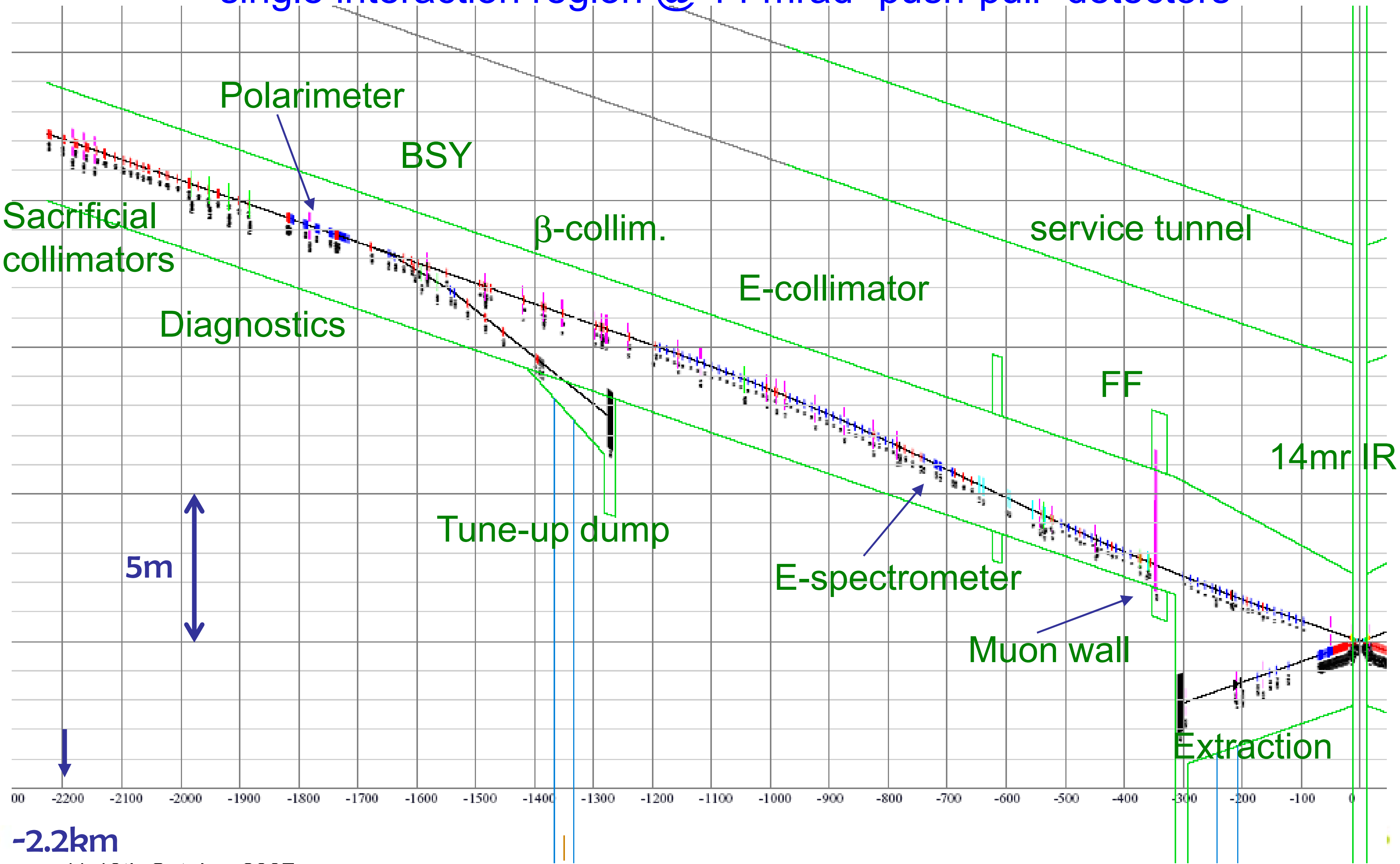
Accelerator and detector requirements specification and optimisation on example of interaction Region

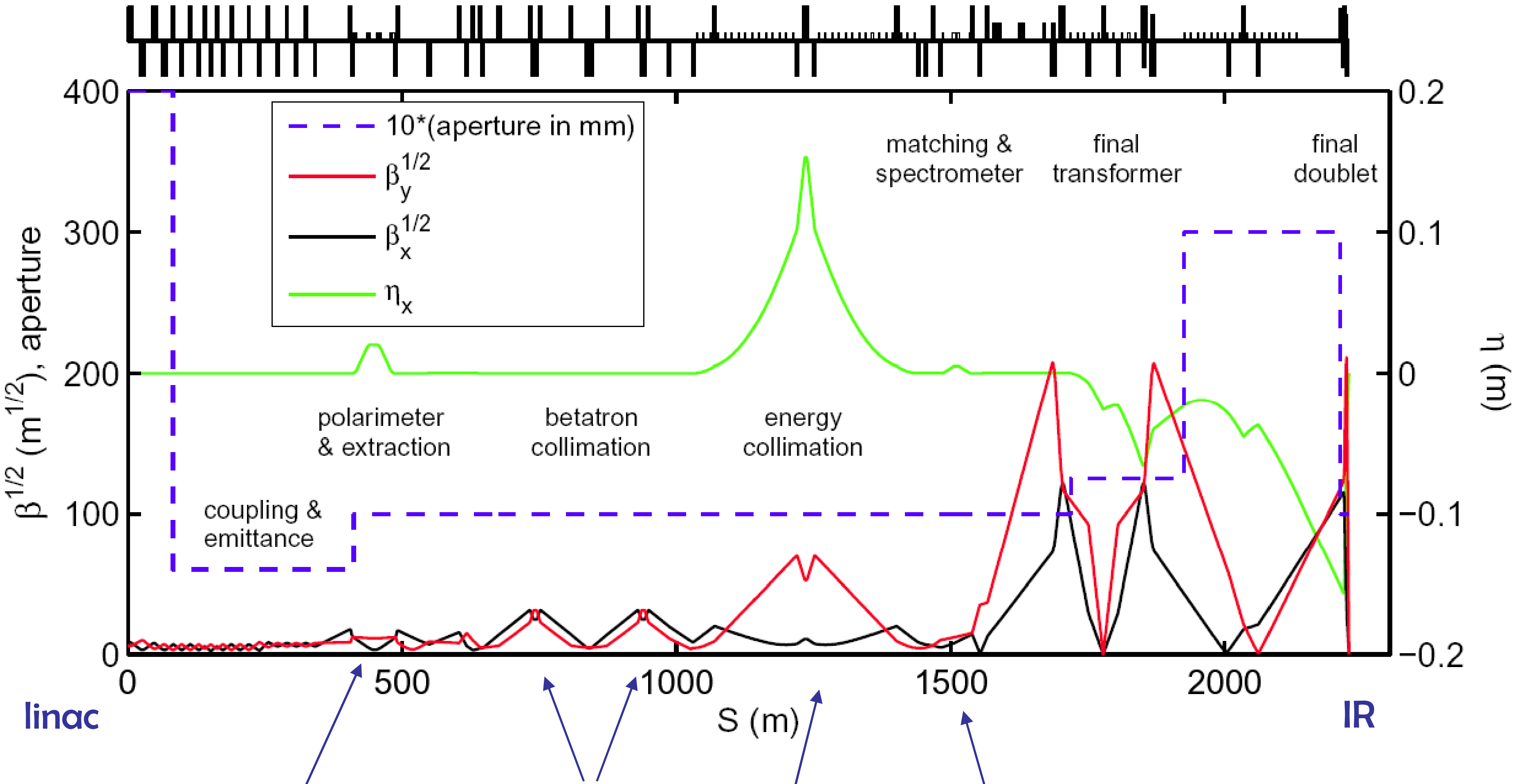
BDS Design Team

RDR BDS Layout

single interaction region @ 14 mrad "push-pull" detectors



BDS optics



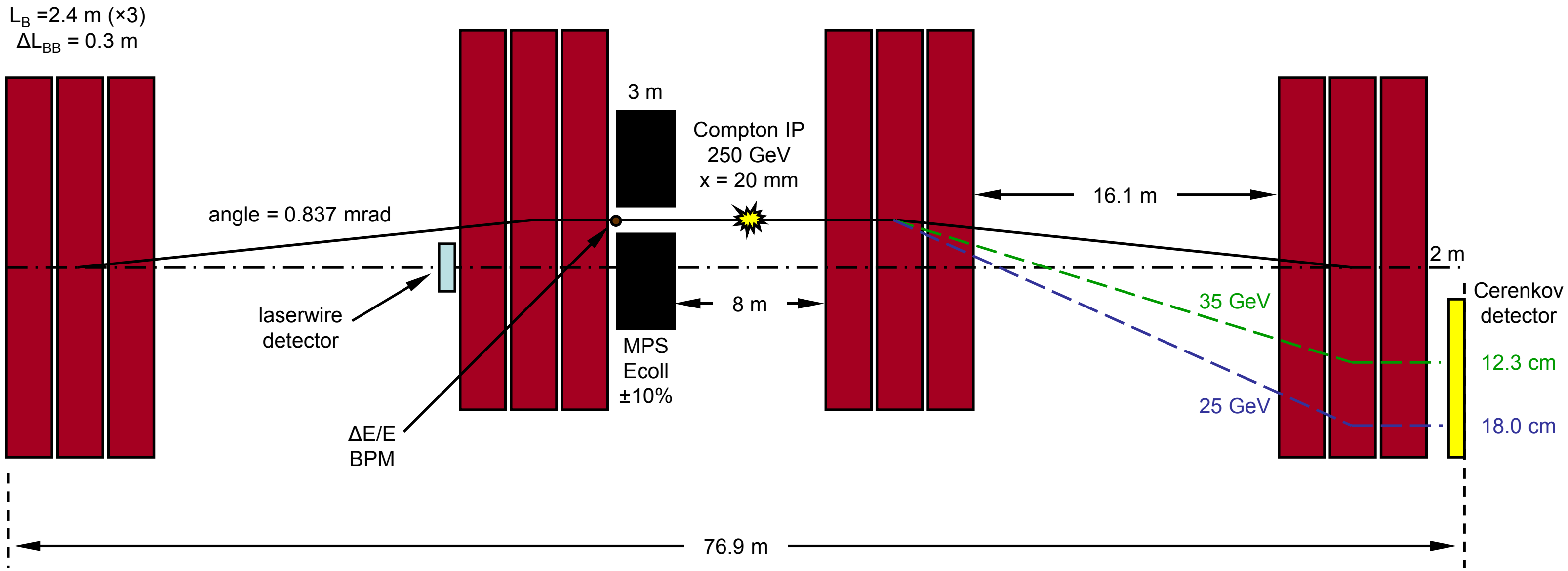
Upstream polarimeter; β & E –collimation ; Energy spectrometers are of particular MDI interest

RDR (ILC2006e) Optics

- Hybrid system upgrade to 1 TeV CM involves adding magnets only
  - **no geometry changes**
  - **no expansion into linac tunnel**
  - **dumps don't move**
  - **upstream polarimeters don't move**
  - **Upgrade to 500 GeV : additional dipoles, septa/kicker & replace FD**
- @ 250 GeV, emit/emit0 = 1.0036 ; @ 500 GeV, emit/emit0 = 1.0078
- Laserwire Spot Size
  - **"nominal" vertical spot size = 1.500 um**
  - **"worst case" vertical spot size = 1.150 um**
- Extraction/tune-up
  - **±10% dE/E acceptance**
  - **Required transverse separation at beam dump> 3m**
  - **Details of dipole+kicker configuration?**
  - **Rastering to achieve 3cm beam spot radius at dump window**

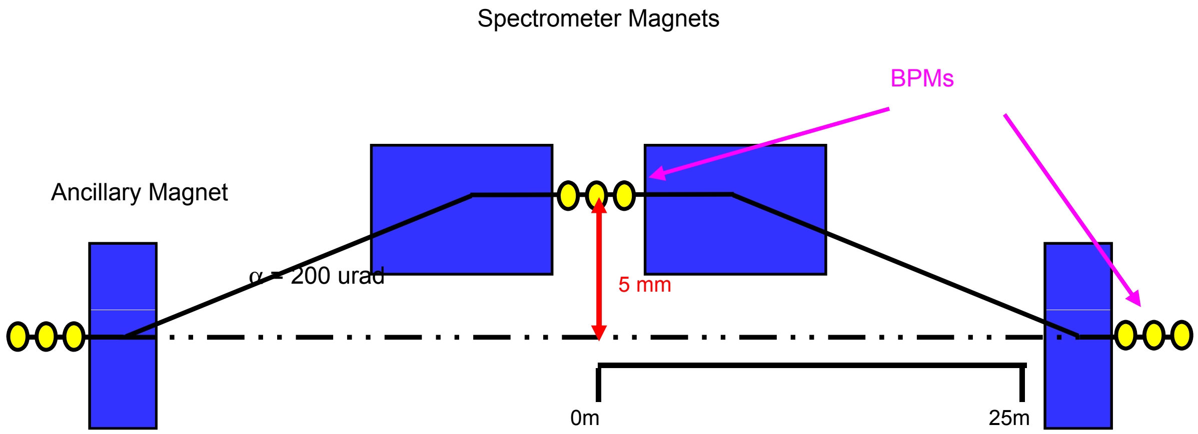
Upstream Polarimeter Chicane

- Constant integrated strength dipoles (B = 0.97 kG)
- Dispersion = 20 mm @ 250 GeV, 10 mm @ 500 GeV
- Dispersion scales inversely with energy (= 110 mm @ 45 GeV)
- Transverse space for laser wire detector @ 500 GeV? (~ 2.5 mm)
- Can the polarimeter chicane be used by the laserwires and the ΔE/E detection system as envisioned over the full energy range?
- Magnet, vacuum chamber and diagnostics engineering issues?



Upstream Energy measurements

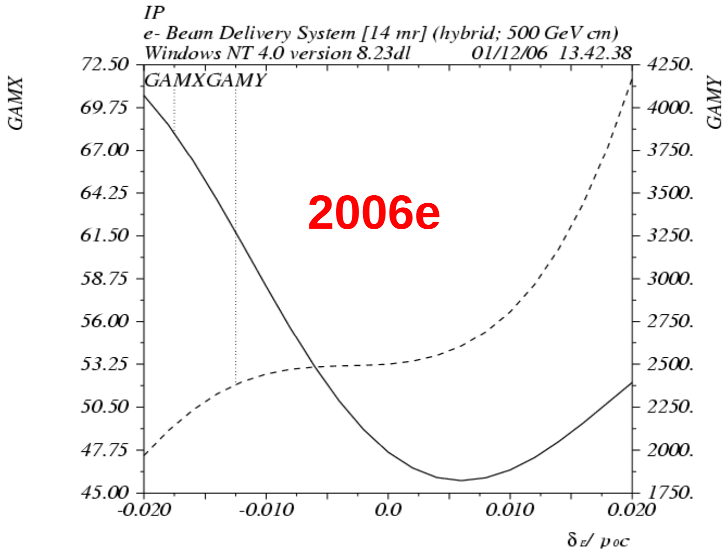
- Upstream Spectrometer
  - **Constrained by allowed emittance growth from SR**
  - **Constrained by available real estate in BDS, overall size**
    - These constraints determine needed BPM resolution/stability
  - **Other issues drive systematic errors, diagnostics**
- Scanning B-field and its effect on beam line?
  - **Betatron phase issues?**

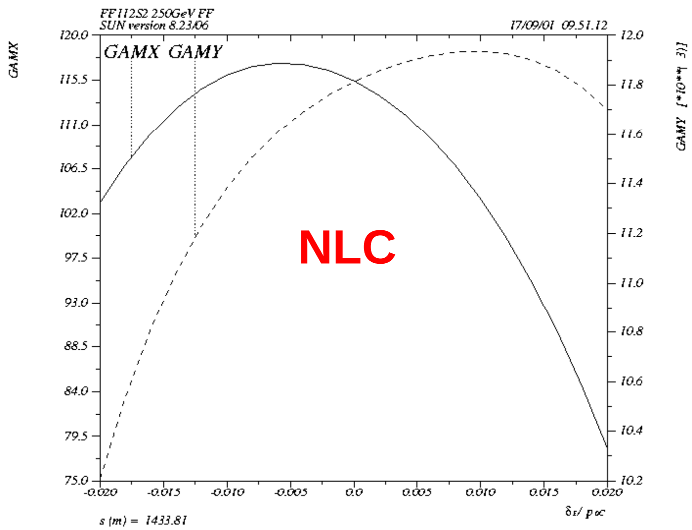


BPM-based

2006e Bandwidth

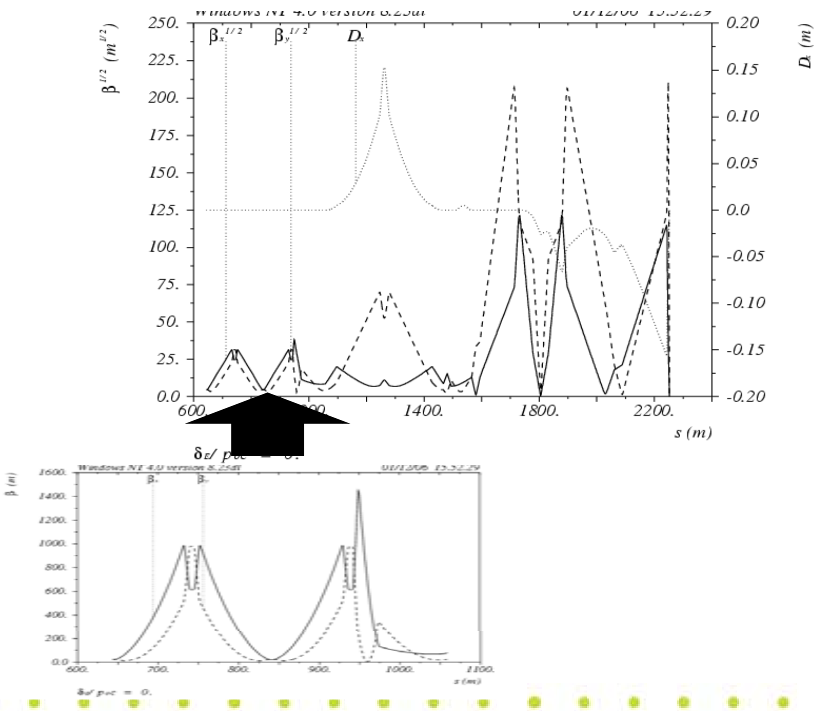
- Bandwidth measured by Twiss γ vs. E at IP
- Define bandwidth FOM as change in γ for δp=±1%
- Changes from NLC consumable spoilers to survivable spoilers
  - **Crucial phase advances and lattice bandwidth not maintained Phases not properly matched**
  - **adverse effects on collimation efficiency**

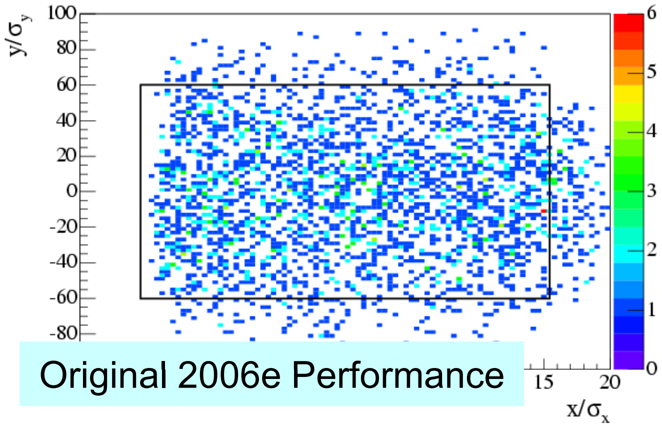




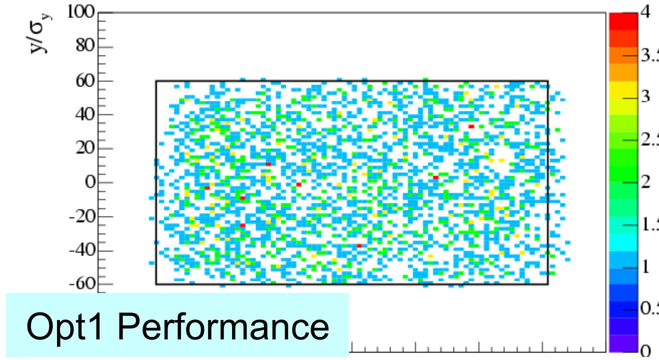
Collimation Performance Improvement (1)

- Restore phase advances to “NLC-like” config, using matching quads strengths and separations
- Opt1 : New lattice is 26 m longer
- Opt2 : Additional quads and phase matching including energy spoiler

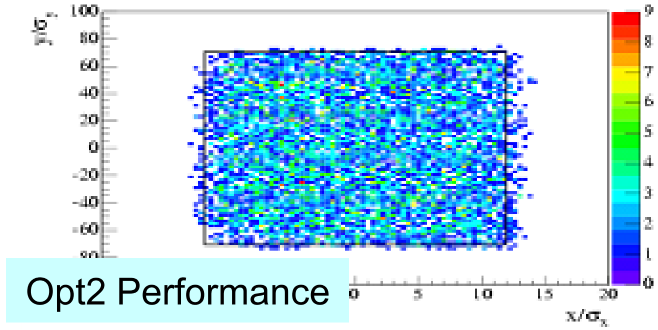




Original 2006e Performance



Opt1 Performance



Opt2 Performance

Collimation Performance Improvement (2)

- Matching section need to be changed to get smooth beta functions
  - **Presently, for nominal parameters**
    - Should cover full parameter range
  - **Different L*s?**
- Use flexibility of adjusting the phase advances (& to obtain better bandwidth for better collimation efficiency) including the energy spectrometer which comes after the energy collimation section.
- Tail folding octupoles are presently zeroed in the 2006e deck. Check the performance with these octupoles for the optimised deck
  - **Does it still give better performance as shown by Andrei et al for the NLC?**
- Finalise the optics for better collimation performance with less tightening which works for all the parameter sets and release this optics as new optics
- The background discussions during IRENG07 concluded that it is important to decouple the function of collimation from that of protecting machine components

Collimation Depths

- L* does not severely affect collimation depth
- Constraints of BeamCal, extraction apertures, QF1 acceptance all fairly close
  - Loosening one constraint does not help
  - Limited scope for loosening collimation depth by IR design
- Effect on wakefields estimate
  - RDR emittance growths 0.08% x and 4.4% y (for ½ σ beam jitter, spoilers and absorber w'fields)
  - Emittance growth increases at least with the square of the collimation aperture
  - So modest changes in collimation depth become significant, e.g. N_x=80$\rightarrow$70 gives 30% increase in emittance growth
  - None-uniqueness of collimation depths could offset this effect (trade N_x for N_y)

Other Issues

- IR beam orbit
  - **Detector field correction schemes (anti-solenoids, DID, Anti-DID) perturb the beam orbit and direction of the SR rays**
  - **Max orbit perturbations of the order ~100 μm, 100 μrad(!) Could lead to ~1 mm deviations in SR rays at apertures**
- Margins – how much SR can be tolerated on apertures?
- Realistic beams and IR geometry
  - **Energy spread, jitter, halo population**
  - **Magnet and mask misalignment, beam pipe thickness**
- Is it possible (or worthwhile) to include precise estimates of all effects – or only consider worst-case scenarios/biggest effects?

Backgrounds(1)

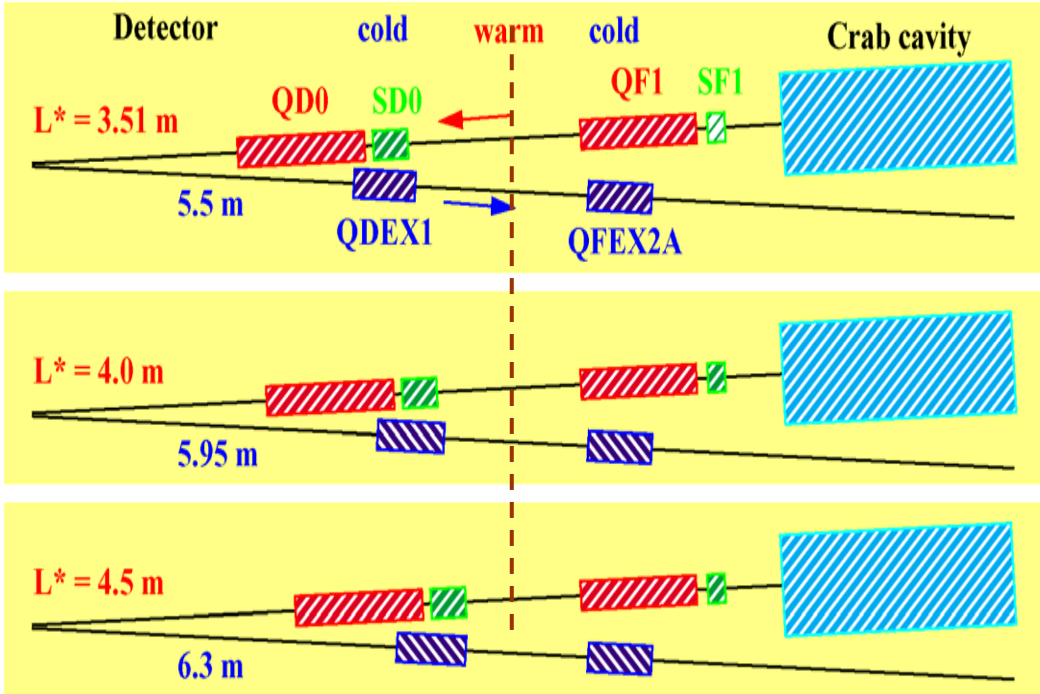
- Background requirements
  - **Impact on apertures**
  - **Collimation**
  - **Vacuum requirements**
    - Pumping inside the detector?
  - **Shielding**
  - **Muon walls**
  - **Neutrons**
- Suggestions at IRENG07
  - **To create a summary spreadsheet of backgrounds including what has been studied, which code/technique used etc**
  - **Each detector concept should form an internal WG/task force that carries out a detailed background simulation using as the input the backgrounds (beam-beam, beam-gas, beam halo, SR etc) predicted by the MDI experts impinging at the relevant detector boundary and vertex detector.**

Backgrounds(2)

- Lot of work already done but still to do
  - **Summary table of back scattering including beam-beam part**
    - need to be done for different detector concepts
  - **More studies are required for small angle reflections from incident photons**
  - **SR from beam halo : electrons outside the collimation depths**
    - how many photons can be tolerated in the detector?
  - **Muons, Neutrons**

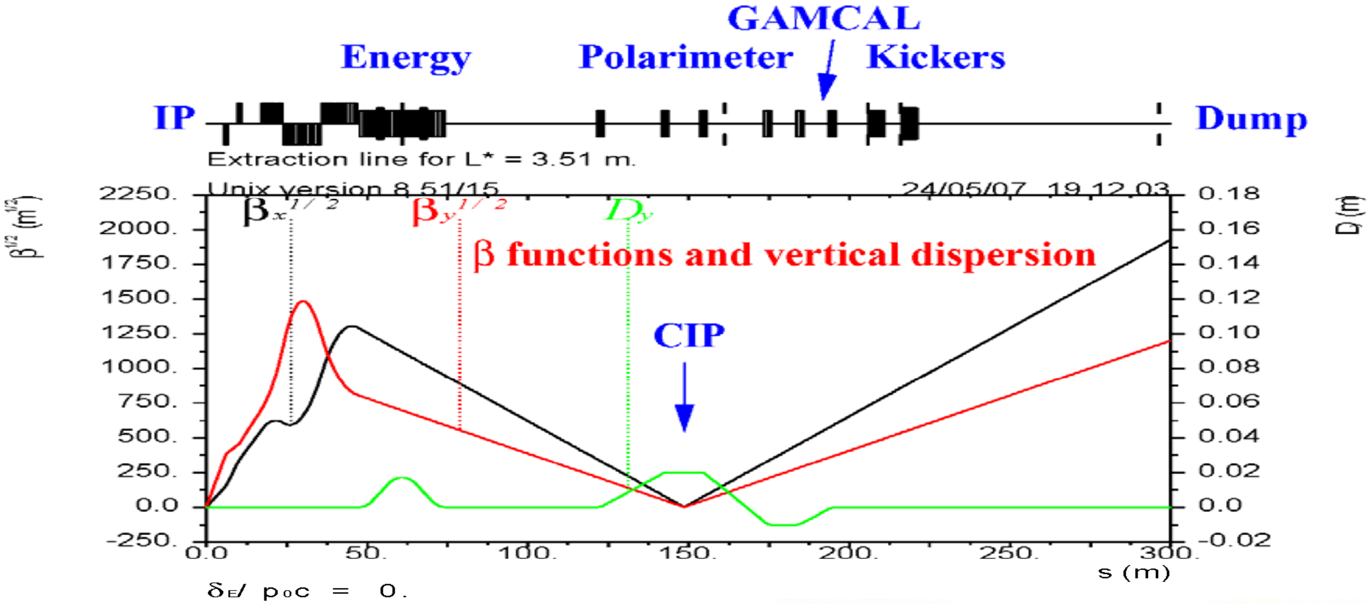
Extraction for Push-pull

- Push-pull optics for L*= 3.51, 4.0, 4.5 m
- SC magnets QD0/ SD0/ QDEX1 exchange with the detector.
- Long warm drift is reserved for break-in point.
- SC QF1/SF1/QFEX2A in a separate cryostat and other magnets outside of detector do not change, except fine strength tuning.

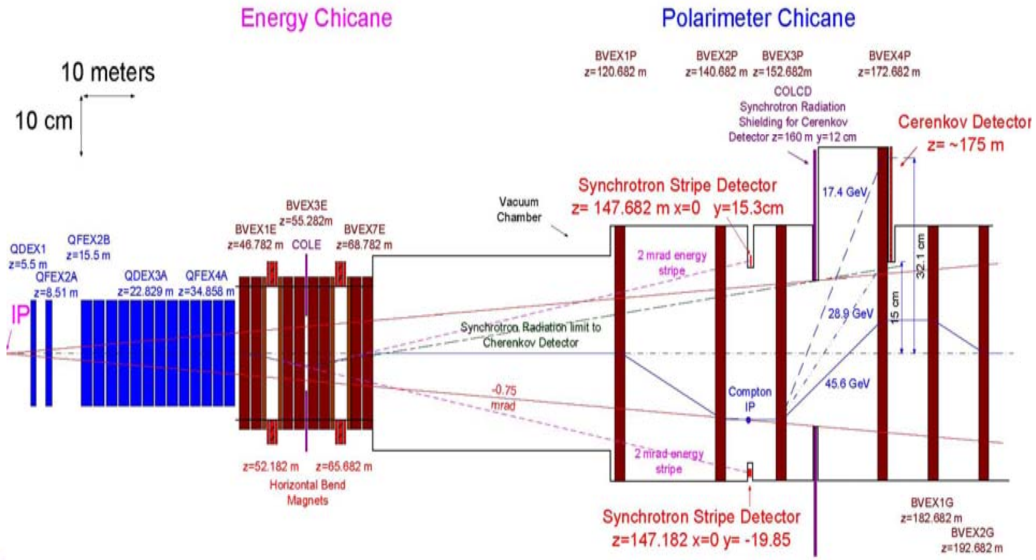


- Consequence to the design due to the need to break point for push pull
    - e.g. present separation of QD0-QF1 is 2.1m, the desired separation is 2.5m for LDC opening (IRENG07)
- Consequence of different L* : Effect on FF and tuning after push-pull operation?

Extraction beam optics



- **Energy measurement** using synchrotron radiation created in 8-bend vertical chicane with horizontal bump magnets.
- **Polarization measurement** using laser to produce Compton-scattered electrons at extraction focal point in the 4-bend chicane.
- **Luminosity diagnostic** using GamCal between 2 vertical bends.



Further studies : extraction line

- Effects of magnet + beam errors on performance of downstream diagnostics
- Backgrounds causing due to beam halo (including machine & beam errors) in the extraction line and its effect on the polarisation and energy measurements
- The requirement of polarimetry measurements need knowledge of angle at the second focus within ±50μrad of IP angle.
  - **Need measurement of two angles : angle at the IP and angle at the second focus.**
- Worse case scenario and its implications to diagnostics measurements & beam losses
- Develop commissioning scenario to understand whether required number of BPMS, steering etc is available to fulfill the requirements of the diagnostics

Detector solenoid & anti-DID

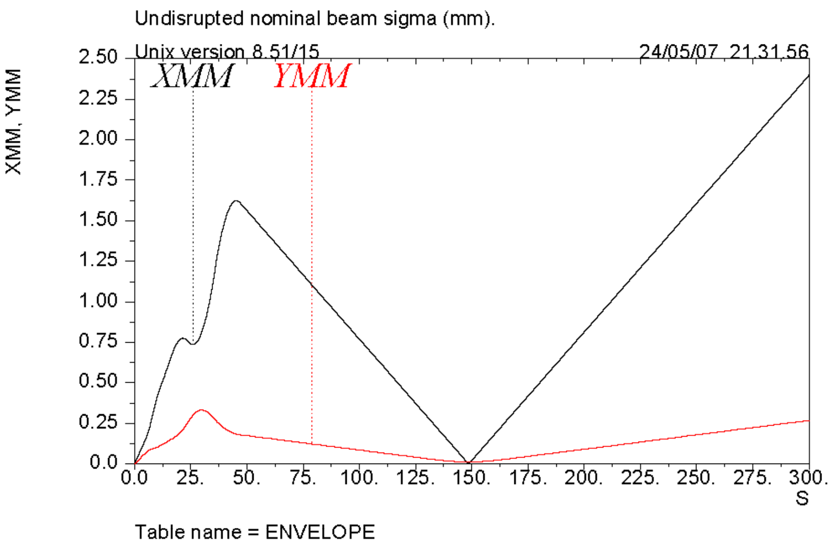
- X-Y coupling due to B_z field causing IP beam size growth. It is corrected independent of crossing angle (anti-solenoid and/or skew quads).
- Orbit due to B_x field induced by crossing angle. It causes the out of IP e^+e^- pairs to miss the beam exit hole thus increasing detector background. Can be corrected by Detector Integrated Dipole (DID).
- Anti-DID (~0.2 kG) is required to reduce detector background.
- Corrector coils built on QDEX1, QFEX2A quads compensate the residual extraction orbit.
- Magnetic field requirements in the IR
  - **The effect of parasitic magnetic field, "leaking" from the detector solenoid, on the beam at the IP.**
  - **What level of field "leakage" can we expect to have in the IR?**

Fast sweeping system

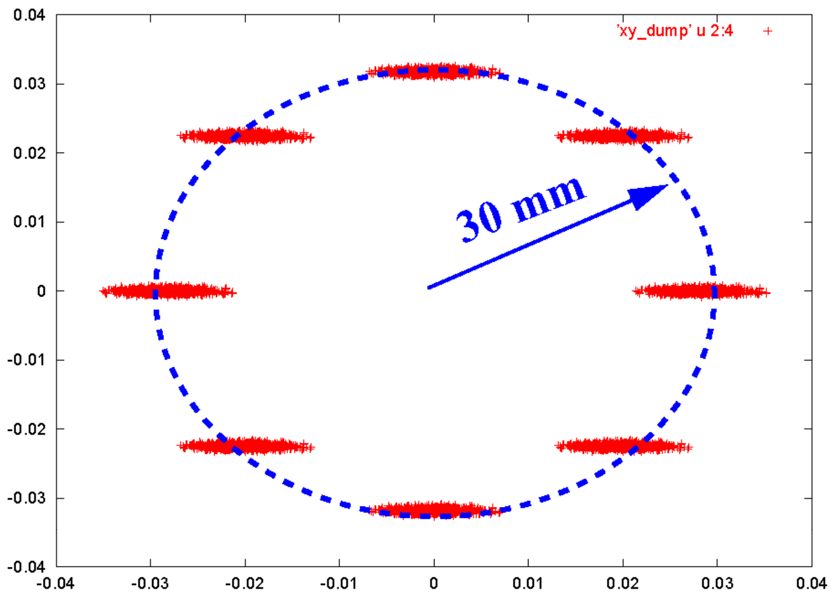
- System of fast (1 kHz) X-Y kickers is included to sweep bunches of each train in one turn on 3 cm circle at the dump window.
- It enlarges the beam area to protect from window damage and water boiling caused by very small beam size in cases of undisrupted beam or under certain abnormal optics conditions (large errors, magnet failures).

Interface with beam dump : provide input for different beam scenarios

Undisrupted σ (mm)



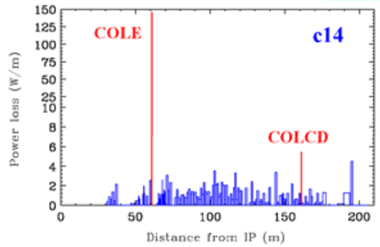
Undisrupted bunches at dump

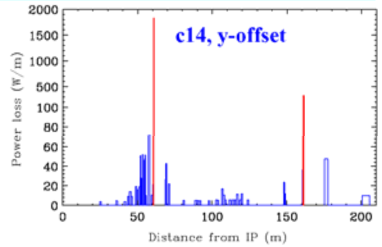


Beam power losses in the extraction line

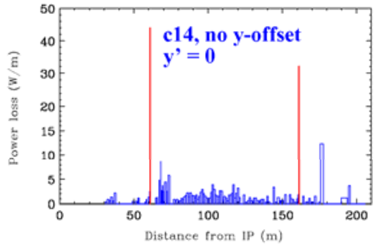
- Quad focusing optimized for minimal beam loss.
- 5 collimators to protect magnets, diagnostics and dump: COLE – for low energy collimation, COLCD – for Cherenkov detector protection, COLW1, COLW2, COLW3 – for fast kicker and dump protection.
- Power loss is small at 500 GeV CM nominal parameters (c11), and acceptable at high disruption parameters (c14).

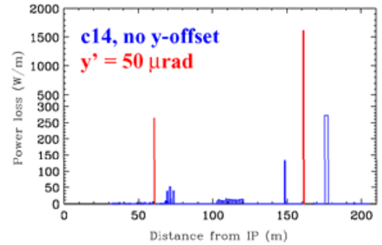
Low-P (c14) w/o solenoid





with solenoid





- No primary and photon loss on SC quads.
- Large y-offset and y-angle at IP increase load on collimators. These non-ideal conditions need to be efficiently corrected.

Beam power loss (kW) for optics with L* = 3.51 m without solenoid

Option	Primary electrons						BS photons		
	Total on magnets and pipe	Diagnostic collimators		Dump collimators			Dump collimators		
		COLE	COLCD	COLW1	COLW2	COLW3	COLW1	COLW2	COLW3
c11	0	0	0	0	0	0.272	0	0	0
c11, y-offset	0.001	0.001	0.0003	1.12	2.59	11.2	0.0001	0.025	0
c13	0.007	0.001	0.0001	1.02	1.57	6.54	0.570	0.820	0
c13, y-offset	0	0.0001	0	1.08	1.76	9.05	0.138	1.82	0
c14	0.126	0.044	0.003	2.62	6.18	26.3	0.035	0.171	0
c14, y-offset	0.581	0.549	0.161	85.9	43.7	82.1	10.9	20.1	0

Alternative IR configurations

- Physics & detector advantaged by smaller crossing-angle IR : simpler forward geometries, better hermeticity, no (or less) DID / anti-DID
- Head-on IR a priori nicest
  - **No crab cavity, no DID/anti-DID**
  - **needs large electrostatic separators**
  - **Design needs to deal with large beam losses**
- 2 mrad scheme
  - **no crab-cavity (initially…)**
  - **no electrostatic separators and order-of-magnitude smaller pre / post-IP trajectory bumps**
  - **Large SC magnets and special magnet designs**
- Designs advanced for both and will be reported in separate talks.

Vibration Tolerances

- Luminosity loss due to jitter of final doublet cryomodules (>5% @ ~200nm RMS).
  - **Needs to be convolved with 'background' environment of GM and other jitter sources.**
- Results are worse-case where everything else is perfect, other errors (e.g. non-linear train shape) will mask this effect to some degree.
- Small effect due to kicker distance from SD0, becomes more pronounced in cases with larger RMS jitter.
- Simulations of BDS tuning show something like ~10% overhead in luminosity after initial tuning. All dynamic lumi-reducing effects should total less than this.
  - **Remaining luminosity overhead dictates how long ILC can run before some (online) re-tuning required (~ 3 days with current assumptions).**

Settlement of Detector (IP)

- Effect of IP moving up or down by ~mm's per year? Assume settlement isolated to IP (+ QD0/SD0).
- If want to keep collision point at same physical location w.r.t. detector, need to periodically re-align BDS.
- How often? – What is tolerance of absolute collision position w.r.t. detectors from physics perspective?
- Can we do nothing? (Leave IP in a shifted location w.r.t. detectors)
- Would need to at least move QD0/SD0 cryomodules. Presumably get info on how far IP has shifted from detector vertex reconstruction?
- Beam offset w.r.t. detector solenoid a problem?

Impact of BDS Realignment

- Rotate 2 sides of BDS starting at first quadrupole (QMBSY1) to collide beams at desired IP location using magnet movers.
  - **Need range of movers ~ few mm (more closer to IP).**
  - **Compensate for change in IP y' offset with IP y' FFB kicker:**
  - **Also need to worry about what else needs to be on movers (PCs, crab?)**
- Degrades lumi through added IP dispersive effects due to required angle change + finite resolution of movers perturbing orbit.
- IP vertical beam spot degrades ~0.3nm (~6%) per mm IP drift (perfect mover resolution).
- Can correct with IP tuning knobs (which have to be applied every few days to combat ground motion and component jitter effects anyway).
- Following a drift rate of ~1mm / year looks bearable, something like 10mm / year may be more tricky (would need more detailed studies with simulations).
- What about beam position in outgoing beam pipe in FD cryomodules given intention to move modules ~mm's?

Stability Issues

- Alignment, stability and audible noise requirements
  - **Impact on detector designs**
  - **Design and location of facilities**
    - Presence of service cavern
  - **Effect on location and design of feedback hardware**
- Required ranges of FD motion and corrected coils
- Effect on presence of interferometer path along the yoke of inside the detectors

Shallow site issues

- Stability requirements
  - **Vibration**
  - **Slow settlement**
- Radiation requirements
  - **Depth? (Do we need to bend extraction lines (all 4 lines) down to reduce number of muons from the beam dumps on the surface?)**

Options : e-e- & γ–γ

- Parameters for these options?
- 14 mrad in e-e-?
- Option for g-g
  - **Layout generated by M. Woodley**
  - **Optics for these stretches**
  - **More stringent focussing requirements at the IP?**
  - **Beam dump**
  - **Detector constraints affecting the integration**
  - **Implications to CFS : hall size etc**

Test facilities and their role in BDS optimisation

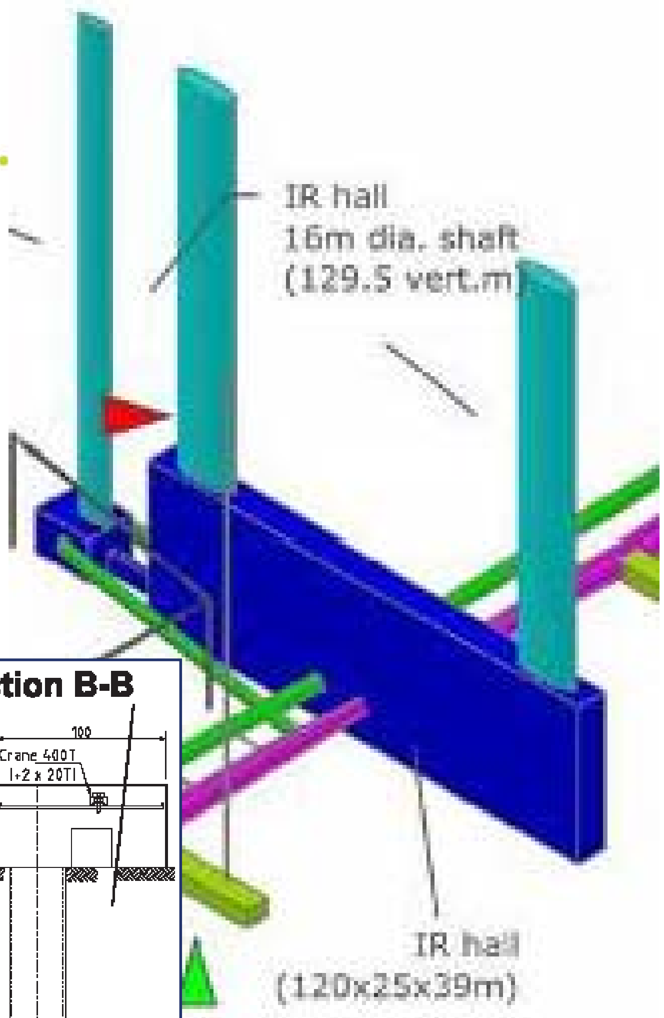
- Final focus tests at ATF2
  - **Optics**
  - **Stability**
  - **Tuning procedures**
  - **Instrumentation**
  - **Beam damage?**
  - **How do these tests feed back to the BDS design?**
- ESA
  - **Collimation wake fields**
  - **Energy spectrometer**
  - **Bunch length?**
  - **Instrumentation?**
- SC quad stability tests
- Crab system phase stability tests (NLCTA)

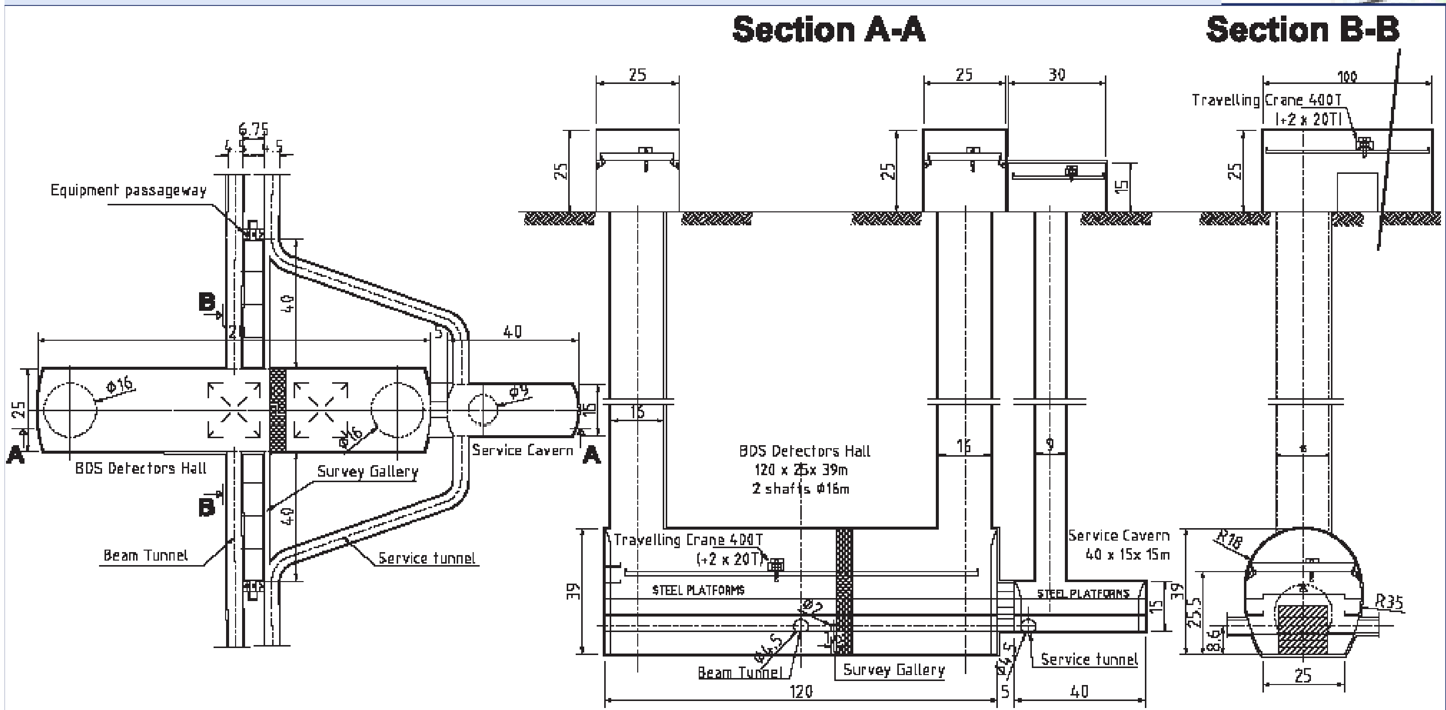
Operable energy

- Z-run
  - **Minimum field in soft dipoles ~ 24 Gauss?**
    - Need to check the performance
  - **Incoming beam : beam jitter**
  - **Collimation requirements?**
  - **Performance of upstream and downstream diagnostics**
- 350 GeV CM?
- How often different energy scans required?

IR hall in RDR

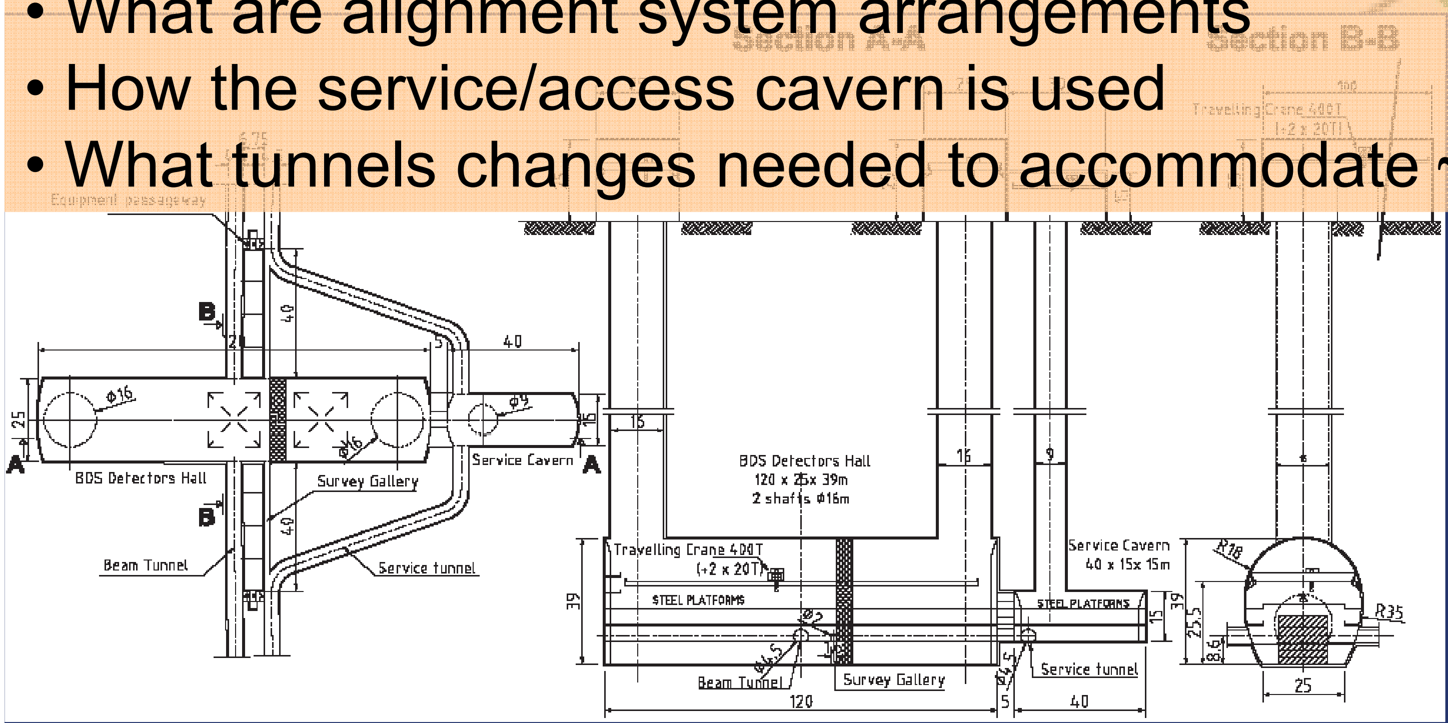
- Buildings for on-surface assembly
- Movable shielding wall to allow not-self shielded detector
- Hall size enlarged to accommodate detector support platforms and service platforms
- Cavern for services & beamline access





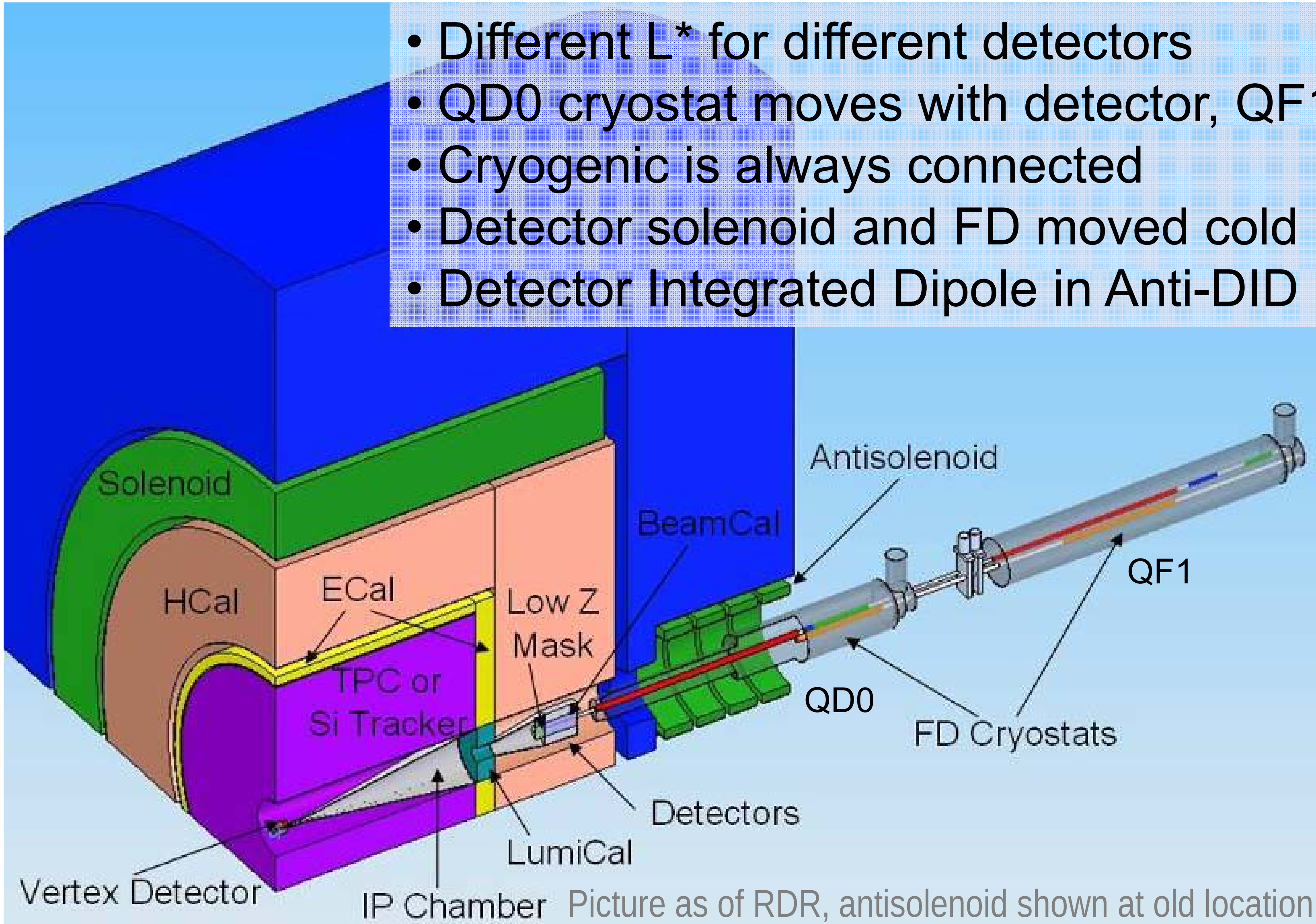
Discussions during IRENG07

- Consider modifications of layout to meet safety rules
- Discuss optimization of sizes, layout, number of shafts
- Optimization of capacity of cranes
- What are power, water and other needs of detectors
- What are detector services, where placed, how connected
- What are alignment system arrangements
- How the service/access cavern is used
- What tunnels changes needed to accommodate $\gamma-\gamma$ option



IR configuration in RDR

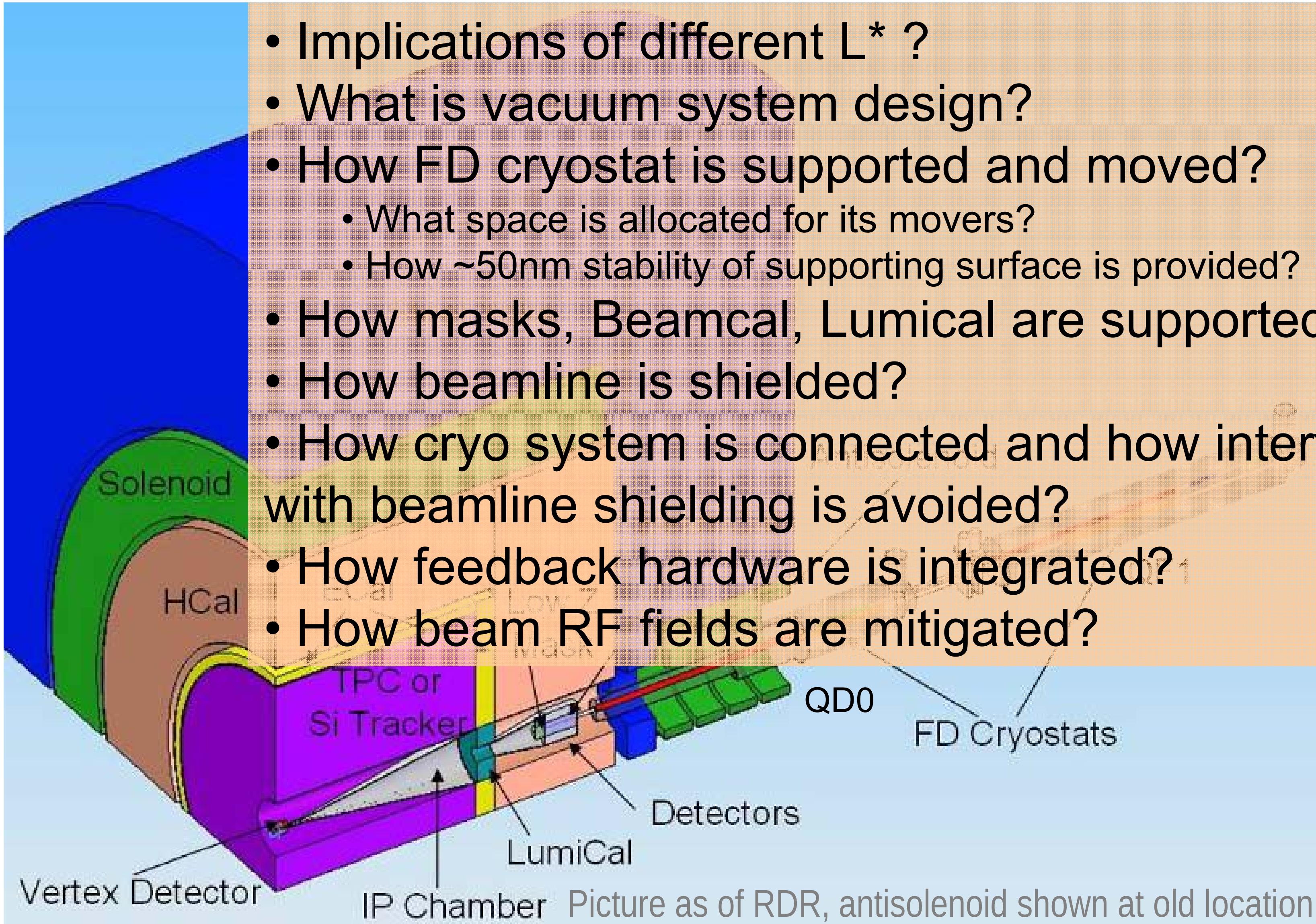
- Different L* for different detectors
- QD0 cryostat moves with detector, QF1 fixed
- Cryogenic is always connected
- Detector solenoid and FD moved cold
- Detector Integrated Dipole in Anti-DID mode



Picture as of RDR, antisolenoid shown at old location

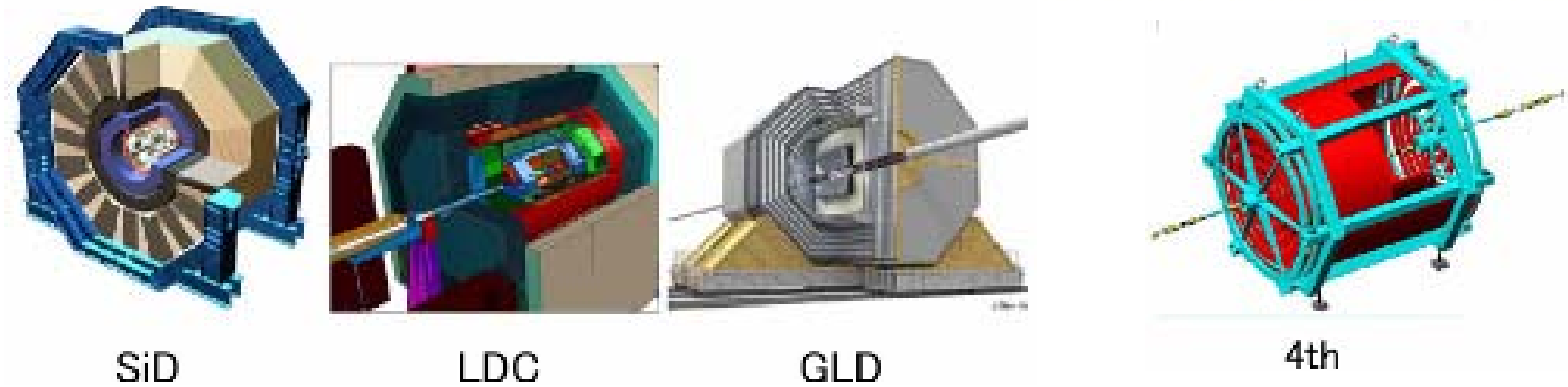
IR configuration

- Implications of different L* ?
- What is vacuum system design?
- How FD cryostat is supported and moved?
  - What space is allocated for its movers?
  - How ~50nm stability of supporting surface is provided?
- How masks, Beamcal, Lumical are supported
- How beamline is shielded?
- How cryo system is connected and how interference with beamline shielding is avoided?
- How feedback hardware is integrated?
- How beam RF fields are mitigated?



Picture as of RDR, antisolenoid shown at old location

Detector designs



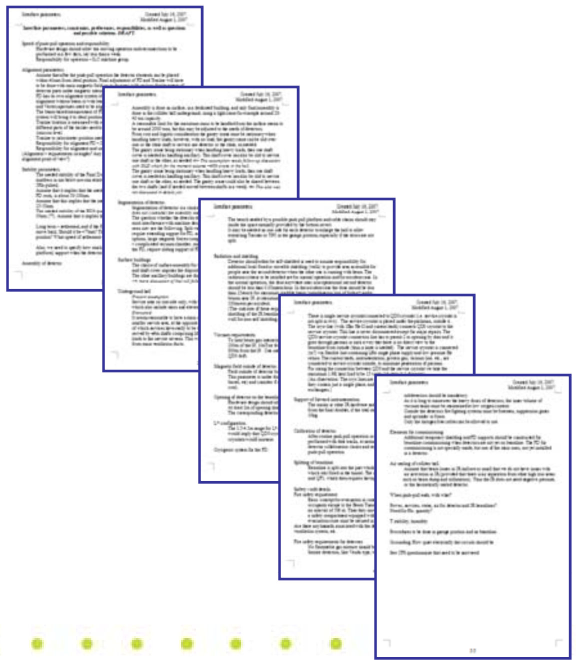
•The two complementary detectors for ILC IR may have different design, sizes etc
• Differences of their interfaces to the machine should be understood, and if possible, unified
• General parameters (size, weight, field in & out, acceptable L*, segmentation)
• How on surface & final underground assembly is done?
• What positioning accuracy needed after push-pull?
• What are opening procedures on-beamline & in garage position?
• What are gaps and how radiation shielding is provided?
• How fire safety is provided?

Interface Document

- Is to define interface parameters, constraints, preferences, responsibilities, as well as questions and possible solutions.
- It includes
  - **Speed of push-pull & responsibility**
  - **Alignment parameters**
  - **Stability parameters**
  - **Assembly of detectors**
  - **Segmentation of detector**
  - **Surface buildings**
  - **Underground hall**
  - **Radiation and shielding**
  - **Vacuum requirements**
  - **Magnetic field outside of detector**
  - **Opening of detector on the beamline**
  - **L* configuration**
  - **Cryogenic system for the FD**
  - **Support of forward instrumentation**
  - **Calibration of detectors**
  - **Splitting of beamline**
  - **Fire safety for IR hall and detectors**
  - **Elements for commissioning**
  - **And should include other not yet described**

The present draft is linked to

http://www-conf.slac.stanford.edu/ireng07/agenda.htm



To be included….

- Radiation safety requirements
  - **Impact on shielding designs**
- Temperature requirements in the tunnel
- Table showing stability requirements?
- Angle feedback and integration of other feedbacks?
- Effect of wakes from pumping ports, IR wakes, HOM heating, wake fields from crab, spoilers, other transitions….

For discussion today

- What is missing?
- Is there much emphasis on something?
- Value engg?
- Aperture standardisation, CFS, magnets on strings, prototypes, commissioning scenario
- Incoming beam jitter and worse case scenario
- MPS issues
- Does it look like more R&D list, if so what to include?
- Link to LET, alignment and other global groups → possibly in EDR WP talk?