Minimal BDS and other thoughts

Andrei Seryi

SLAC

for BDS design team

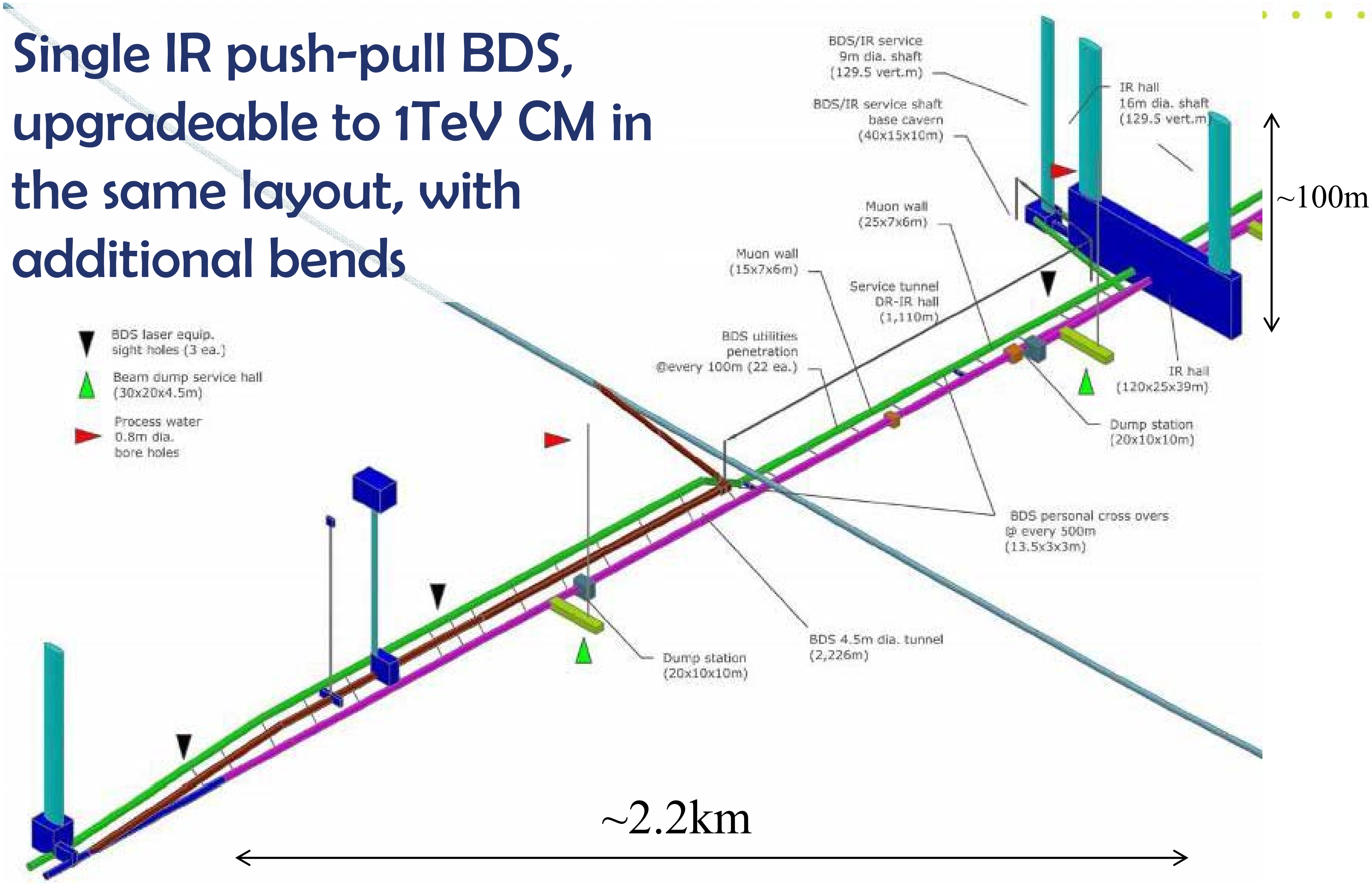
GDE meeting, Dubna, June 4-6, 2008

Contents

- 500 GeV CM BDS
- Merged dumps
- Simplified IR design
  - All what is shown is very tentative and require detailed studies before it may be considered to be implemented

Layout of Beam Delivery tunnels

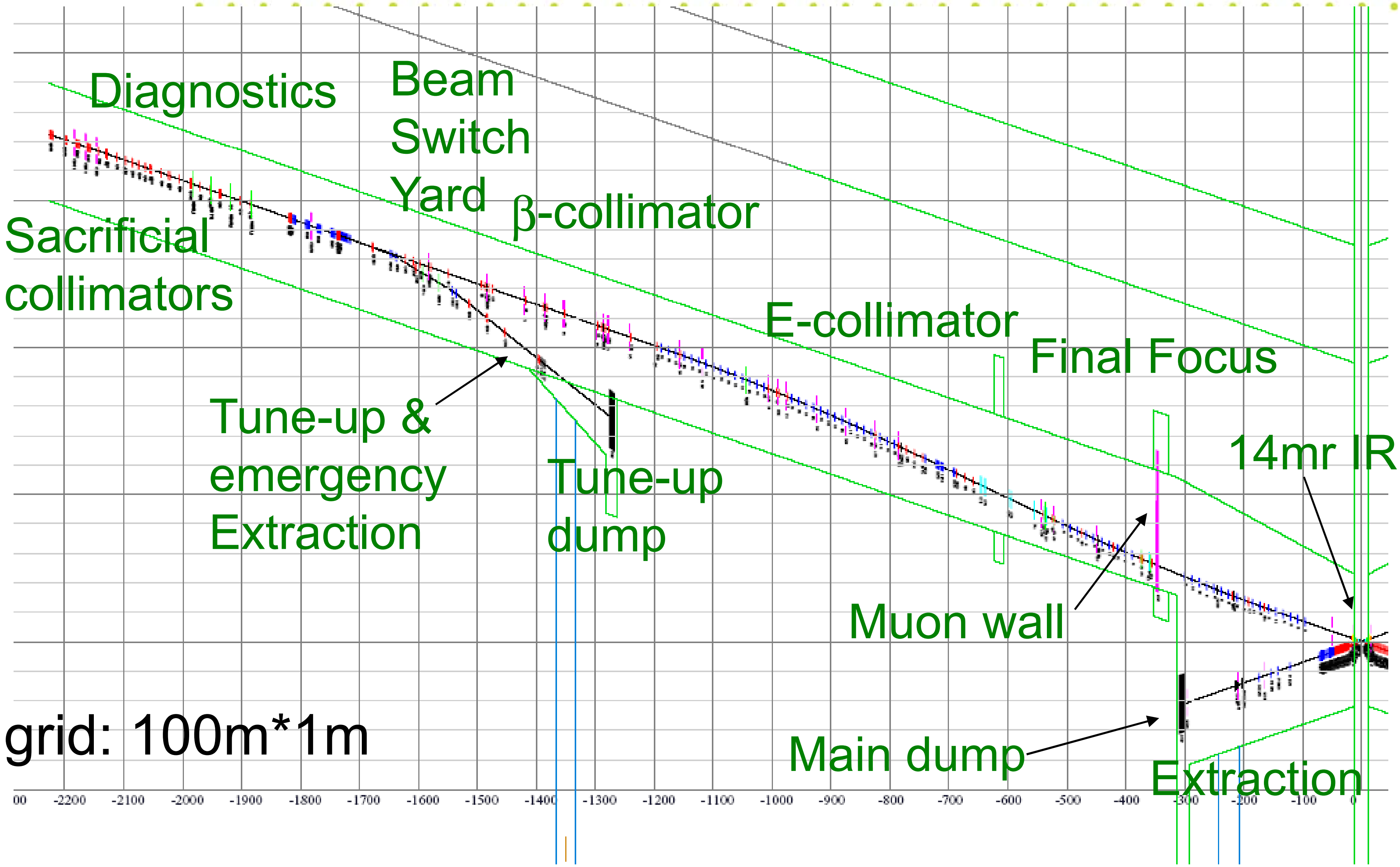
- Single IR push-pull BDS, upgradeable to 1TeV CM in the same layout, with additional bends



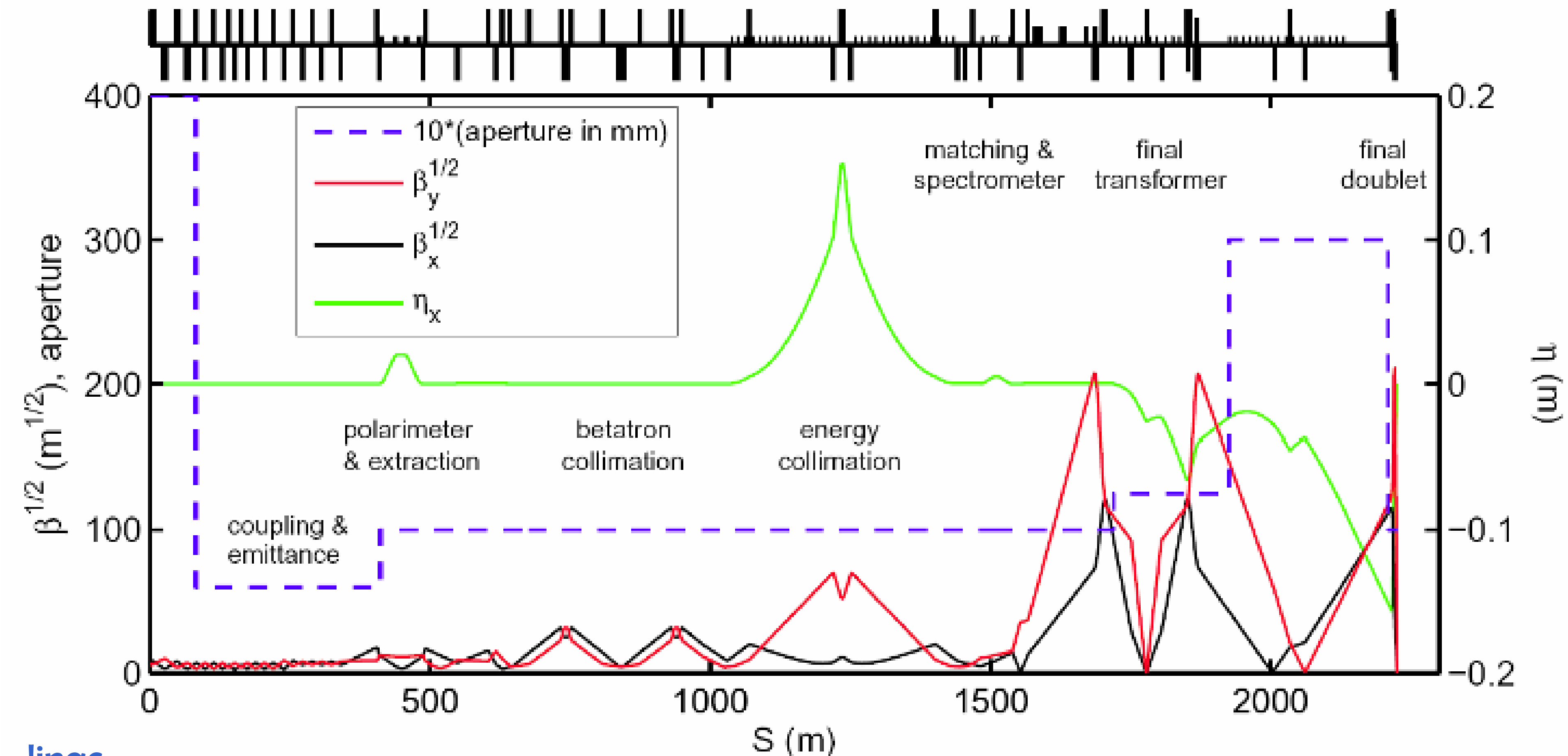
500GeV CM BDS, motivation

- Present BDS layout is designed for 1 TeV CM
- Question: what is BDS design for 500 GeV CM?
  - and if such BDS is built, how to upgrade it to 1 TeV?
- There is no complete answer, in this talk. It require detailed studies.
- However, a tentative 500GeV CM design will be shown
  - The design was done in ~2006

ILC BDS, RDR, 1TeV CM layout

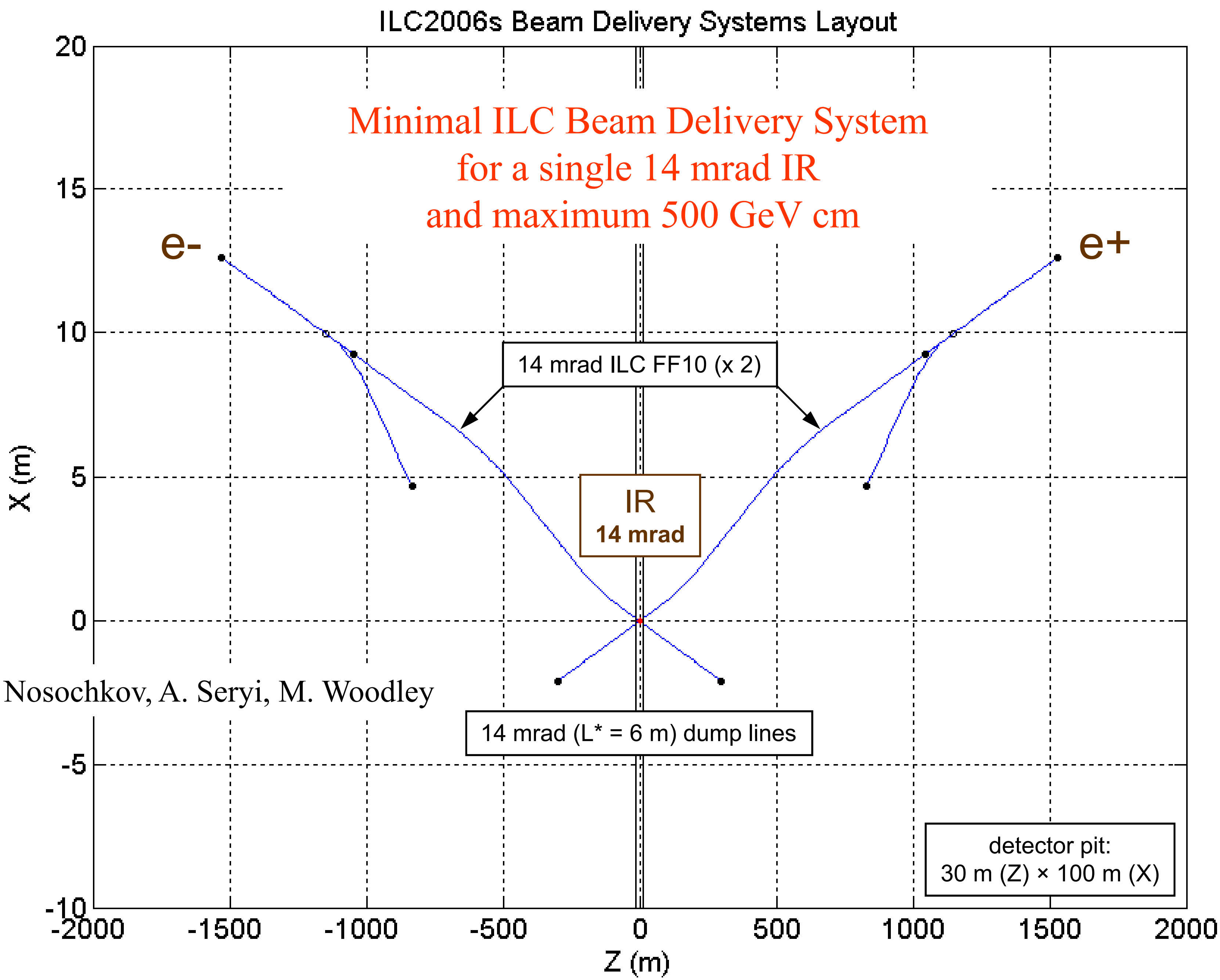


BDS, 1TeV CM capable

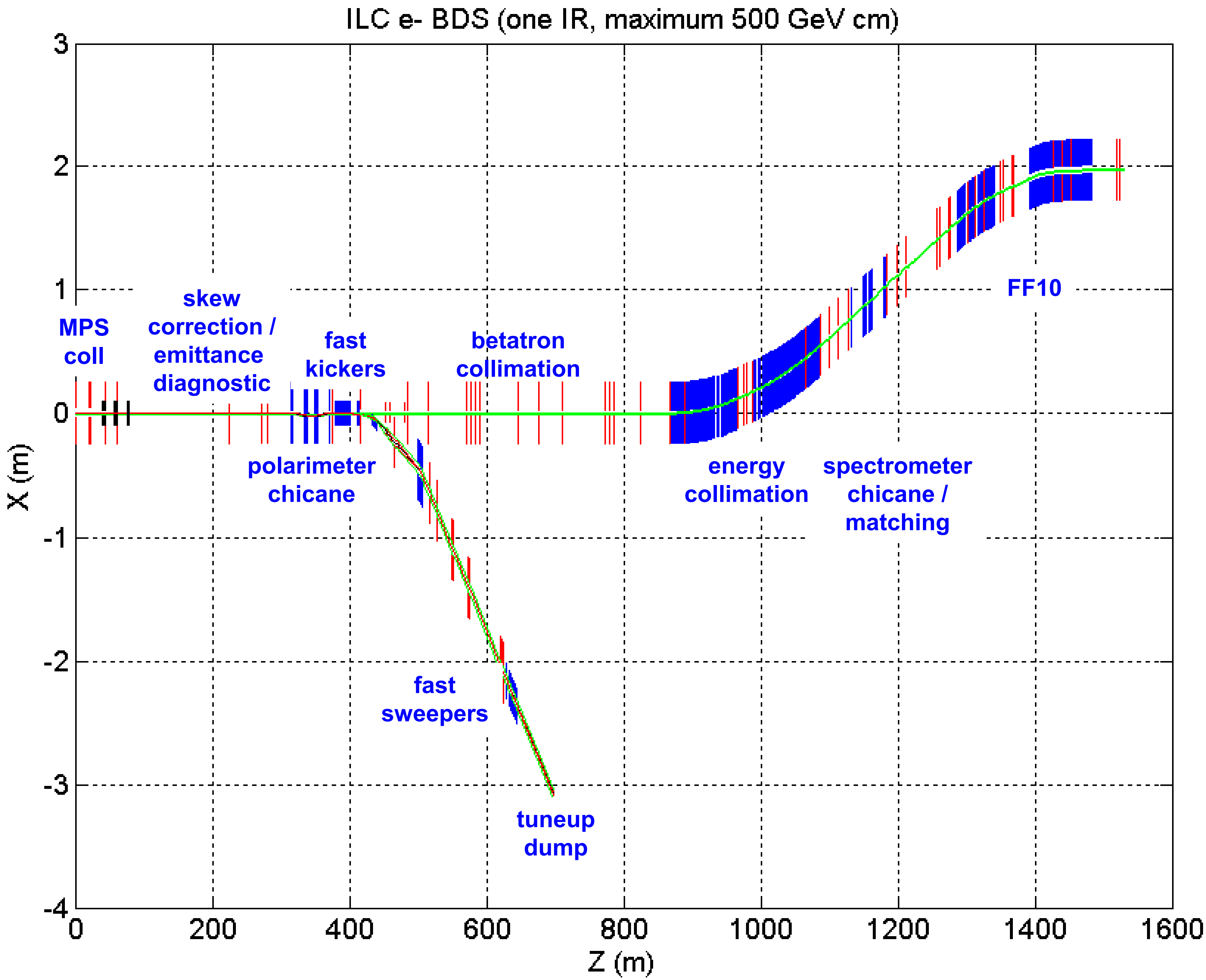


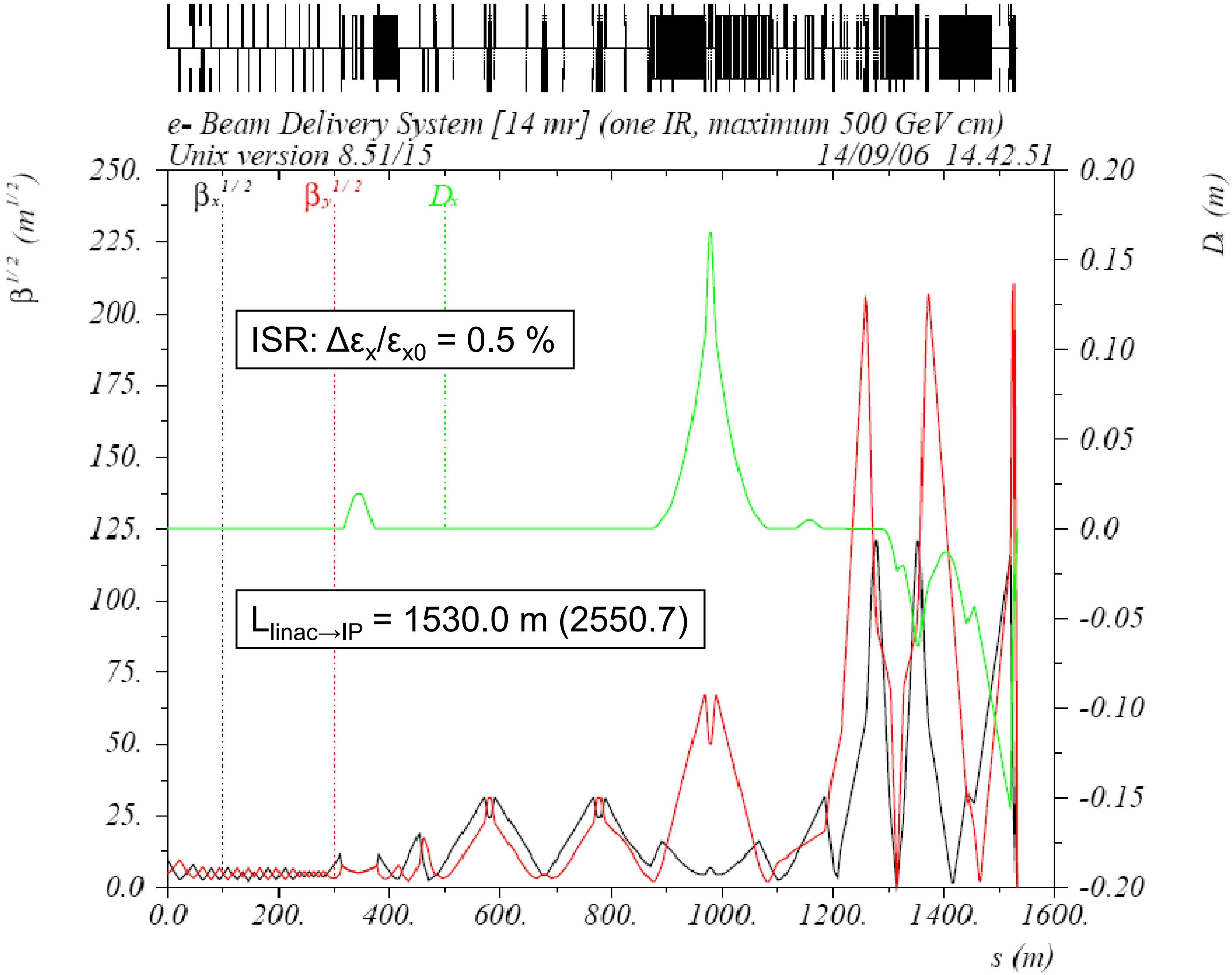
linac

IP



Y. Nosochkov, A. Seryi, M. Woodley


ILC e- BDS (one IR, maximum 500 GeV cm)
MPS coll
skew correction / emittance diagnostic
fast kickers
betatron collimation
FF10
polarimeter chicane
energy collimation
spectrometer chicane / matching
fast sweepers
tuneup dump
X (m)
Z (m)
3
2
1
0
-1
-2
-3
-4
0
200
400
600
800
1000
1200
1400
1600



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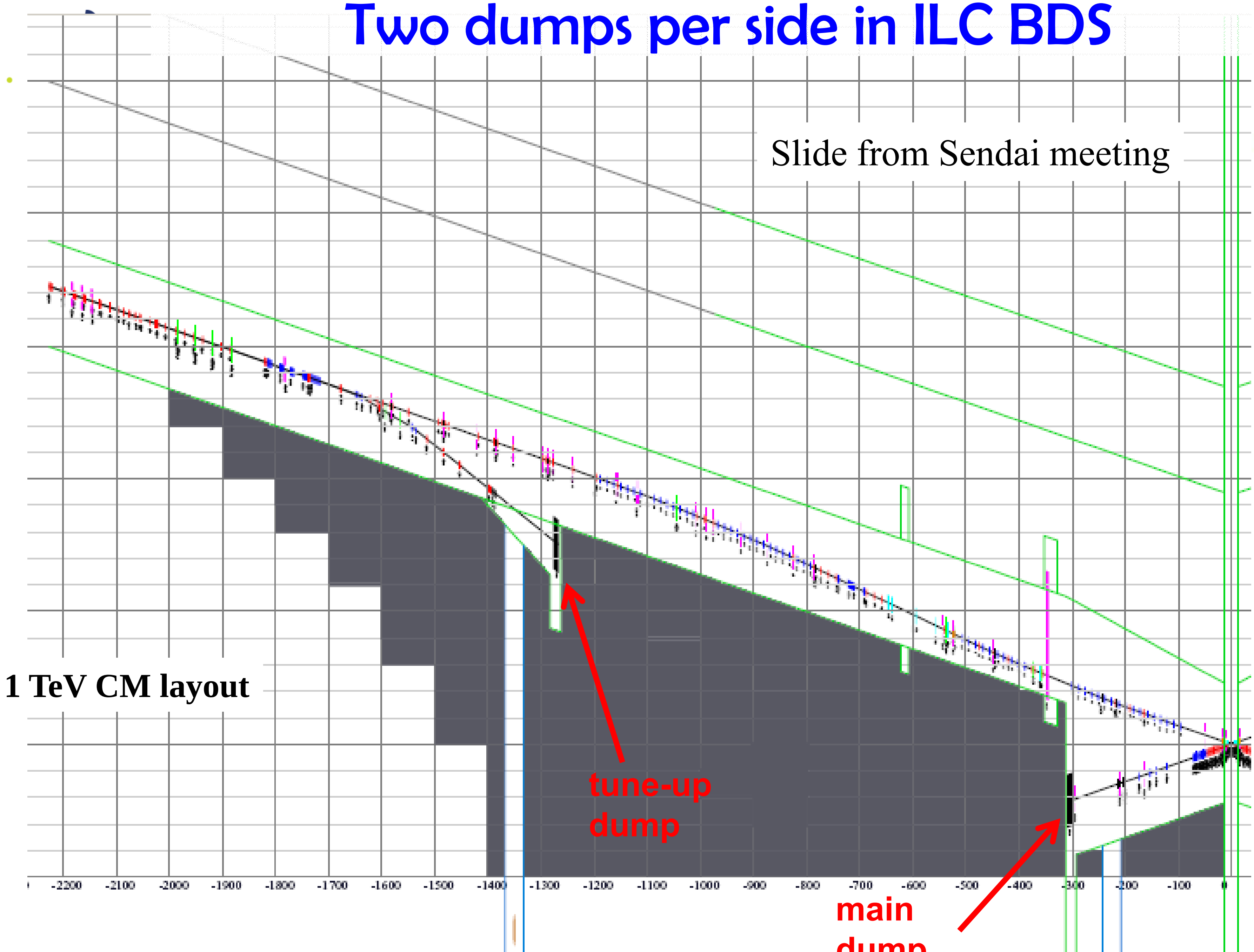
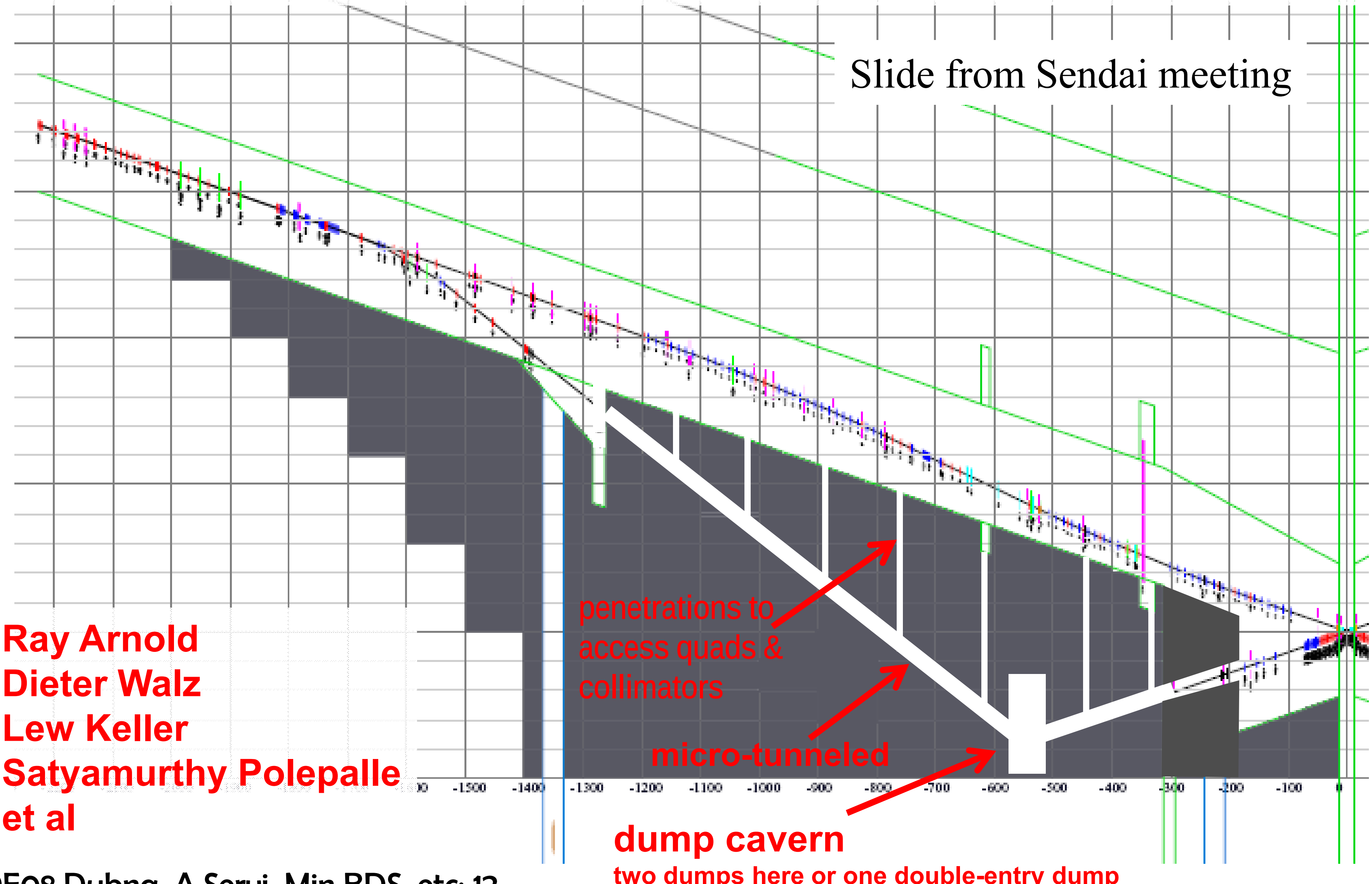
Upgrades and issues

- Upgrade: default assumption is that at 1TeV CM energy upgrade part of the linac will be removed, allowing for BDS lengthening
  - Unconventional upgrade, in the same short length, based on new ideas, is not excluded, but cannot be predicted or guaranteed now
- Issues with upgrade of 500GeV CM BDS:
  - Sufficient tunnel width, laser straightness, interface with service tunnel and other beamlines must be foreseen in advance
  - One of the issues is location of tune-up dump: in 500GeV CM version it moves closer to IP, and this location must work for 1TeV CM as well
    - This inspired the following idea about dumps merging

Two dumps per side in ILC BDS



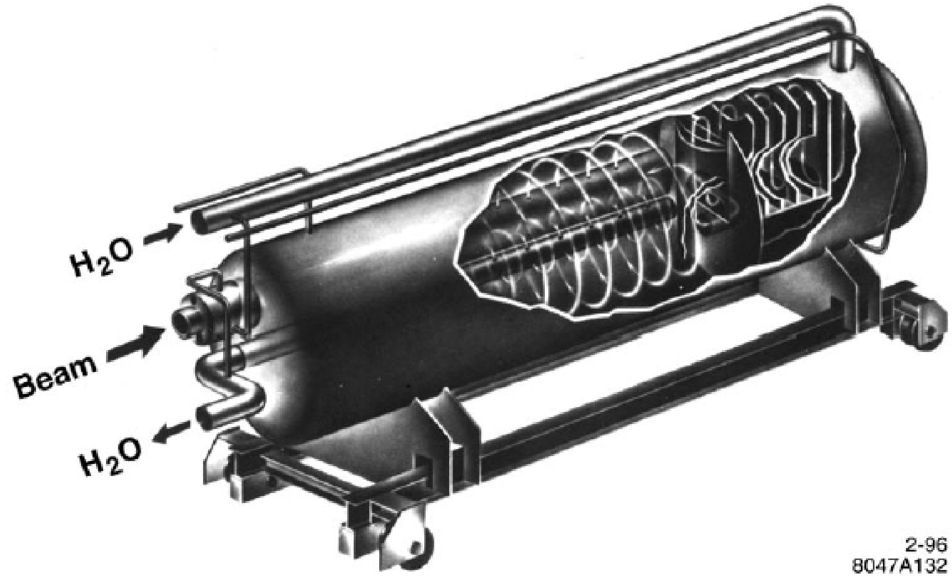
Suggestion for discussion & study: Merged dumps with micro-tunneling

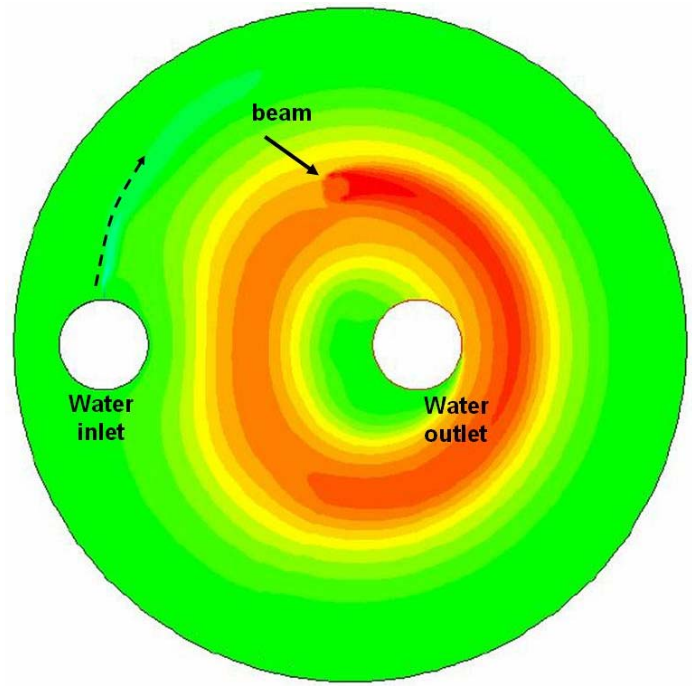


Ray Arnold
Dieter Walz
Lew Keller
Satyamurthy Polepalle
et al

Beam dump

- 17MW power (for 1TeV CM)
- Rastering of the beam on 30cm double window
- 6.5m water vessel; ~1m/s flow
- 10atm pressure to prevent boiling
- Three loop water system
- Catalytic H_2-O_2 recombiner
- Filters for 7Be
- Shielding 0.5m Fe & 1.5m concrete





In the situation of growing concerns about energy conservation and environmental impact, we must be ready to answer the question if dumping the 17MW of CW beam is the only possible solution

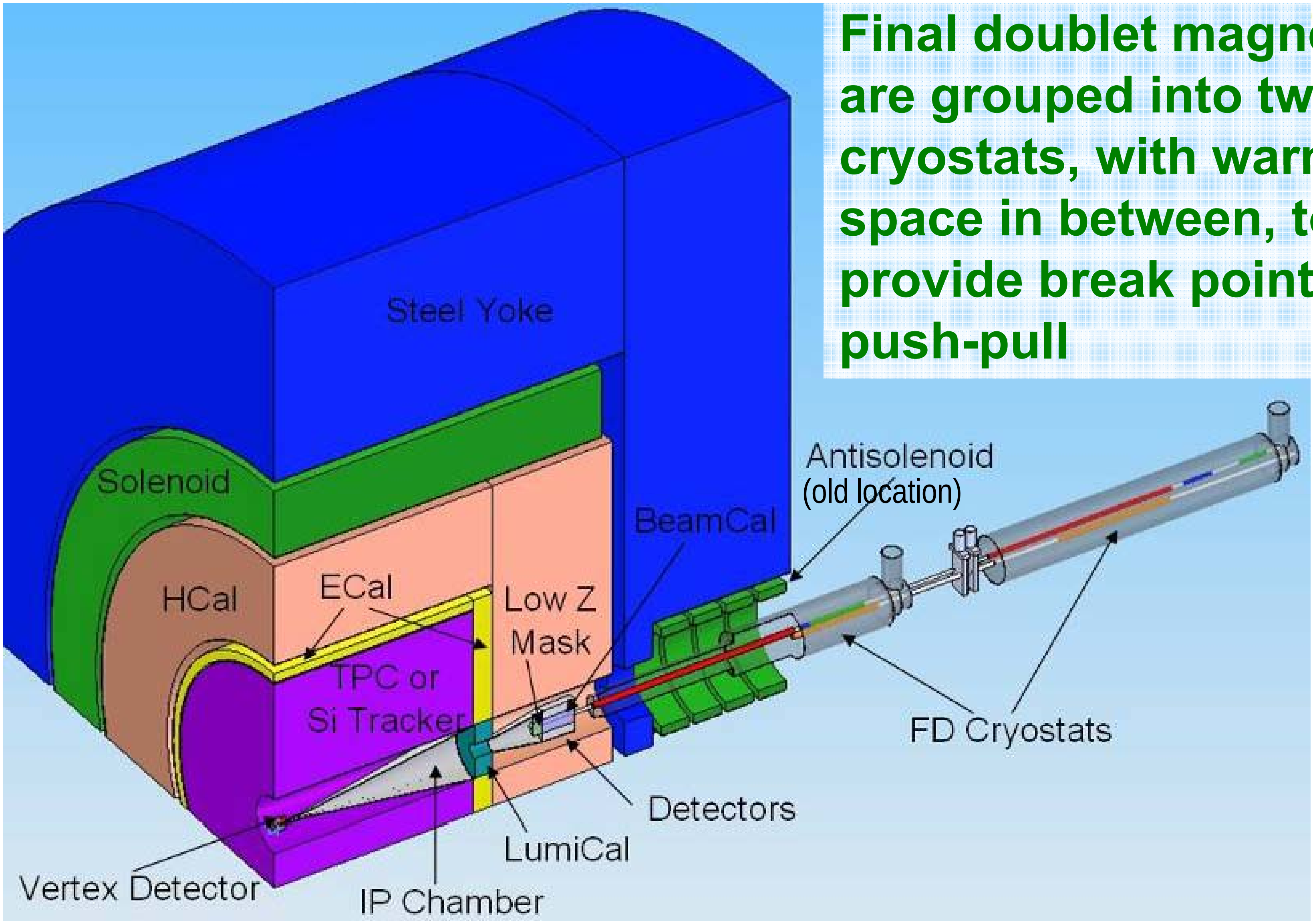
SLAC and BARC, India

IR design

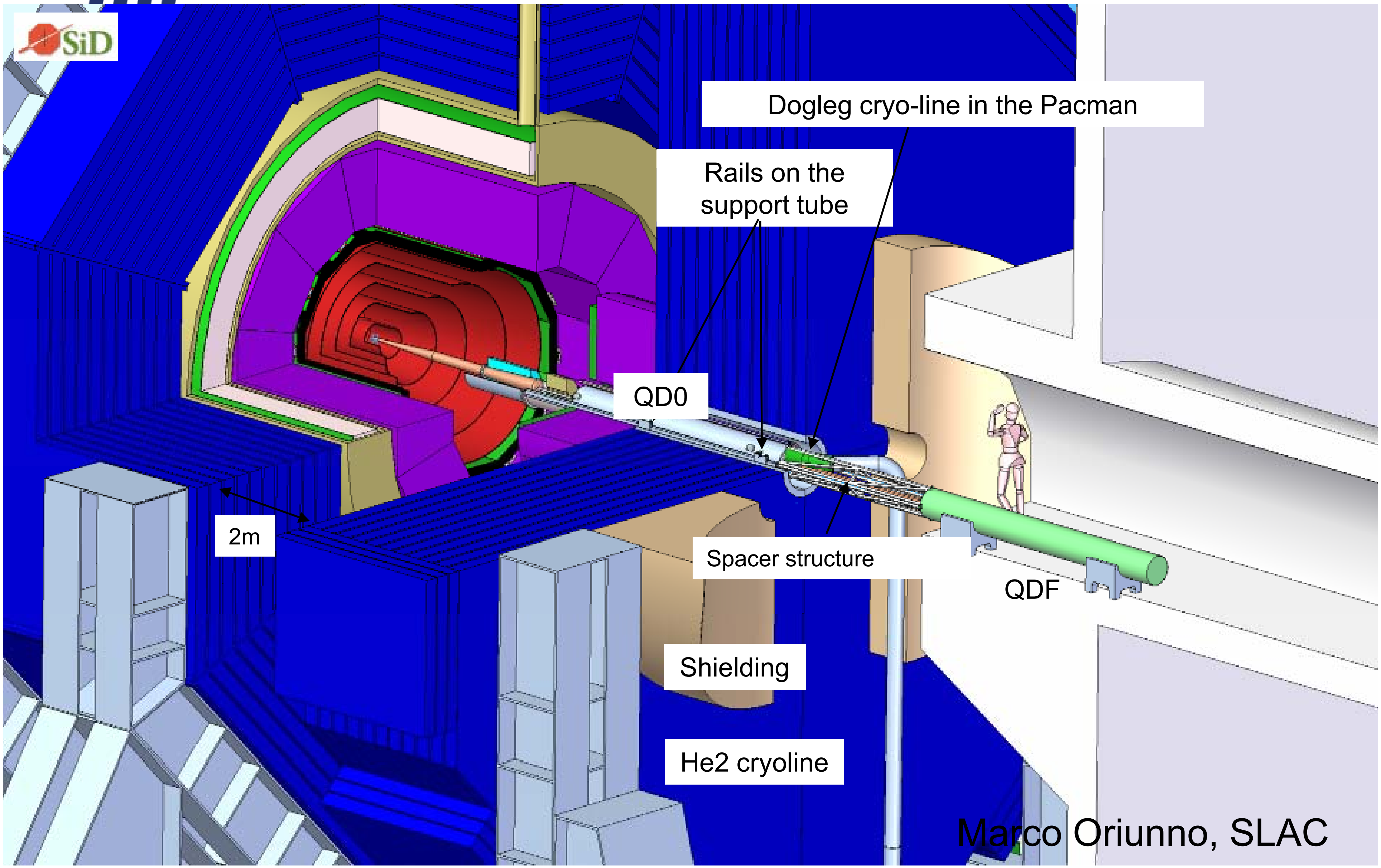
- The push-pull mode of operation sets specific requirements and challenges for many systems of detector and machine
  - in particular for the IR magnets, for the cryogenics system, for alignment system, for beamline shielding, for detector design and overall integration, and so on.
- The Machine and Detector groups are now working on the optimized IR design, and on particular on so called IR Interface Document, that should specify
  - functional requirements, specifications, responsibilities, technical solutions, etc

IR integration

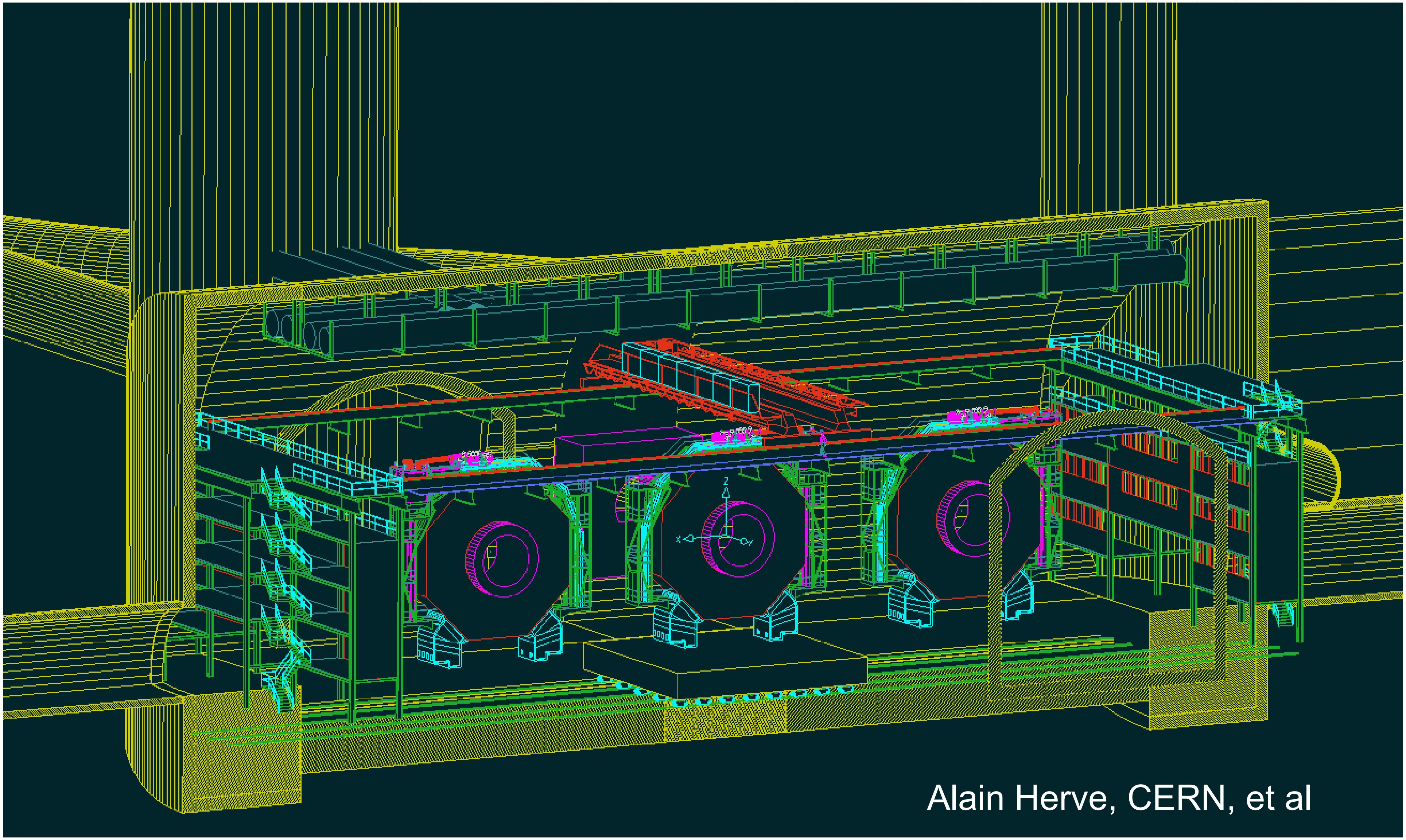
Final doublet magnets are grouped into two cryostats, with warm space in between, to provide break point for push-pull



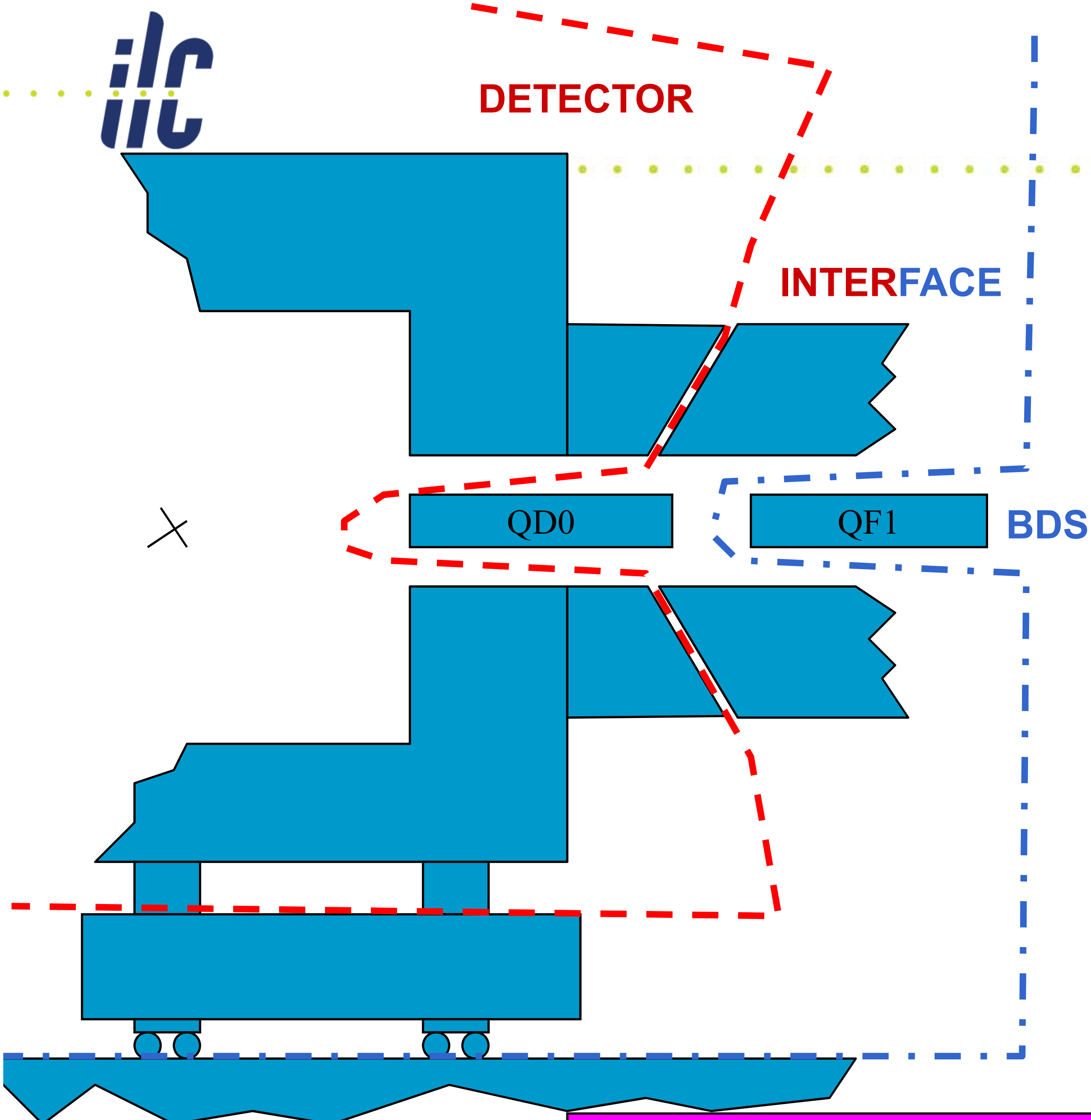
IR integration, SiD example



Push-Pull studies for two detectors



IR Interface boundaries



- This picture is over simplified
- But it shows that interface and boundaries of responsibilities will be complicated
- A question can be asked if a simpler interface would be possible and what impact on performance it would make

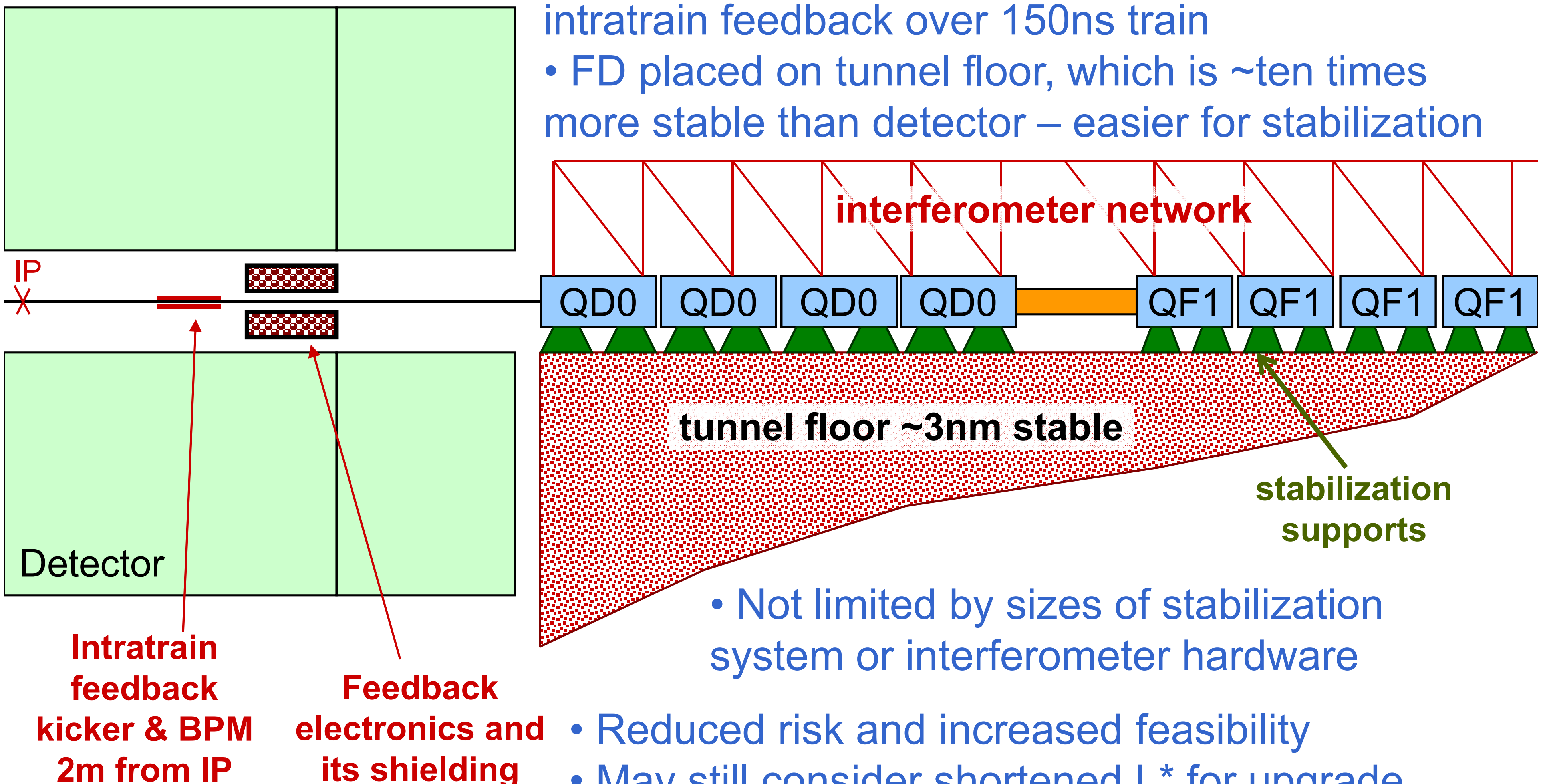
GDE08 Dubna, A.Seryi, Min BDS, etc: **From BDS summary talk, TILC08, March 6, 2008, Sendai, Japan**

Simplified IR interface

- Longer L*, long enough to have QD0 outside of detector, separating M/D more cleanly and simplifying push-pull
  - Some impact on luminosity is unavoidable; R_{vx} may need to be increased
  - Discussed at Sendai as a way to ease CLIC IR stability issue
- If a longer L* design will be found viable, a question will be
  - whether to consider it as a permanent solution
  - if a Luminosity upgrade, by shortening the L*, would be considered later, after operational experience will be gained with a simpler system

Discussed an approach to CLIC IR stability

- Slower than 1/L* dependence of Lum => ↑L*
- Reduced feedback latency – several iteration of intratrain feedback over 150ns train
- FD placed on tunnel floor, which is ~ten times more stable than detector – easier for stabilization



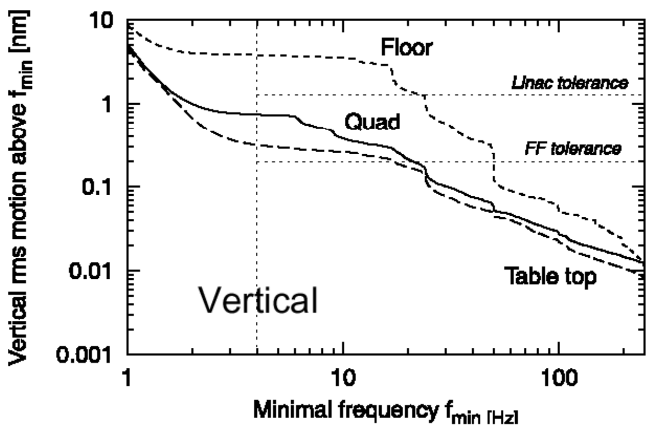
- Not limited by sizes of stabilization system or interferometer hardware

- Reduced risk and increased feasibility
- May still consider shortened L* for upgrade

GDE08 Dubna, A.Seryi, Min BDS, etc: **From BDS summary talk, TILC08, March 6, 2008, Sendai, Japan**

L(L*); achievements & sizes of hardware

Quadrupole vibration:



On magnet top:

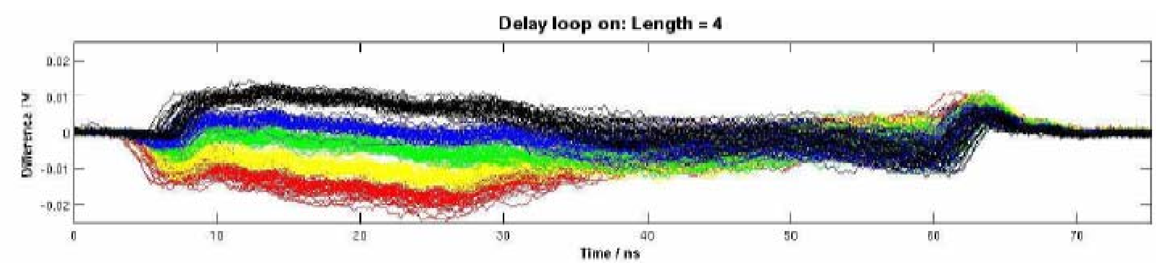
X: (0.4 ± 0.1) nm

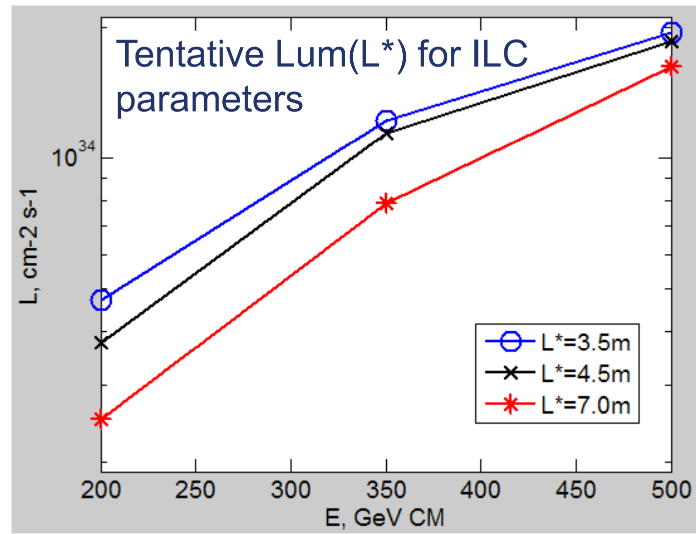
Y: (0.9 ± 0.1) nm
(0.3 nm on table top)

Z: (3.2 ± 0.4) nm

without cooling water.

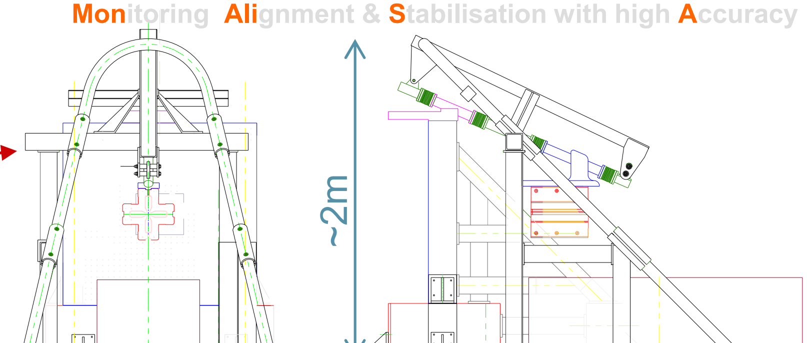
R.Assmann et al, Stabilization with STACIS give ~10 reduction of tunnel floor vibration





P.Burrows et al, FONT3 demonstrated latency of 23ns, including 10ns of irreducible time-of flight

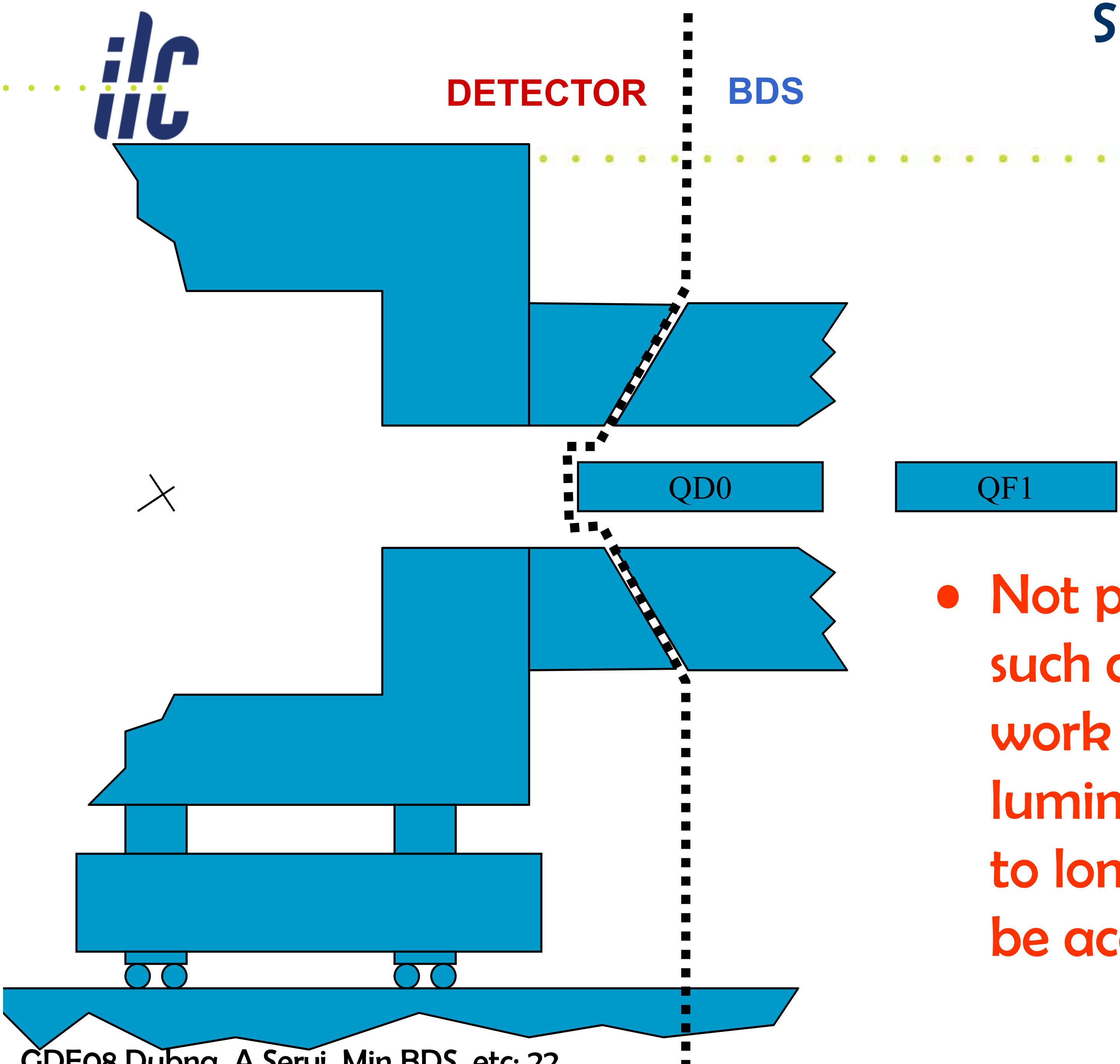
Monitoring Alignment & Stabilisation with high Accuracy



D.Urner et al, MONALISA interferometer system for ATF2 final doublet: space availability matters

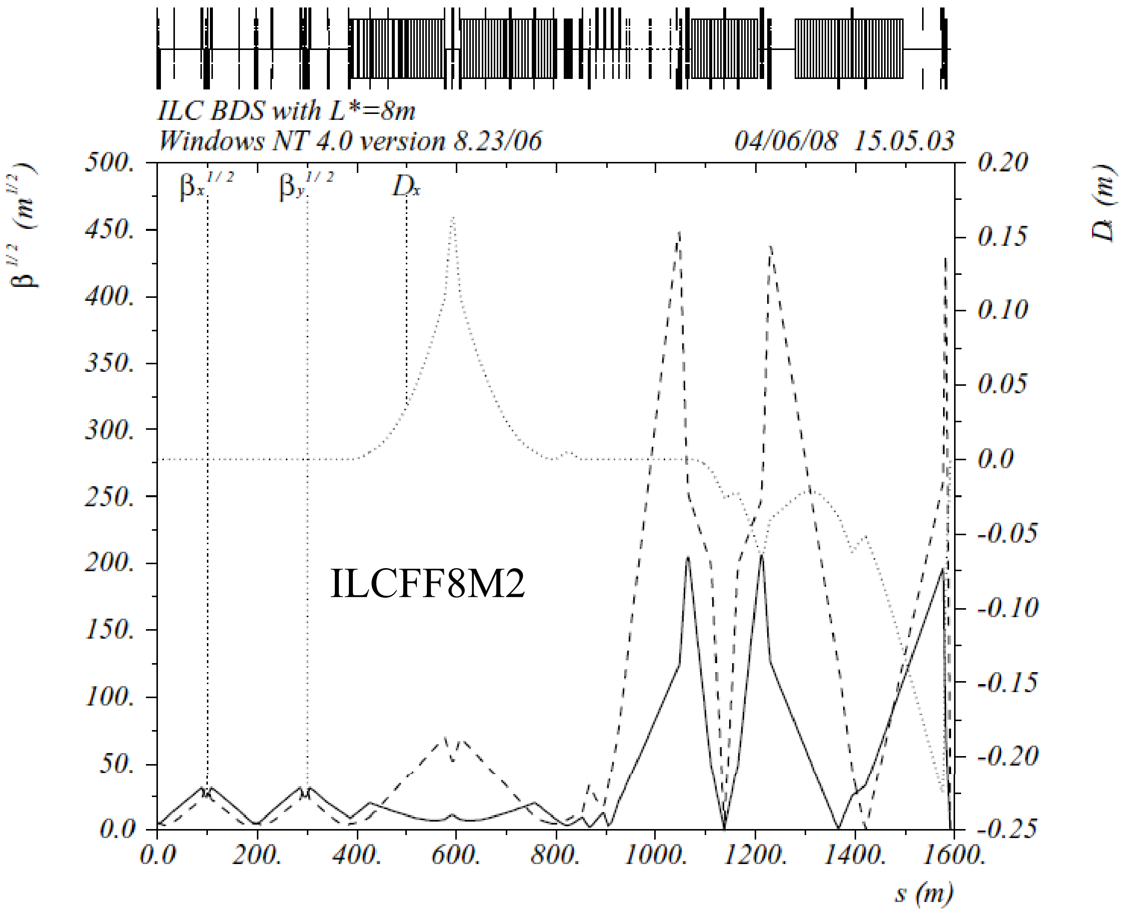
GDE08 Dubna, A.Seryi, Min BDS, etc: **From BDS summary talk, TILC08, March 6, 2008, Sendai, Japan**

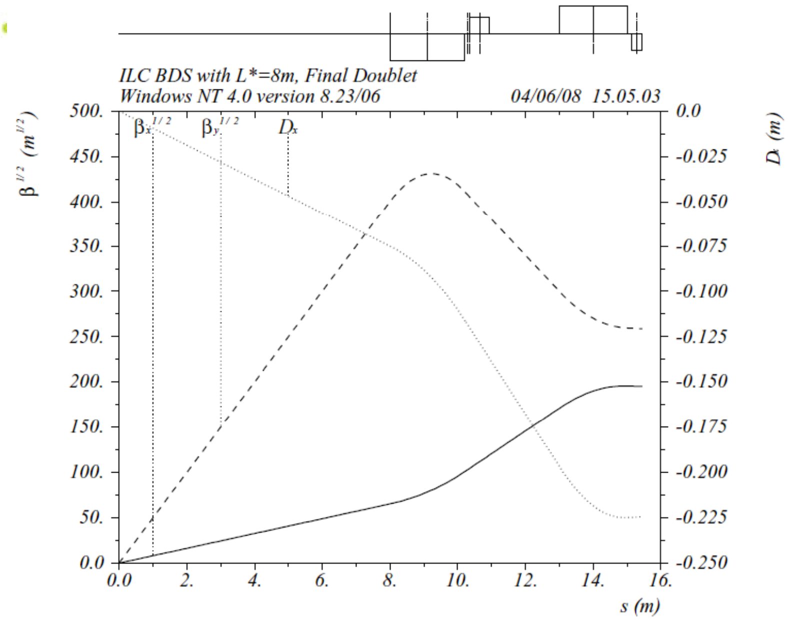
Simplified IR Interface?

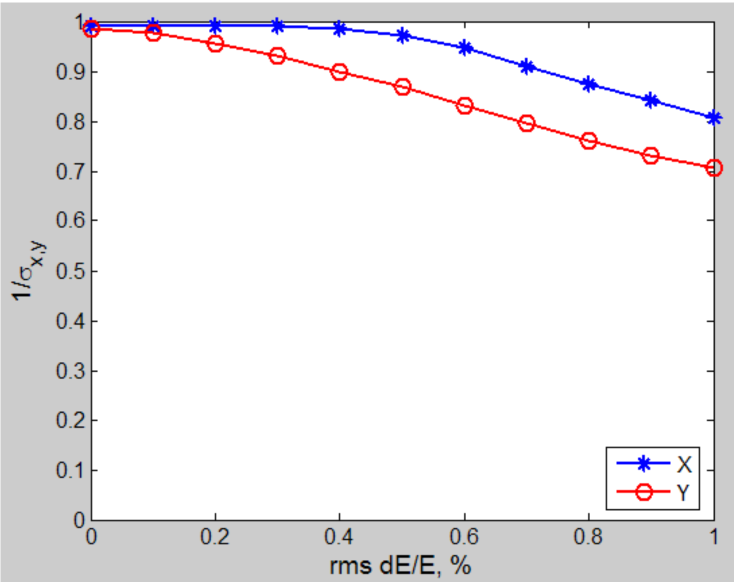


- Not proven that such design would work or the luminosity loss due to longer L* would be acceptable

Tentative BDS with L*=8m (1TeV CM)







Detailed studies of long L* design and its implication on the performance are needed before a conclusion can be made

Summary

- Three things were brought for discussion
  - shorter BDS limited to 500GeV CM reach
  - merged tune-up and main beam dumps for BDS
  - twice longer L* to ease IR design & push-pull
- All these things require detailed evaluation
- Comments, critics, suggestions are welcome

- Extra slides show some more details on the designs

Extra slides

- Describe details of criteria for 500GeV CM BDS design

BSY design criteria

- Minimize system length
- Remove dedicated energy / emittance diagnostic chicane
  - use polarimeter chicane
- Quadrupoles: lengths reduced by factor of 2
  - quad pairs become singlets
  - pole-tip fields remain ~ the same
  - number of quads reduced from 57 to 35
- Kickers: strength unchanged
  - number of kickers reduced from 25 to 16
- Septa: 4 × 5 kG × 2 m (was 3 × 5 kG × 2 m + 2 × 10 kG × 2 m)
- Large bore extraction magnets: unchanged
- Rastering dipoles: number and strength unchanged
  - reduce distance from sweepers to dump (R_{sweep} = 3 cm)
- Spot size on dump window unchanged (round; 1σ area = 2π mm^2)
- Resulting BSY is ~482 m (was ~968 m)
- Resulting dump line is ~318 m (was ~471 m)

Additional Design Criteria: "Beam Switchyard" Area

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Synchrotron Radiation Emittance Growth
======================================

- ILC2006c: @250 GeV, emit/emit0 = 1.0075 ; @500 GeV, emit/emit0 = 1.0137 (emit0 = 1e-5 m)

Laserwire Spot Size
===================

- "worst case" laserwire spot size: maximum energy, DR extracted emittance (2e-8 m)
- "nominal" laserwire spot size: nominal energy, BSY budgeted emittance (3.4e-8 m)
- emittance diagnostic FODO cell length: "worst case" spot > 1.0 um AND "nominal" spot > 1.5 um
- 250 GeV beam (maximum):
  > L45 = 8.3 m
  > BETY(WS) = 32.385 m
  > "nominal" vertical spot size = 1.5002 um
  > "worst case" vertical spot size = 1.1506 um
  > skew/emit length =  203.424 m

Polarimeter Chicane
===================

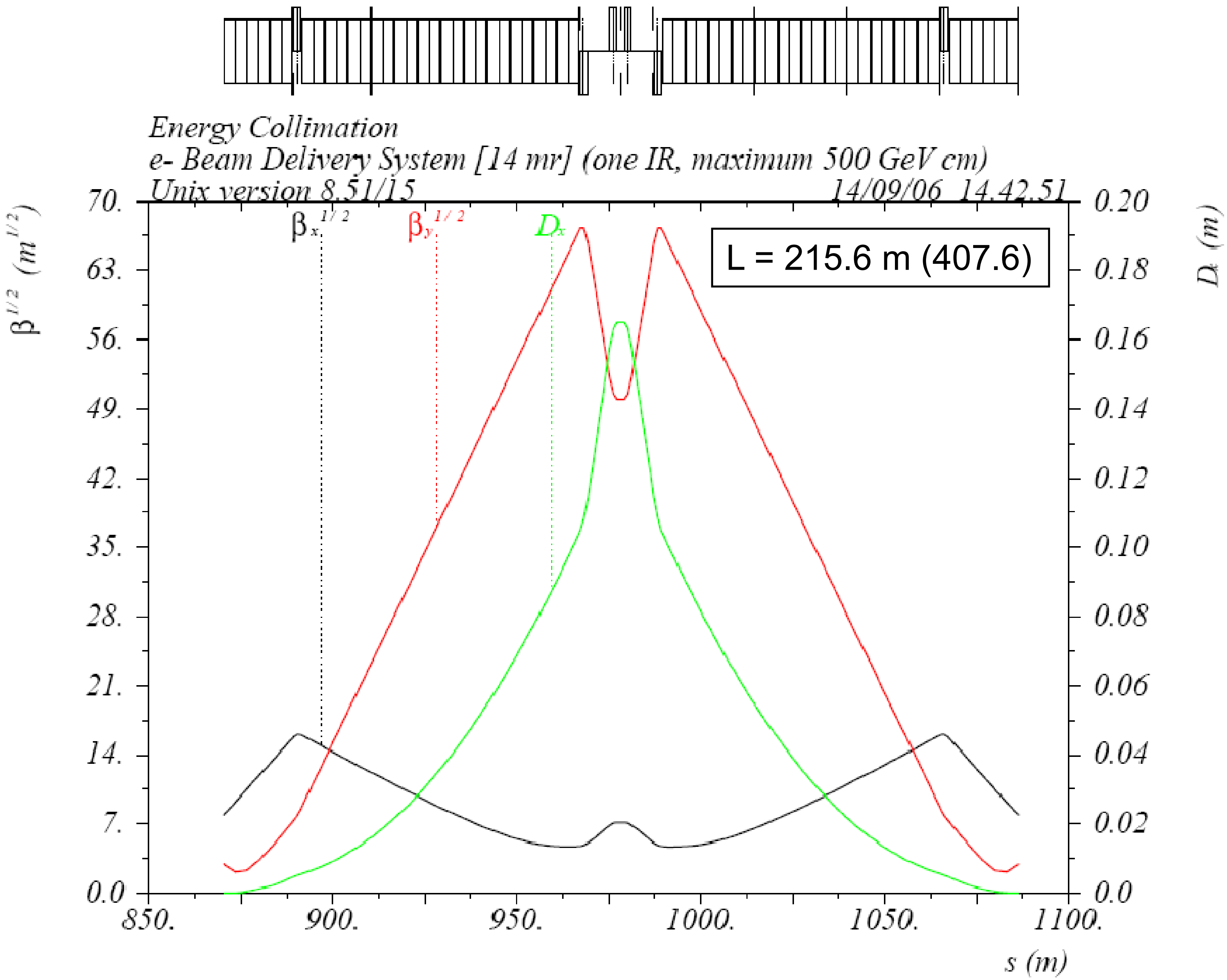
- minimum dispersion = 20 mm
- minimum center dipole separation = 8 m

Extraction
==========

- septum aperture: R = 15 mm (+-10% dE/E acceptance)
- required offset at septum entrance: dX = 35 mm
- 16 kickers (L = 2 m, B = 0.133 kG)
  > Lkick/(Lkick+Ldrift) = 2/3
- 4 septa (L = 2 m, B = 5 kG)
- transverse clearance for IRT "Type B" quads: 135 mm
  > 0.5 * 171 mm (quad half-width) + 40 mm (extraction line beam pipe radius) + 10 mm (clearance)
- transverse clearance for extraction line 8 cm bore quad QFSM1: 220 mm
  > 0.5 * 16 inches (quad half-width) + 6 mm (IRT beam pipe radius) + 10 mm (clearance)
- required offset at dump: dX > 3 m
```

E-collimation design criteria

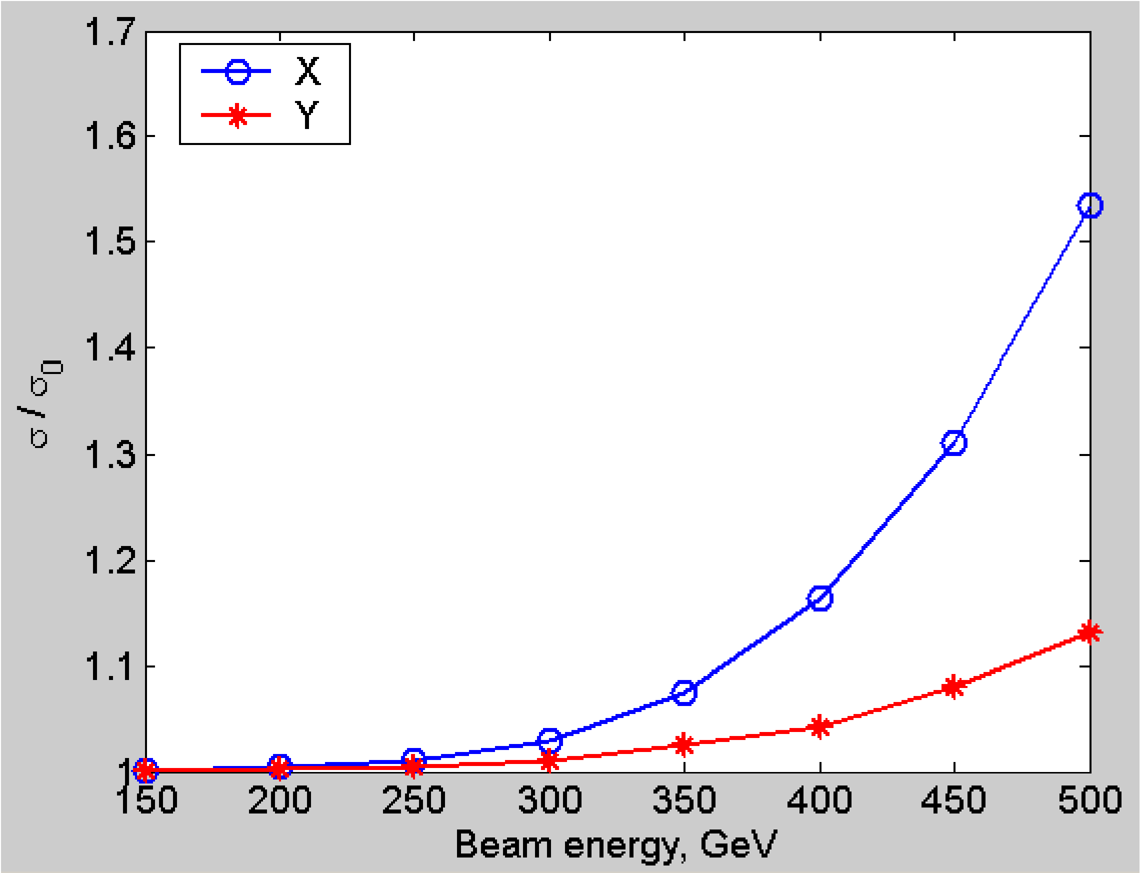
- Shorten 30 BS1 bends from 12 m to 6 m and keep the same 30 cm bend-to-bend gaps.
- Double the bending angles to match the doubled angle in the short FF.
- Reduce two long central drifts from 12 m to 6 m.
- Maintain about the same beam spot $\sigma_x \sigma_y \sim \beta_y^{1/2} \eta_x$ at the energy spoiler.
- Match to upstream betatron collimation and downstream FF sections.
- No change in E-spectrometer chicane.
- E-collimation length reduction: 192 m.


Energy Collimation
e- Beam Delivery System [14 mr] (one IR, maximum 500 GeV cm)
Unix version 8.51/15
14/09/06 14.42.51
L = 215.6 m (407.6)
βx^1/2
βy^1/2
Dx
β^1/2 (m^1/2)
Dx (m)
s (m)
70.
63.
56.
49.
42.
35.
28.
21.
14.
7.
0.0
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.0
850.
900.
950.
1000.
1050.
1100.

FF design criteria

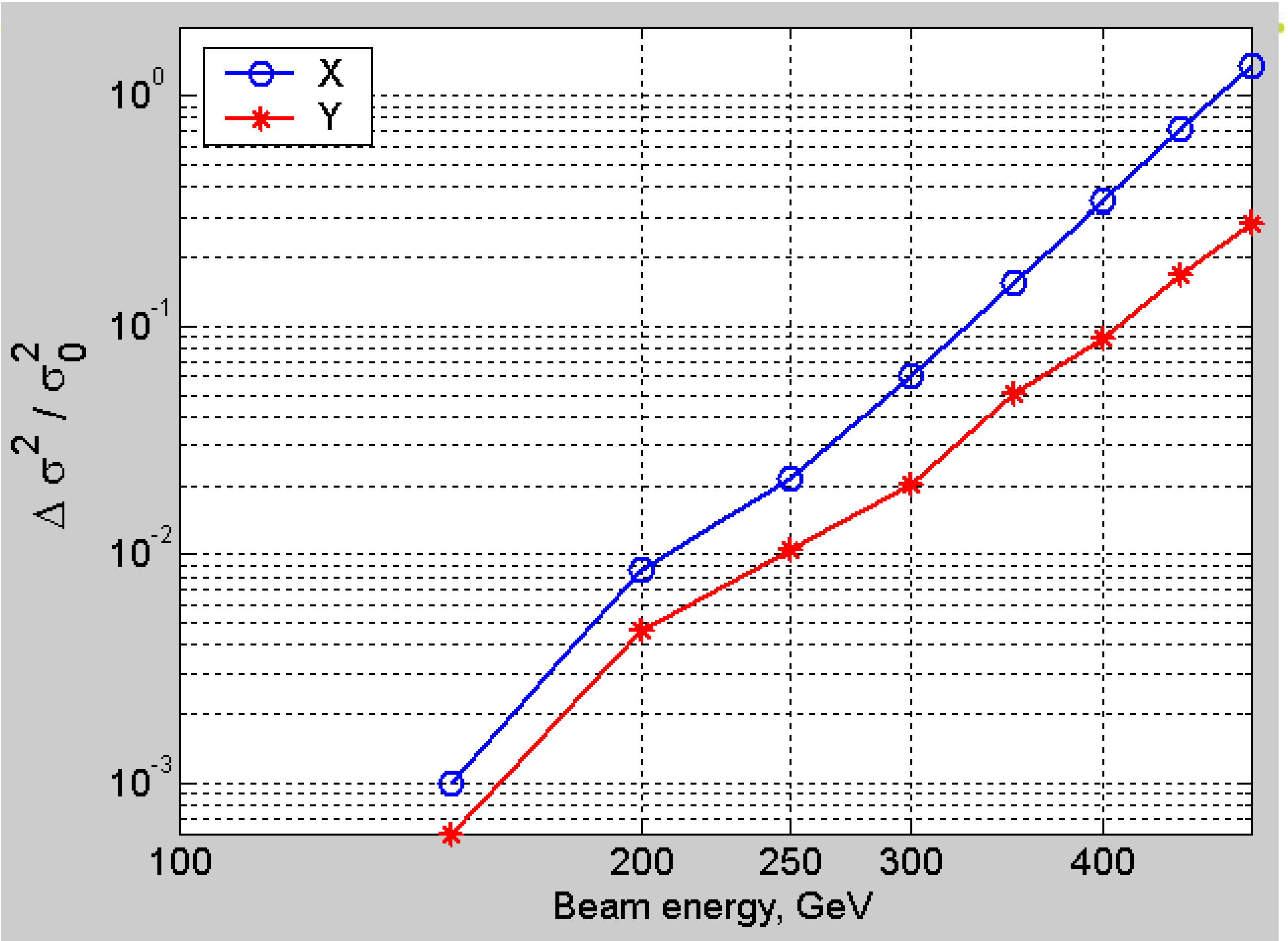
- Shorten bends & long drifts 2.5 times
  - as estimated, this reduces the energy reach to 250 GeV/beam
- Increased bend strength so that angle of FF would be twice of that of ILCFF9, and cancel the E-coll angle
  - so that twice shortened E-collimator with doubled angle have the same horizontal dispersion for survival of the E-spoiler
- Short drifts unchanged
- Fit location of the 300 m point (from IP) with the location of long drift in the FF beam matching section, so that one could place both the muon wall and beam dump at that point
- Resulting FF is ~390 m
- QM11→IP: ~315 m (was ~658 m)

emittance growth in FF



Beam parameters 250 GeV/beam, nominal
Beam size growth due to bends only (DIMAD option 2)

emittance growth in FF



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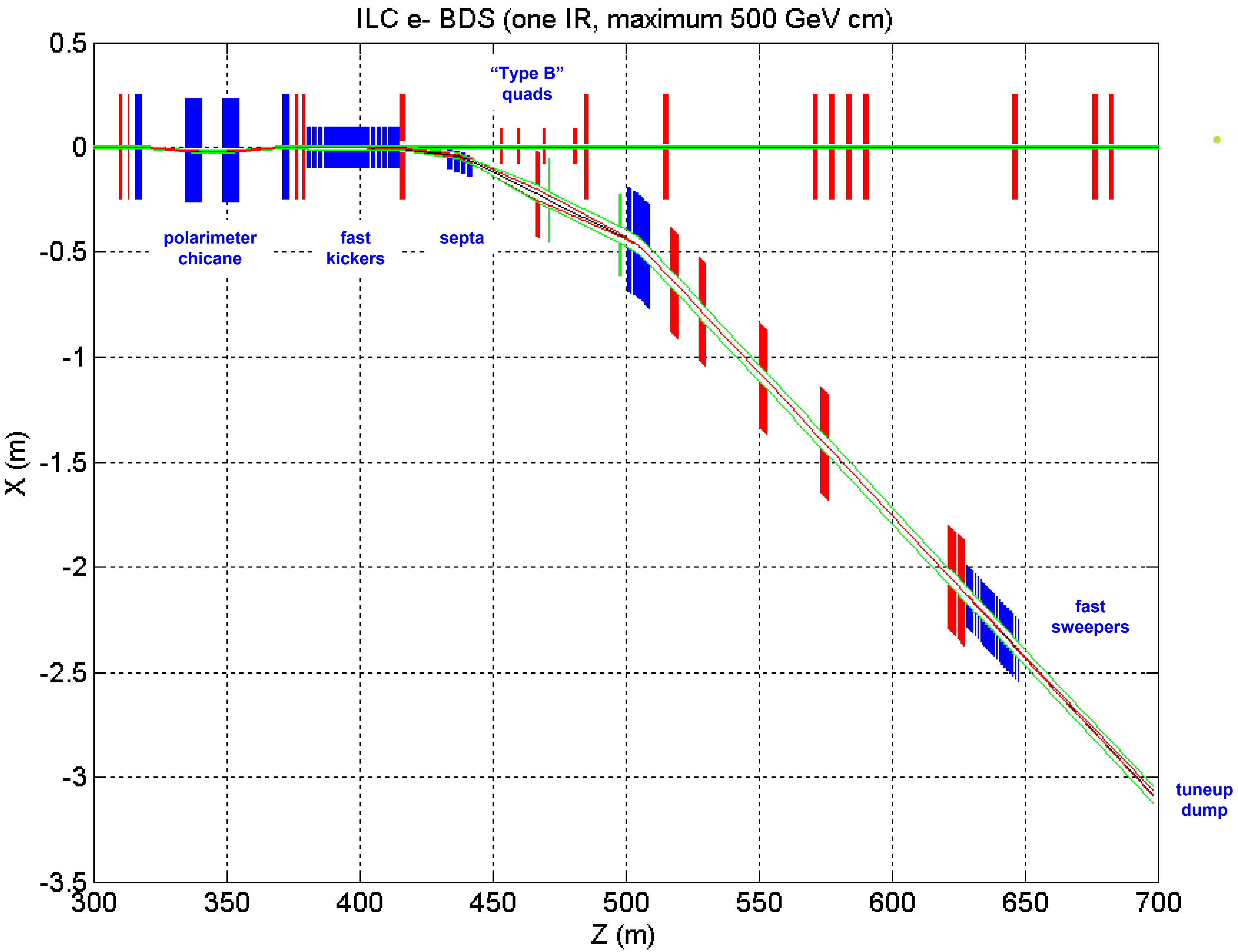
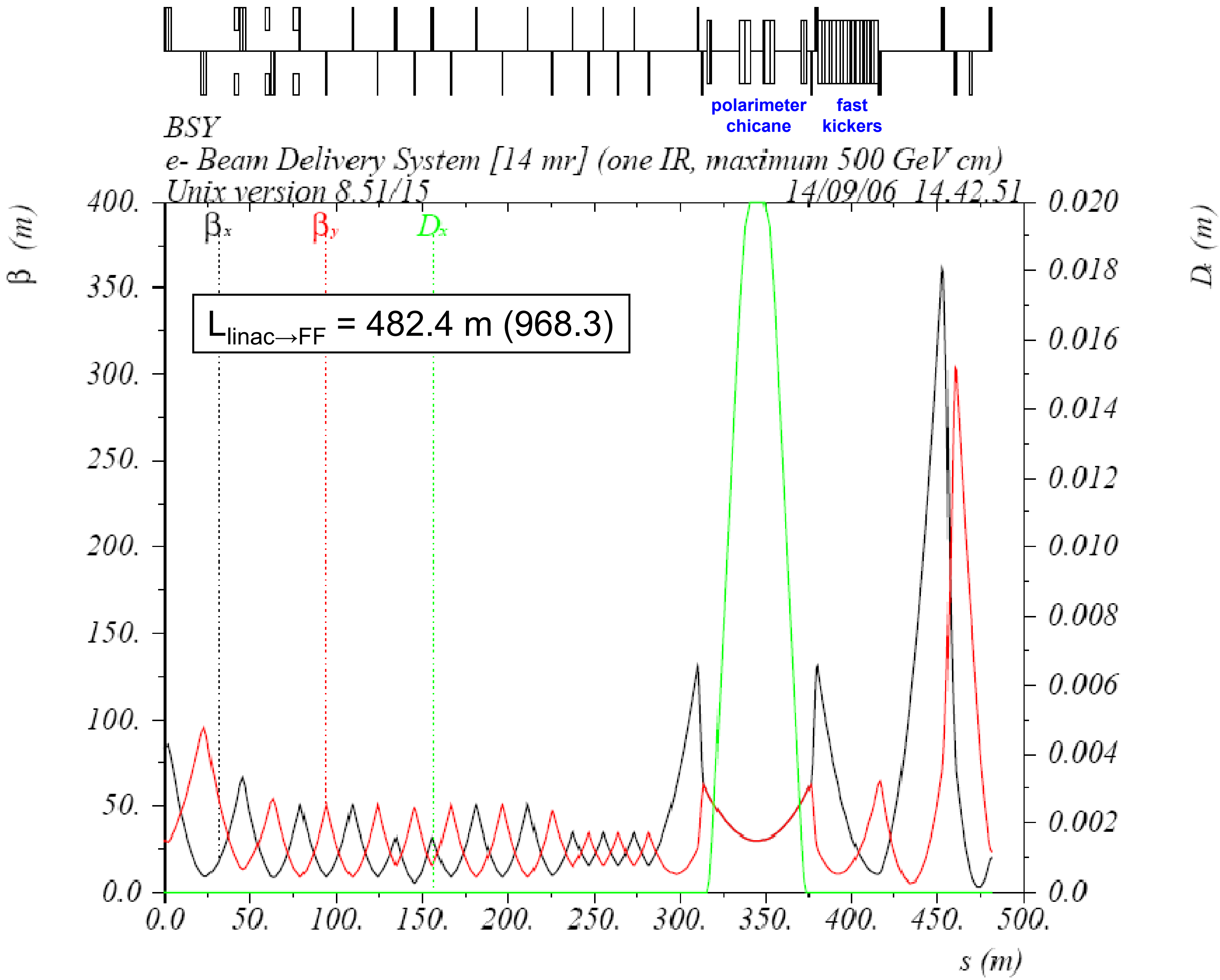
Beam size growth due to bends only (DIMAD option 2)



ILC e- BDS (one IR, maximum 500 GeV cm)
"Type B" quads
polarimeter chicane
fast kickers
septa
fast sweepers
tuneup dump
X (m)
Z (m)
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
300
350
400
450
500
550
600
650
700



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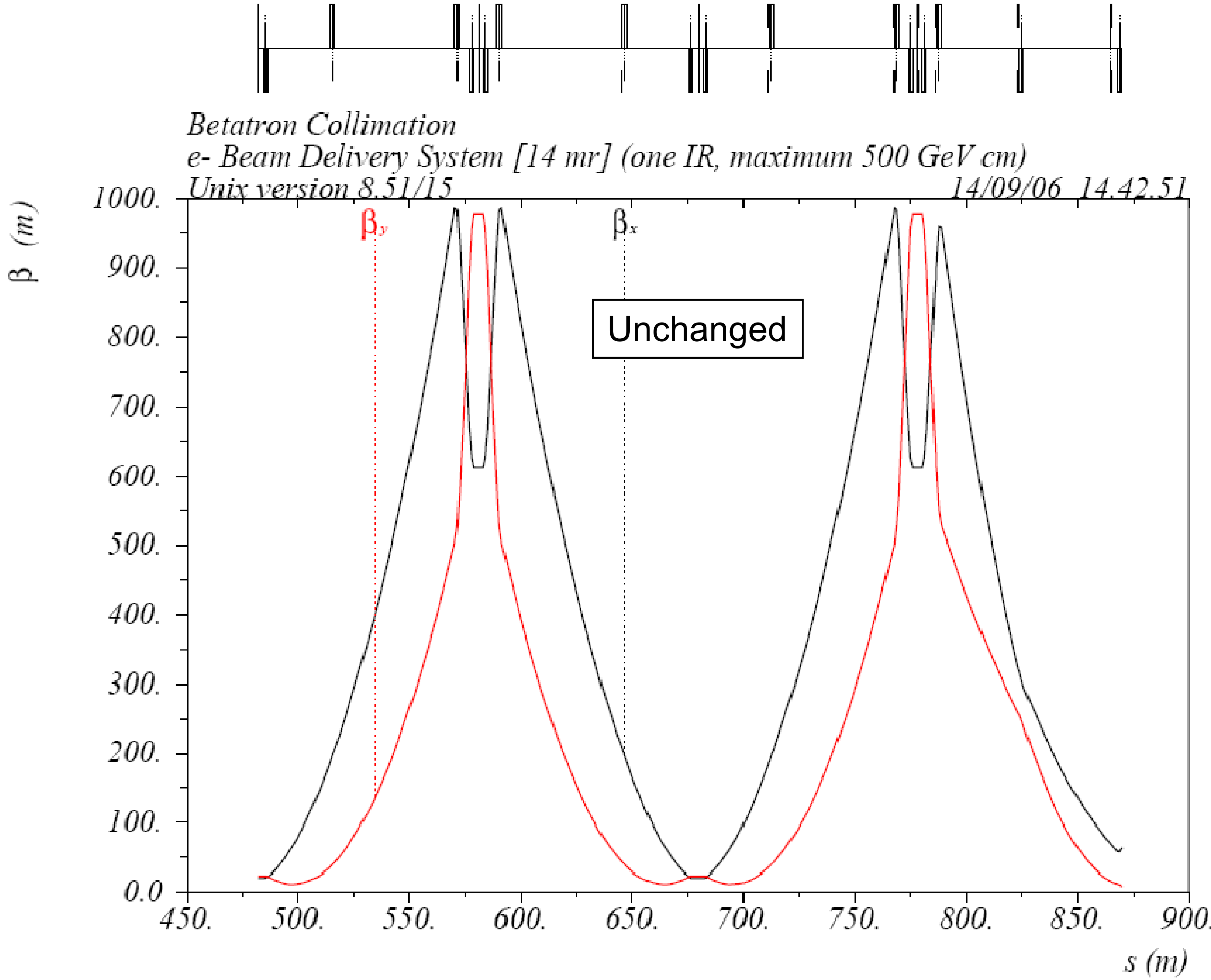

Betatron Collimation
e- Beam Delivery System [14 mr] (one IR, maximum 500 GeV cm)
Unix version 8.51/15
14/09/06 14.42.51
β (m)
βy
βx
Unchanged
s (m)
1000.
900.
800.
700.
600.
500.
400.
300.
200.
100.
0.0
450.
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750.
800.
850.
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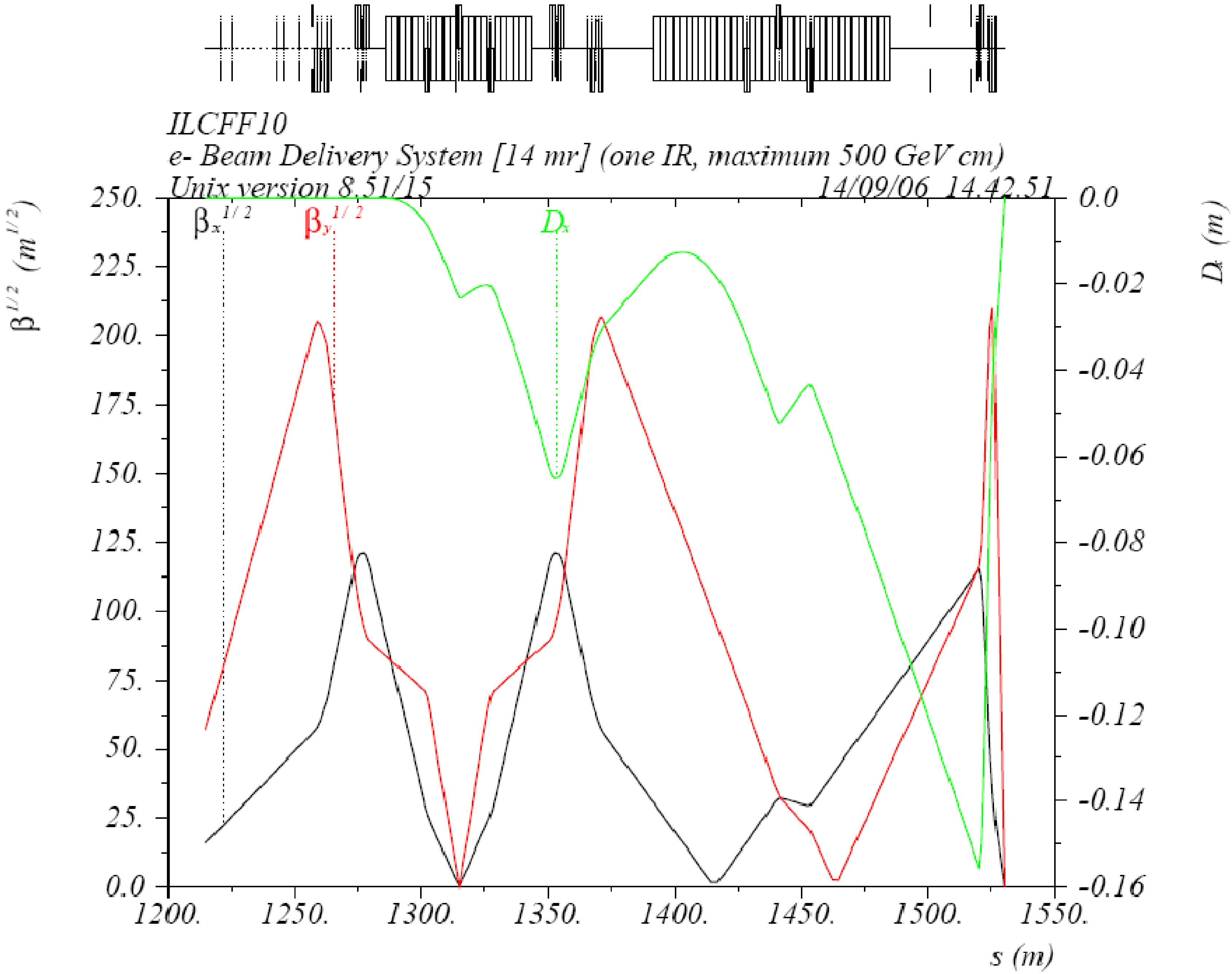

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More extra slides

- IR interface document

IR Interface document – motivation

- Two experimental detectors working in a push-pull mode has been considered for the Interaction Region of ILC
- The push-pull mode of operation sets specific requirements and challenges for many systems of detector and machine
  - in particular for the IR magnets, for the cryogenics system, for alignment system, for beamline shielding, for detector design and overall integration, and so on.
- These challenges and the identified conceptual solutions discussed in the paper intend to form a draft of the Interface Document which will be developed further in the nearest future.

Min Functional Requirements

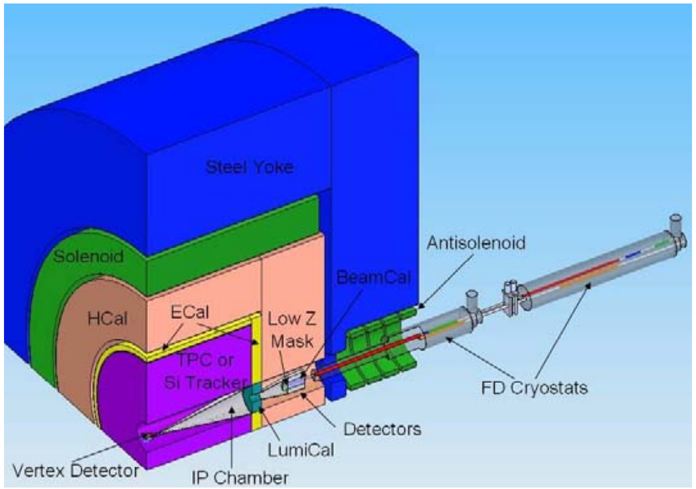
- Minimal functional requirements, to which all detector concepts are bound
  - These requirements are closely related to fundamental properties of design and less dependent on site location and similar specifics
    - In contrast, the next section will describe more detailed specification and outline the present working models and likely technical solutions.
- The list of minimal functional requirements
  - the need to have two detectors in a single collider hall, able to work in turns, in push-pull mode
  - The speed of push-pull operation -- the goal that hardware design should allow the moving operation, reconnections and possible rearrangements of shielding to be performed in a few days, or less than a week

Min Functional Requirements

- The list of minimal functional requirements (cont.):
  - allow range of dimensions: detector half size of 6-7m, detector optimal L* of 3.5-4.5m, different L* is allowed for different detectors
  - The off-beamline detector is shifted in transverse direction to a garage position, 15m from the IP. The radiation and magnetic environment, suitable for people access to the off-beamline detector during beam collision, are to be guaranteed by the beamline detector using their chosen solution
  - The IR and detector design is to satisfy the beam parameters defined in the RDR including nominal, Low N, Large Y and Low P parameter sets

Interface Specifications: Final Doublet

- The superconducting final doublets, consisting from QD0 and QF1 quadrupoles (and associated 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



Interface Specifications: Radiation safety

- Radiation shielding is essential with two detectors occupying the same IR hall.
- Detector should either be self-shielded or need to assume responsibility for additional local fixed or movable shielding (walls) to provide area accessible for people near the second detector when the first is running with beam.
- Radiation criteria to be satisfied are for normal operation and for accident case
  - In the normal operation, the dose anywhere near non-operational second detector should be less than 0.05mrem/hour.
  - In the accident case the dose should be less than 25rem/h for maximum credible beam (simultaneous loss of both e+ and e- beams anywhere near the IP, at maximum beam power), and the integrated dose less than 100mrem per accident.
  - The criteria are to be satisfied with consideration of all realistic gaps, cable and cryogenics openings in the detector or shielding.
- The outcome of these radiation requirements is understood to be the need for "Pacman" shielding of the IR beamlines, and additional shielding of detector and possibly a shielding wall for non-self shielding detector. The Pacman consists of two parts, with the one roughly overlapping with QF1 being machine responsibility, while the detector specific QD0 part being detector responsibility.

Interface Specifications: Cryo system

- Proper design of cryogenic system for the FD is critical to ensure quick and reliable push-pull operation.
  - There is a service cryostat connected to each QD0 cryostat. The service cryostat is placed outside of the Pacman.
  - The cryo-line (with 1Bar He-II and current leads) connects QD0 cryostat to the service cryostat. This line is never disconnected except for major repairs.
  - The line goes through Pacman in such a way that there is no direct view to the beamline from outside (thus, a knee may be needed) to satisfy radiation requirements.
  - The service cryostat is connected to cryo-system via flexible line containing LHe single phase supply and low pressure He return.
  - The QD0 cryo system and connections are sized from the assumption of maximum of 15 Watts (14 static + 1 dynamic) load at 1.9K.

Interface Specifications: Detector opening

- Opening of the detector on the beamline must be allowed by design of all hardware (in particular supports, QD0 cryo-line, shielding, etc). Hardware design should allow opening or closing to be performed in half-a-day. At least 2m of opening should be provided. The corresponding detector collaboration is responsible for the operation

Interface Specifications: Detector assembly

- Assembly of the detectors, for considered deep site configuration, is assumed to be done on surface, in a dedicated building, and only the final assembly is done in the collider hall underground, using a light crane with several tens of ton capacity and using air-pads for motion of larger weights underground. The assembled parts of detector are lowered from surface using a 2000-2500 ton gantry crane, which must be stationary when handling heavy loads (thus, a shaft cover is needed as handling ancillary), however, with no load, the gantry crane can be slid over one or the other shaft to service one detector or the other
  - While the above described on-surface assembly is a baseline, the underground assembly will be evaluated as alternative approach, and may be found beneficial especially for the shallow location of the collider.
  - Segmentation of detector is entirely a choice of detector collaboration, provided that it does not contradict other agreed upon assumptions. The question whether the detector door is split vertically or not, seems to have most interference with machine design. The choice will involve evaluation of consequences for the vacuum chamber design, for support of FD and cryogenic line connection, for the magnetic forces acting on end caps, etc.

Interface Specifications: Alignment

- Alignment requirements are by far the most critical in determining the design of infrastructure in the Interaction Region.
- It is assumed that after the push-pull operation the detector elements would be placed within ±1mm from the ideal position and in that range the motion system should compensate for any elastic deformations or long term settlements.
- The QD0 cryostat would have its own alignment system of the ±2mm range for fine alignment.
- Before starting the beam, the FD apertures and Vertex apertures need to be aligned to better than ±0.2mm, and for that, the detector would provide to machine the means to know the vertex position and also provide four channels for an optical path to each of the QD0 cryostats, to perform interferometer triangulation from underneath of the detector.
- The responsibility to align the FD belongs to the machine.
  - For reference, the detector has its own internal alignment requirements, which typically involve measuring Vertex position with respect to tracker on a micron level, and measuring tracker to calorimeter on mm level. Such measurements and kinematic adjustments would likely have to be with magnetic field switched on, to take into account deformations under magnetic stress. The internal alignment of detector is entirely the responsibility of the detector groups, and mentioned here inasmuch as it is relevant for the following.

Interface Specifications: Motion system

- The design of detector motion system must be determined from the functional requirements of providing prompt push-pull operation and satisfying the alignment requirements.
  - The working assumption for the motion system assumes the use of two platforms, with dimensions approximately 20x20x2m, on which the detectors and part of its services and shielding will reside.
  - The motion system (thought to be a set of Hilman rollers) would be placed under the platform together with hydraulic jacks which would allow pushing the rollers to working height before the push-pull operation, or insertion of shims for fine adjustment of the height. The platform would be designed to limit deformation of its surface, where detector is placed, to be less than a millimeter during the entire push-pull operation. The responsibility for the motion of platform would belong to the machine group.
- The concept of using the moving platform is an approach where an additional device is employed at the machine side to ease the alignment of detectors. One can also imagine another approach, where the problem and responsibility are pushed to the detector side entirely. While at this moment it is not clear if detectors can solve the alignment problem without the use of platform, study of such approach are planned and the eventual configuration will be determined from consideration of both the technical feasibility and cost effectiveness.

Interface Specifications: Vacuum

- Vacuum requirements in the Interaction Region may determine the background condition in IR via beam gas interaction.
- We assume that vacuum should be less than 1nTorr within 200m of the IP, with the exception of the drift inside of detector, where 10nTorr are allowed (pressure specified at room temperature and for composition of 62% H_2, 22% CO, 16% CO_2).
  - It will be investigated further if higher pressure is allowable in the QD0-QD0 drift.
- It is assumed that detector concepts responsible for providing space for needed pumps near the IP side of QD0, and that the cold bore of the QD0 cryostat is not considered as a free cryo-pump.

Interface Specifications: Magnetic field

- Requirement for the magnetic field outside of detector is an important factor which defines the amount of iron in the detector (or degree of compensation for iron-free design).
- We assume that effects of any static field outside of detectors on the beam can be corrected, and the requirements should come only from human safety factor and from the limit of field map distortion due to off-beamline detector.
- Assuming that access to the IR hall will be restricted for people with pacemakers, we require that the field on any external surface of on-beamline detector to be less than 2kGs, while its field in non-restricted area (including near the off-beamline detector) to be less than 100Gs.
- The magnetic field effect from the off-beamline detector onto the on-beamline detector must limit distortion of magnetic field map of the latter to less than 0.01% anywhere inside its tracking volume.

Interface Specifications: Fire safety

- Fire safety considerations impose an absolute restriction for use of flammable gas mixtures underground.
- Only the halogen free cables are allowed.
- Smoke detectors with sufficient granularity are mandatory inside the sub-detectors.
- The inner enclosed volumes of detector must be maintained at low oxygen content.
- Outside of the detector the fire fighting systems must be foreseen, which may use suppression gases and sprinkler or foam.
- Fire safety also imposes the use of safety evacuation passages (small tunnels) around the collider hall, and affects location of the shafts and cross-galleries, to avoid corners with single escape route.

Interface Specifications: Commissioning

- Elements for machine commissioning include an additional temporary shielding, FD supports and special instrumentation that would be constructed and used when detectors are not yet on the beamline. The FD for commissioning would be one of those not yet installed in a detector.

Interface Specifications: Vibration stability

- Vibration stability requirements define construction of the inner parts of detector and location of its services.
- We assume that the needed stability of detector surface on which the FD rests, is about 50nm, and that detector concepts are responsible for providing this stability (the mentioned number is rms relative displacement of two FDs between any of 5Hz pulses).
- This also assumes that final stability of the Final Doublet would be about 100nm and the difference constitutes the machine vibration budget.

Interface Specifications: P-p definition

- Definition of the push-pull operation – we assume that it includes time from the switch-off the beam until the moment when luminosity is restored to 70% level and at the same energy, after the detector exchange.
- Any possible calibration of the detector, at nominal or lower energy, is not included in the time of push-pull operation and is entirely up to the detector collaboration.

Interface Specifications: unfinished..

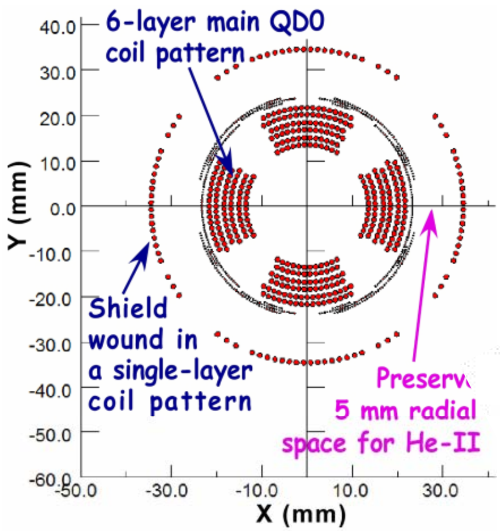
- Configuration of the collider hall and surface buildings must encompass all the requirements for detector and services, and must also be extremely carefully scrutinized, being one of the cost drivers of the design. Continue … describe layouts, sizes, shafts, alternative, who use the space, etc…
- Continue… Air, power, remove its own heat, T stability, humidity, grounding, procedures for on-beamline and garage, DID & anti-DID, design for gamma-gamma, … etc…
- Continue… Describe steps to arrive to final interface document… Mention studies to be done, e.g. near surface collider hall, twice longer L*, etc…

Summary

- IR Interface Document is being prepared by Machine-Detector colleagues
- Preparation of this document is one of the ways to focus the design efforts, highlight contradictions and resolve them, and eventually to optimize the design
- Comments, suggestions, critics, will be greatly appreciated

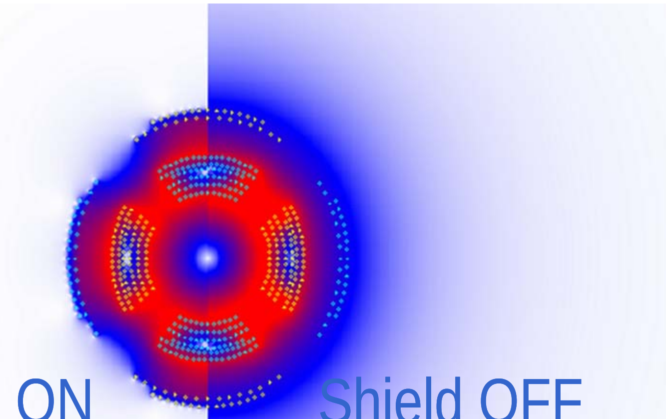
Back up slides

- ILLUSTRATIONS



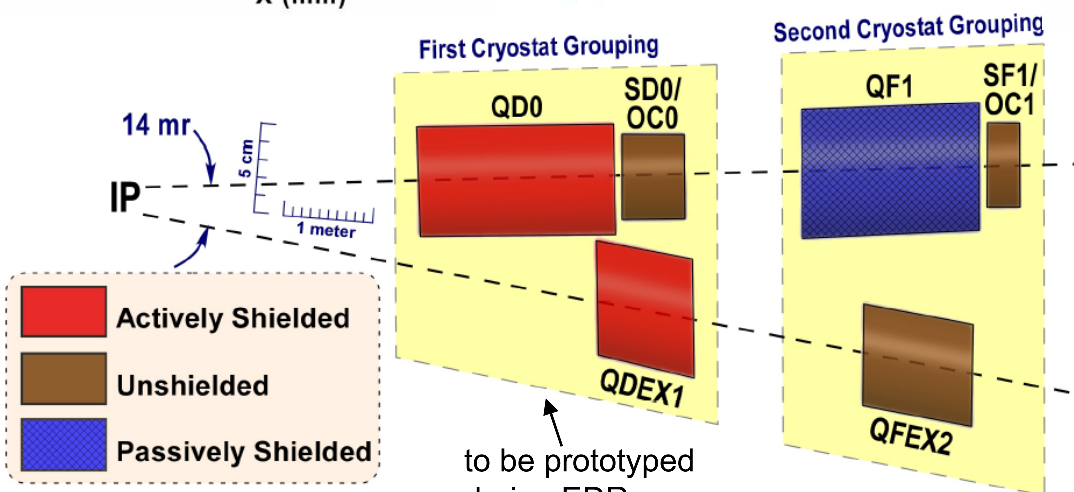
14mr IR

BNL



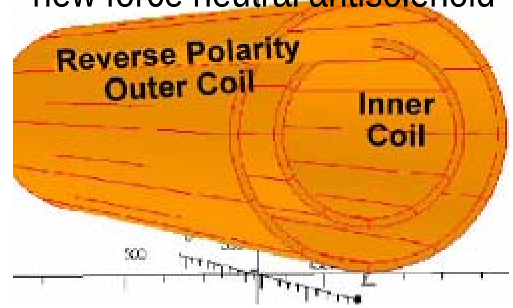
Shield ON Shield OFF

Intensity of color represents value of magnetic field.



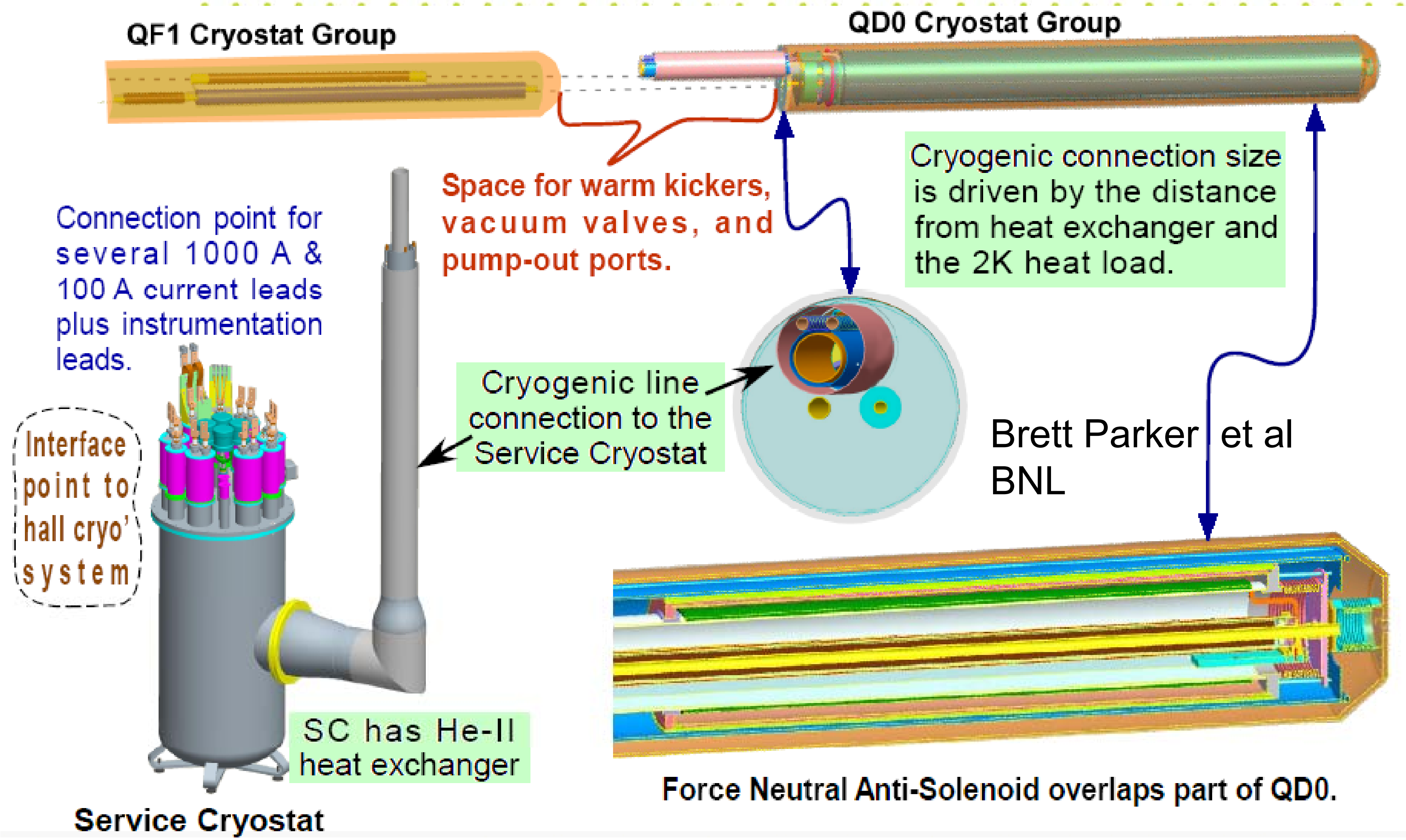
Two Coils; Different Radii

new force neutral antisolenoid

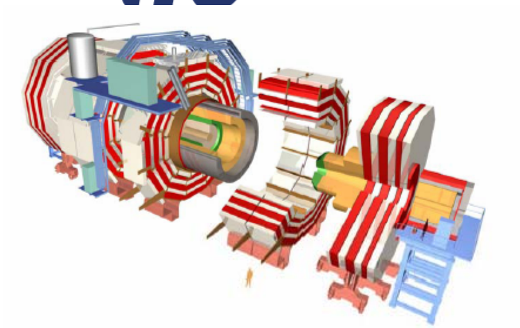


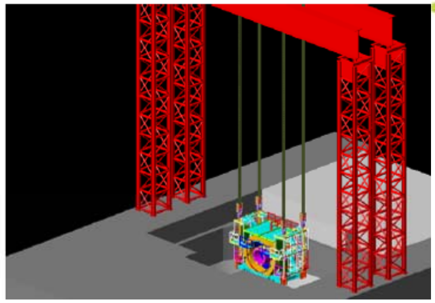
- Interaction region uses compact self-shielding SC magnets
- Independent adjustment of in- & out-going beamlines
- Force-neutral anti-solenoid for local coupling correction

SC final double & its cryo system



Detector assembly

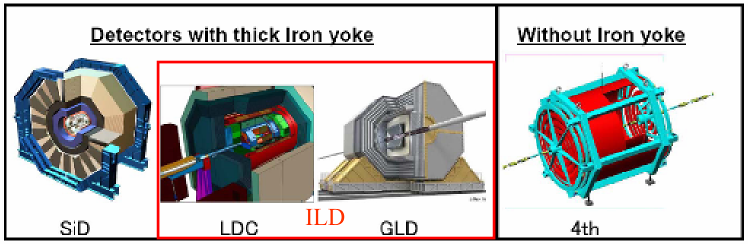


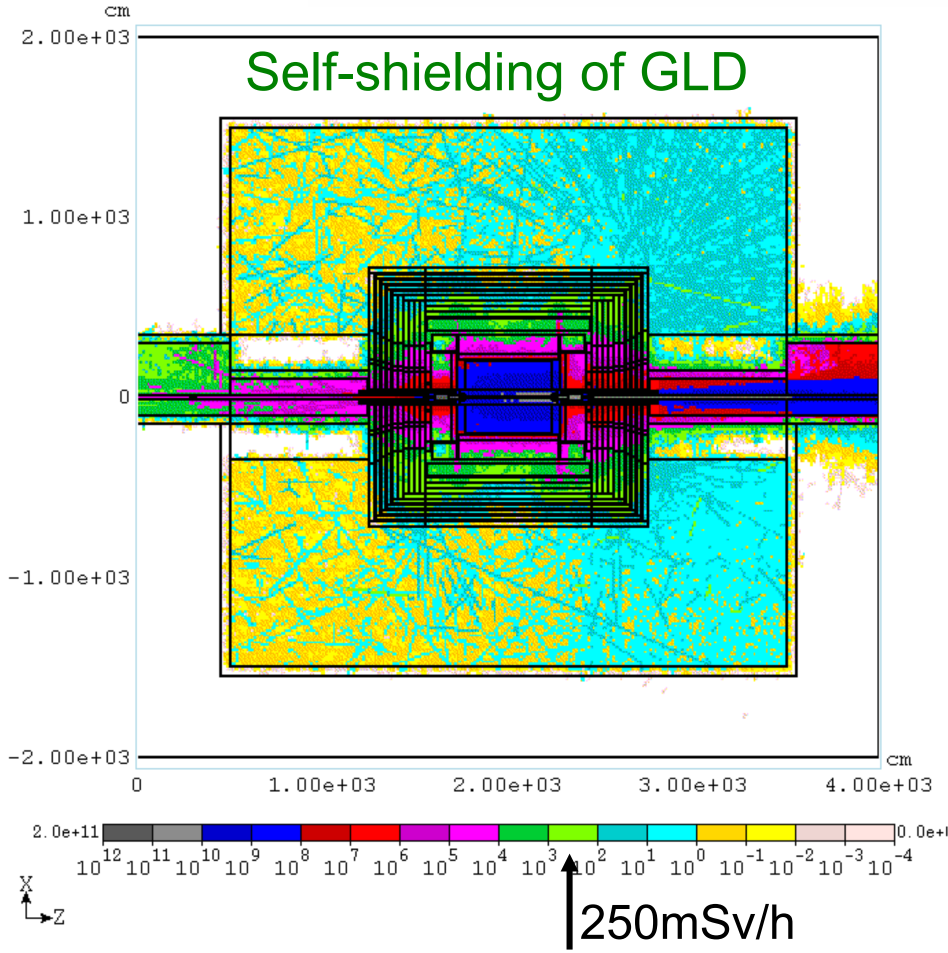


- CMS detector assembled on surface in parallel with underground work, lowered down with rented crane
- Adopted this method for ILC, to save 2-2.5 years that allows to fit into 7 years of construction

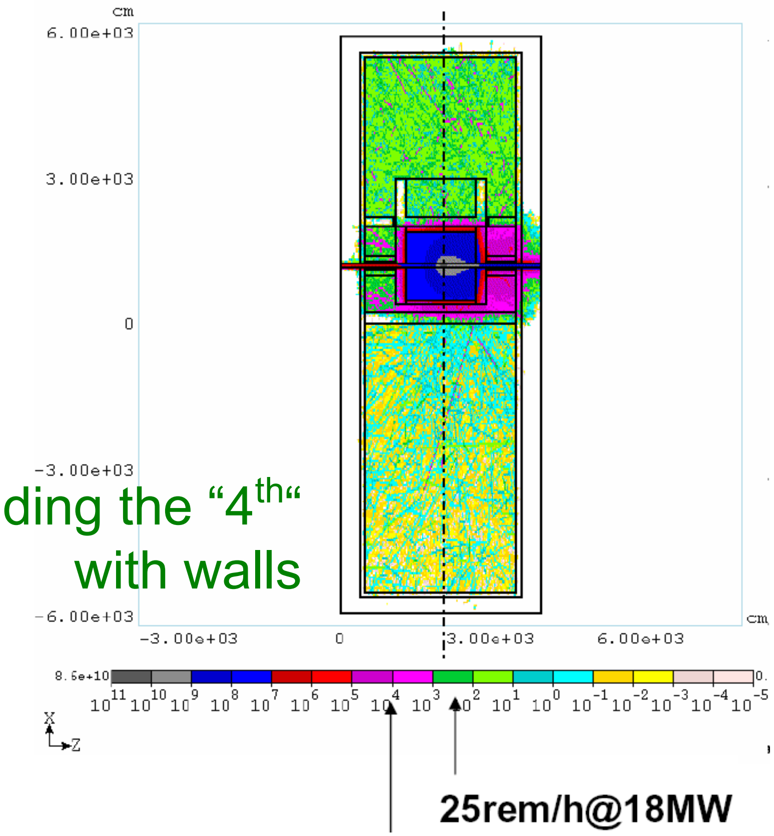
photos courtesy CERN colleagues

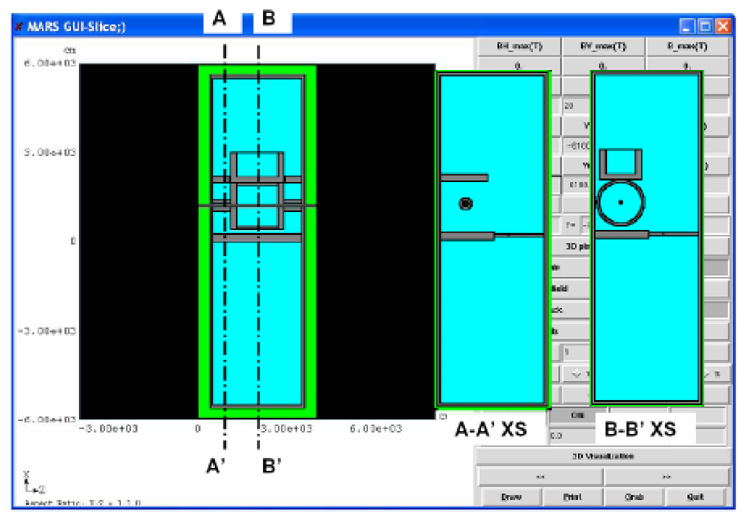
Shielding the IR hall



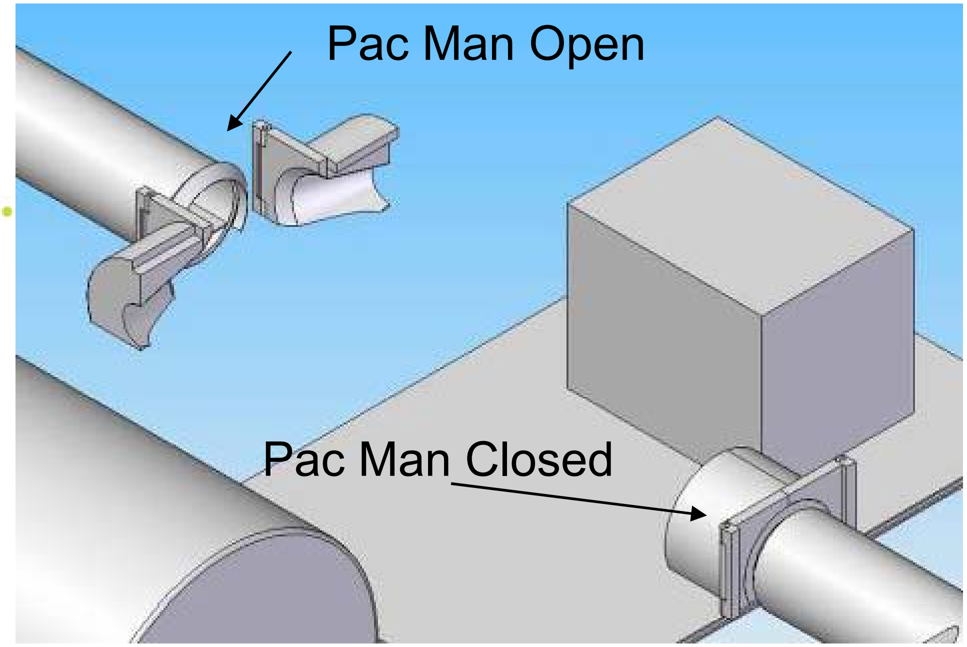


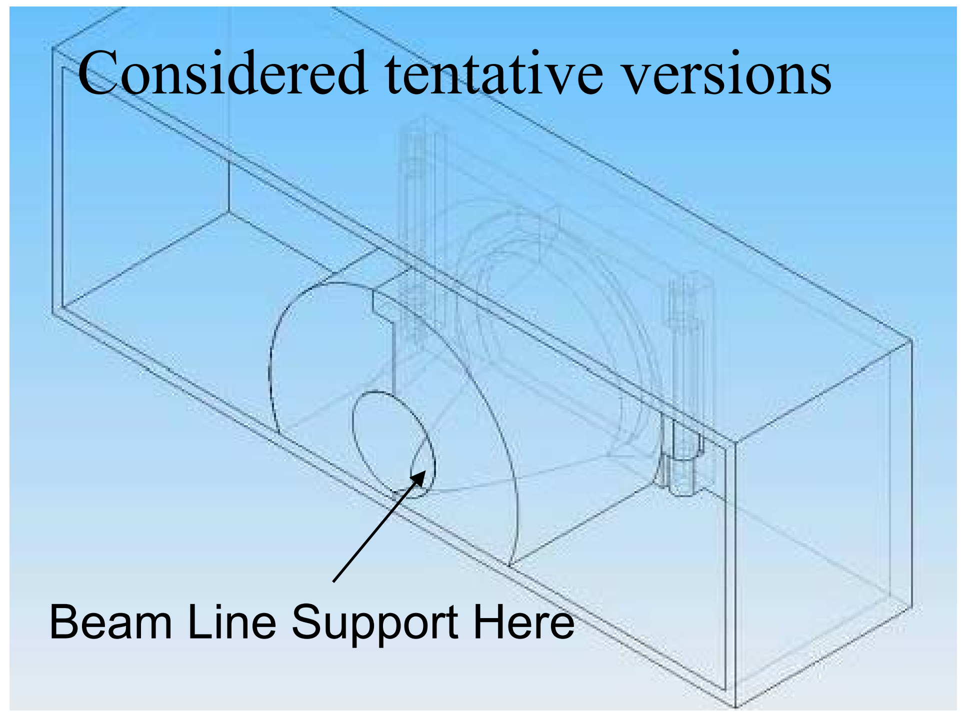
Shielding the "4th" with walls





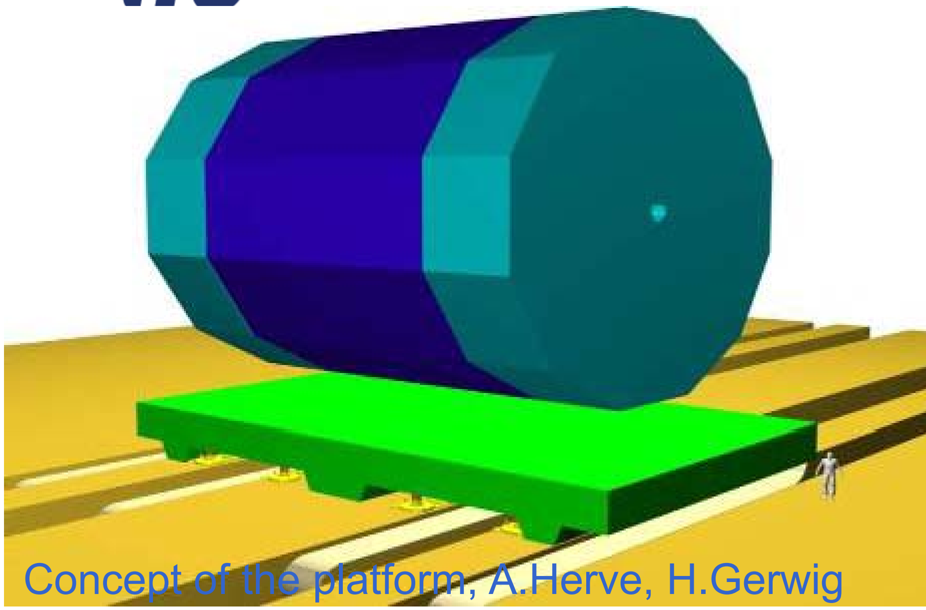
Pacman design



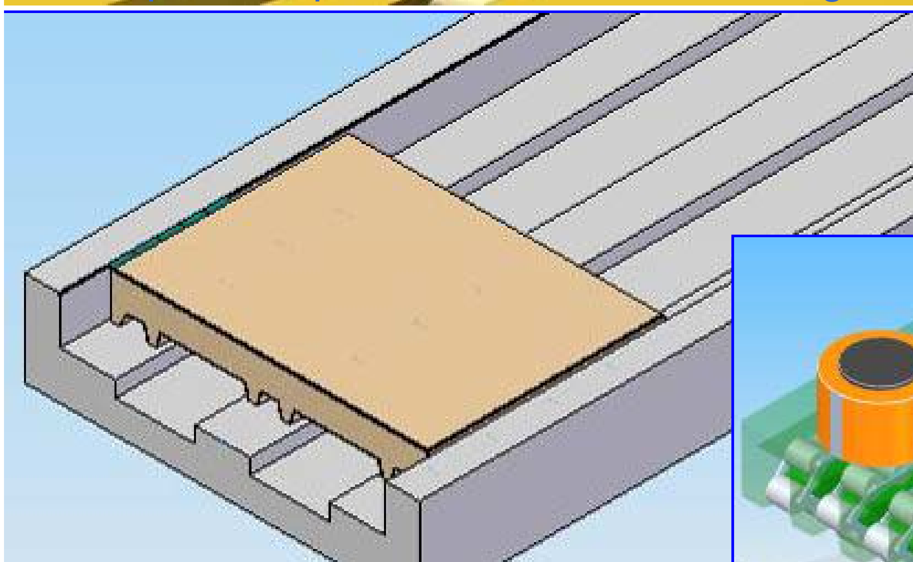


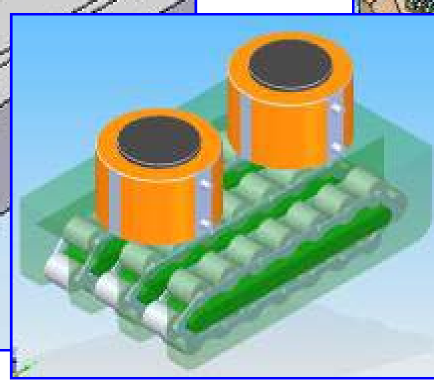
John Amann

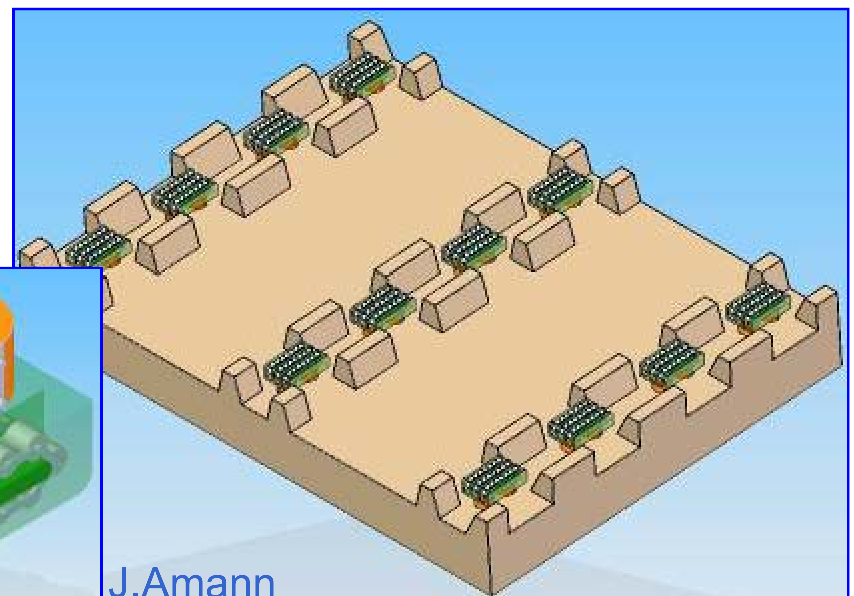
Moving the detector


Concept of the platform, A.Herve, H.Gerwig

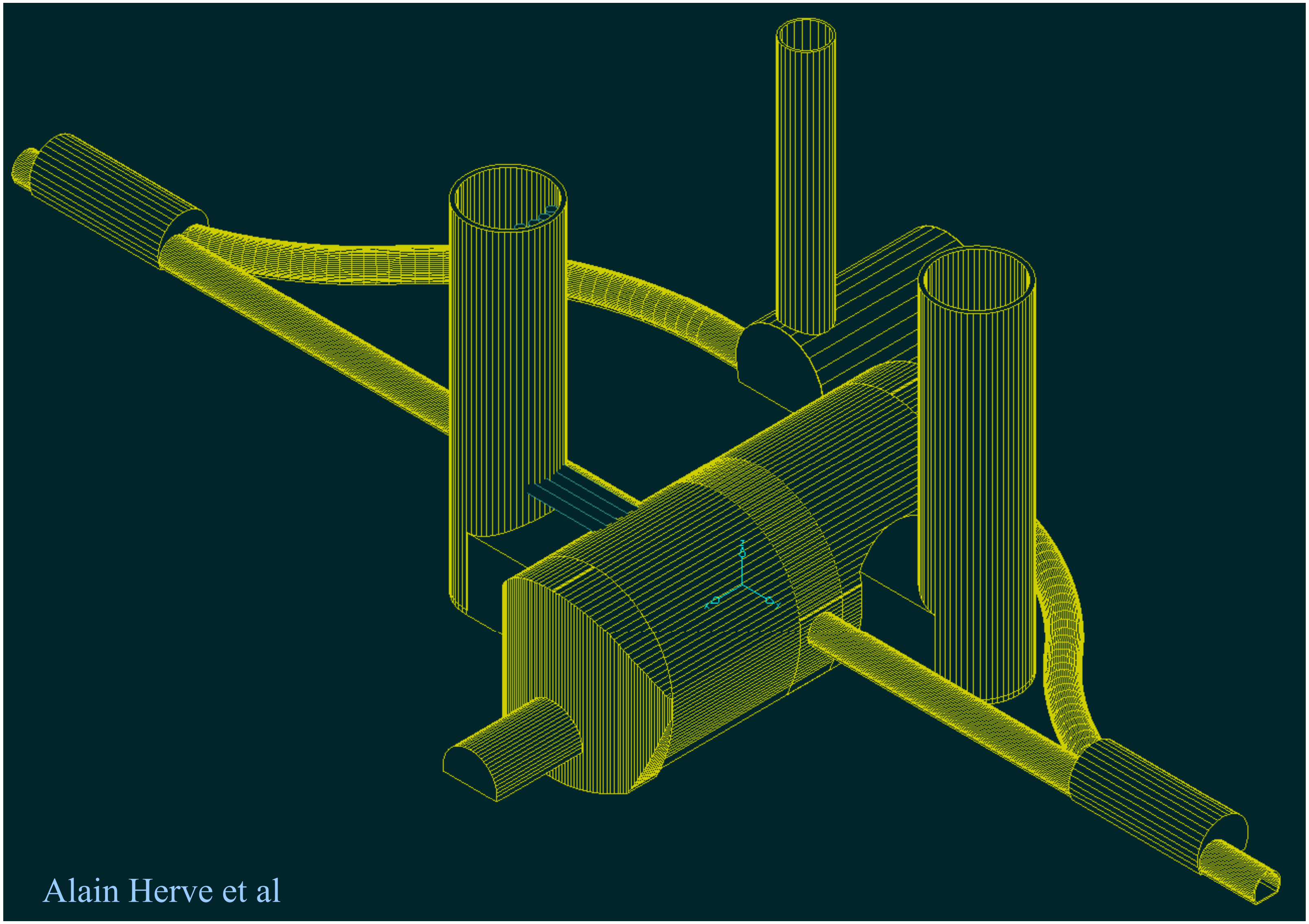

Air-pads at CMS – move 2000k



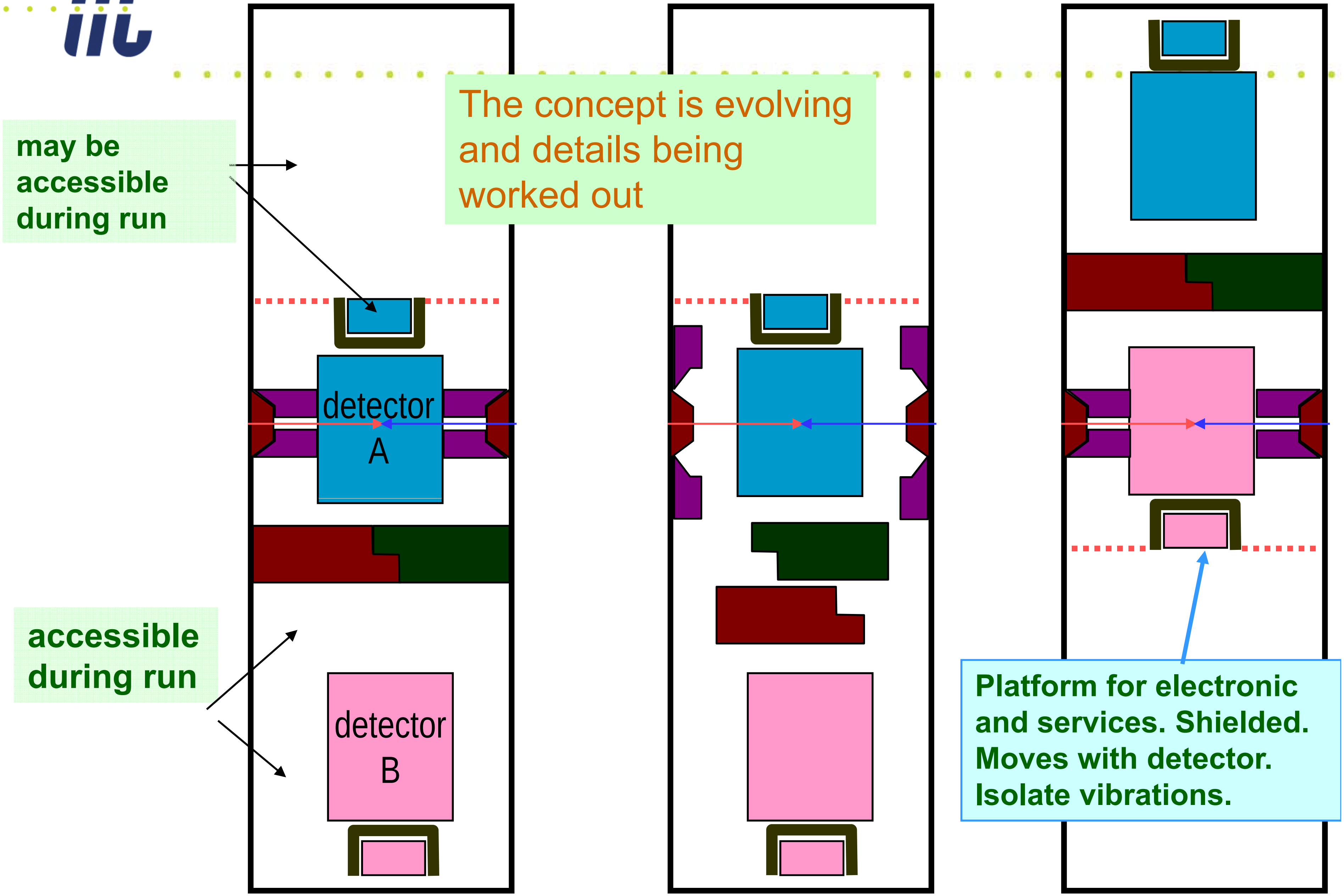



J.Amann

Configuration of IR tunnels and halls



Concept of single IR with two detectors



Present concept of cryo connection