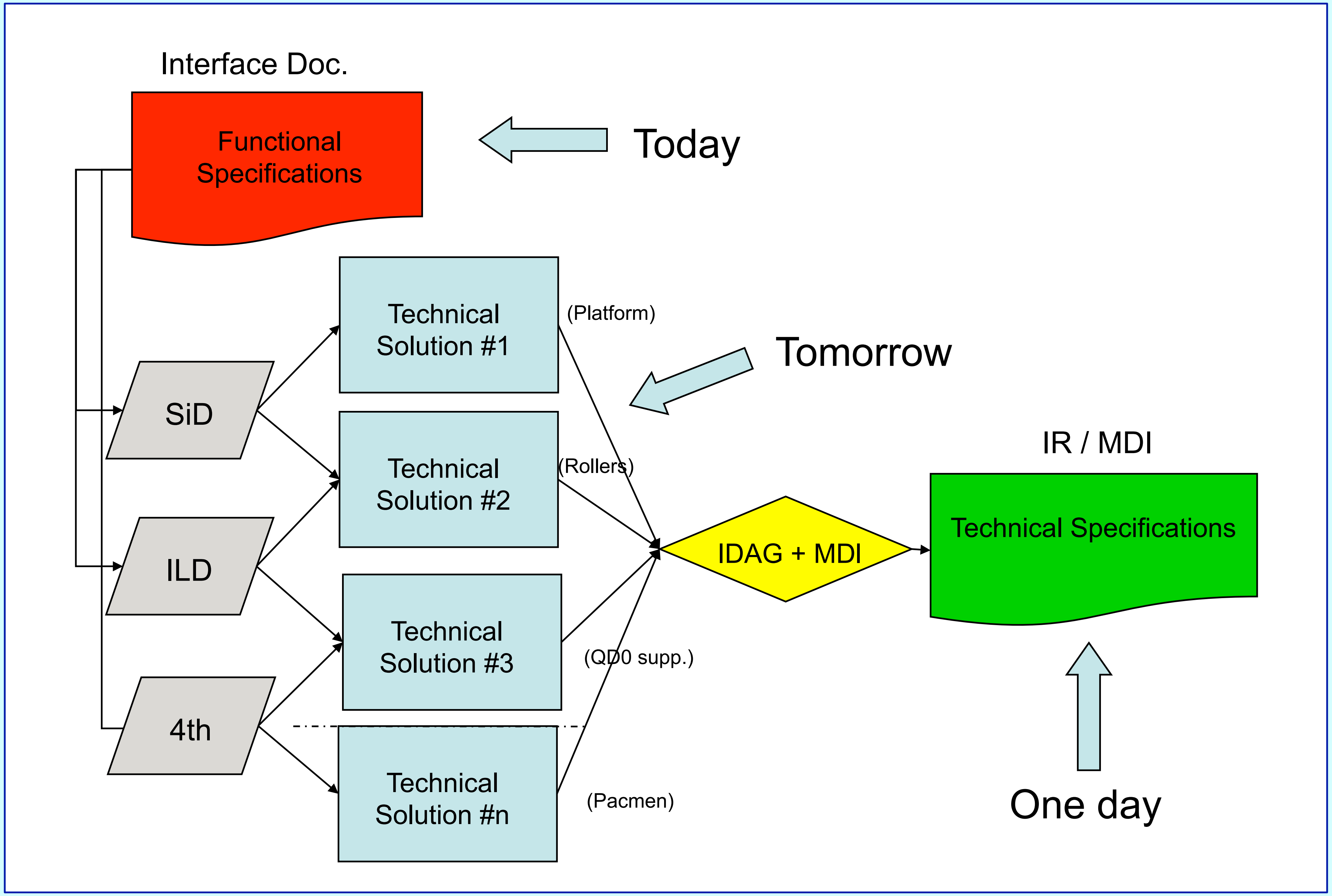
Abstract

This article gives an overview of current plans and issues for polarimeters and energy spectrometers in the Beam Delivery System of the ILC. It is meant to serve as a useful reference for the Detector Letter of Intent documents currently being prepared.

- Has been quoted in all three LoIs

How to proceed

- Many technical details need to be specified in bi-lateral agreements between the two final detectors:



- Bilateral discussions will start this summer!